Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D

Habitat Suitability Criteria Development

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
AIC	Akaike's Information Criteria
AICc	AIC corrected for sample size
cfs	cubic feet per second
deltaAIC	Difference in Akaike's Information Criteria between two models
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
FA	Focus Area
FDAML	Fish Distribution and Abundance in the Middle and Lower Susitna River (Study 9.6)
FERC	Federal Energy Regulatory Commission
fps	feet per second
GW	Groundwater
HSC	Habitat Suitability Criteria
HSI	Habitat Suitability Indices
IFS	Fish and Aquatics Instream Flow Study 8.5
ISR	Initial Study Report
LR	Lower Susitna River Segment, PRM 102.4 to PRM 0
MR	Middle Susitna River Segment, PRM 187.1 to PRM 102.4
NTU	Nephelometric Turbidity Units
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project, FERC No. 14241
RSP	Revised Study Plan
SIR	Study Implementation Report
SPD	Study Plan Determination
TWG	Technical Workgroup
USGS	United States Geological Survey
USR	Updated Study Report
VHG	Vertical Hydraulic Gradient (used to detect positive or negative intergravel flow)
VIF	Variance Inflation Factor

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC) its Revised Study Plan (RSP), which included 58 individual study plans (AEA 2012). Included within the RSP was the Fish and Aquatics Instream Flow Study (IFS), Section 8.5. RSP Section 8.5 focused on establishing an understanding of important biological communities and associated habitats, and of the hydrologic, physical, and chemical processes in the Susitna River that directly influence those resources. RSP Section 8.5 also described the study methods that would be used to evaluate Susitna-Watana Hydroelectric Project, FERC No. 14241 (Project) effects, including the selection of study sites, collection of field data, data analysis, and modeling.

The goal of the IFS and its component study efforts is to provide quantitative indices of existing aquatic habitats that enable a determination of the effects of alternative Project operational scenarios. As part of this effort, AEA is developing site-specific Habitat Suitability Criteria (HSC) and Habitat Suitability Indices (HSI) for various species and life stages of fish for biologically relevant time periods. These criteria will include observed physical phenomena that may be a factor in predicting fish habitat use (e.g., depth, velocity, substrate, water quality, groundwater (GW) influence, turbidity, etc.).

This report and accompanying material provide an update on HSC Development Study activities completed since filing of the Initial Study Report (ISR) in June 2014. AEA has continued to implement the FERC-approved Study Plan for HSC Development with specific activities including: 1) selection of priority fish species and life stages and development of periodicity Tables; 2) continued collection of summer and winter microhabitat use and availability data in the Middle Susitna River Segment (MR) and Lower Susitna River Segment (LR); 3) development of histograms displaying frequency of use for different microhabitat variables by season (summer vs. winter) and by river segment (MR and LR); 4) development of draft final multivariate preference curves for Chinook salmon *(Oncorhynchus tshawytscha)* fry and juvenile, chum salmon *(O. keta)* spawning, coho salmon *(O. kisutch)* fry and juvenile, sockeye salmon *(O. nerka)* spawning, Arctic grayling (*Thymallus arcticus)* fry and juvenile, whitefish fry and juvenile, and longnose sucker *(Catostomus catostomus)* juvenile and adult; 5) recommendation of HSC/HSI thresholds values to help define habitat preference; 6) for species and life stage with insufficient site-specific observations for development of preference curves, habitat utilization measurements were compared to HSC developed as part of the 1980s Susitna River studies; and 7) identifying the species and life stages to be targeted for future data collection efforts and those for which alternative HSC curve development methods are warranted.

In furtherance of the next round of ISR meetings and the FERC's Director's Study Determination expected in 2016, this report describes AEA's overall progress in implementing the HSC Development since June 2014. Rather than a comprehensive reporting of all field work, data collection, and analysis since the beginning of AEA's study program, this report is intended to supplement and update the information presented in Part A of the ISR Study 8.5 for the HSC Development Study since June 2014. As described in RSP Section 8.5.4.5.1.1.2 and ISR Study 8.5, Part A, Section 4.5.1.8, this Study Implementation Report (SIR) Study 8.5, Appendix D presents updated multivariate HSC models for all species and life stages with sufficient site-specific observations (Table 1-1). The revised HSC models incorporate site-specific data collected in 2013 and 2014. The same statistical approach applied in ISR Study 8.5, Appendix M, *Habitat Suitability Curve Development*, submitted to the FERC June 3, 2014 (R2 2014a) has been used in development of the HSC models presented in this Appendix D. Comparisons of habitat use between river segments (LR and MR), season (summer and winter), and 1980s HSC are presented as histogram plots for each species and life stage with sufficient observations. The HSC models presented in this Appendix replace those presented in ISR Study 8.5, Part C, Appendix M (R2 2014a).

2. STUDY OBJECTIVES

Individual study objectives were established in RSP Section 8.5.1.2. Specific IFS (Study 8.5) Study Plan objectives for this study are to: develop site-specific HSC and HSI for various species and life stages of fish for biologically relevant time periods selected in consultation with the Technical Workgroup (TWG). Criteria will include observed physical phenomena that may be a factor in fish preference (e.g., depth, velocity, substrate, embeddedness, proximity to cover, GW influence, turbidity). If study efforts are unable to develop robust site-specific data, HSC/HSI will be developed using the best available information and selected in consultation with the TWG.

3. STUDY AREA

The IFS program is focused on assessing flow-related effects of Project operations downstream of the proposed Watana Dam (Project River Mile [PRM] 187.1). As established in the Study Plan, the Susitna River is characterized by three segments (Figure 3-1). The IFS study area includes the two lower segments of the river: the MR which extends from PRM 187.1 downstream to the Three Rivers Confluence at PRM 102.4 (Figure 3-1) and the LR which extends from the Three Rivers Confluence to Cook Inlet (Figure 3-1). These river segments are described further in the ISR Study 8.5, Part A, Section 4.2. The 2013 HSC data collection effort was concentrated in the MR while the 2014 effort included sampling in both the MR and LR.

4. METHODS

The HSC Development Study has been implemented following methods described in the FERC-approved Study Plan with the exception of variances noted in ISR Study 8.5, Part A, Section 4.5.2 and the SIR Study 8.5, Section 4.5. Throughout this report, reference is made to the summer period (May-September) and the winter period (October-April). From a riverine modeling and hydrology perspective, there are four periods: 1) the open-water period is June-September; 2) October is treated as a period of transition from the open-water to the ice period; 3) the ice period is November-April; and 4) May is treated as a period of transition from the ice to the open-water period (SIR Study 8.5, Appendix B, *Open-water Hydrology Data Collection and Open-water Flow Routing Model (Version 2.8)* submitted to the FERC November 2015 [R2 2015a]). For purposes of this HSC report, summer is analogous to the May transition and open-water period of June-September, and winter is analogous to the transition month of October and the ice period of November-April.

Specific activities used in development of the draft HSC include: 1) study site selection and distribution; 2) collection of site-specific HSC/HSI data during summer and winter sampling events; 3) development of histograms using 2013-2014 habitat utilization data to display the frequency of microhabitat use by river segment, season, and comparisons with 1980s HSC for specific species and life stages; 4) data considerations and threshold values; and 5) development of draft HSC for those species and life stages with sufficient observations (2013 and 2014 data) using statistical methods.

4.1 Selection of Priority Species and Development of Species Periodicity Information

Defining the species of interest (i.e., priority species) and then developing an understanding of the timing of different life stage functions (i.e., periodicity) for each of the species is an important aspect of instream flow studies. Both the 1980s studies and the current licensing studies (IFS Study 8.5, and Fish Distribution and Abundance in the Middle and Lower Susitna River [FDAML] Study 9.6) recognized the importance of defining priority species and their life stage periodicities for evaluating potential Project effects. Understanding the timing and duration of these life stage functions as they exist under an unregulated flow regime is important for being able to evaluate potential changes that may occur following construction and operation of a hydroelectric project.

A proposed final list of priority fish species for potential development of HSC curves was developed in collaboration with the TWG (Q1 and Q2 2013 TWG meetings, Q1 2014 Technical Team Meeting). The species rankings were based on information presented in the 1980s technical studies, results of the 2013 and 2014 HSC surveys, management status, and perceived sensitivity to changes in habitat due to potential Project operations. The ranking specifies the general methodology that will be used to develop HSC for a particular species and life stage based the number of site-specific observations collected during 2013-2014 surveys, availability of HSC curves developed during the 1980s Susitna studies, availability of HSC curves from outside the Susitna basin, and life history information.

Draft periodicity tables were developed to describe the temporal periods which each priority species and life stage are expected to occur in the Project area (ISR Study 8.5, Part A, Appendix H, *Periodicity Tables* submitted to the FERC June 3, 2014 [R2 2014b]). These tables were based largely on information from the 1980s studies as presented in a TM submitted to the FERC March 25, 2013 titled *Summary Review of Susitna River Aquatic and Instream Flow Studies Conducted in the 1980s with Relevance to Proposed Susitna – Watana Dam Project – 2012: A Compendium of Technical Memoranda* (R2 2013). The 1980s information was supplemented with contemporary information provided in Alaska Department of Fish and Game (ADF&G) reports prepared in the 2000s (e.g., Merizon et al. 2010). To the extent possible, the timing of use by macrohabitat type (i.e., main channel, side channel, side slough, upland slough, tributary mouth, and tributary; see ISR Study 9.9 [Characterization and Mapping of Aquatic Habitats] for detailed description of habitat types) was provided by species and life stage for each river segment (Upper, MR, LR) based on reviews of these studies. These draft periodicities will need to be reviewed and modified based on results of fish distribution sampling (FDAML [Study 9.6] and HSC surveys conducted as part of the IFS [Study 8.5]) and input from agency participants. The final periodicity analyses will be used to guide habitat-specific modeling and spatial and temporal habitat analyses.

4.2 HSC Sampling

4.2.1 Study Site Selection

Summer and winter HSC surveys utilized both random and non-random sampling in selection of HSC sampling sites. Utilizing both a random and non-random site selection approach provided representative sampling of a range of macrohabitat types available to fish, while also ensuring that sufficient numbers of observations were collected.

Summer HSC sampling occurred at random locations within the LR and MRs of the Susitna River (Figure 3-1). A majority of the HSC sampling sites were within the ten Focus Areas located within the MR of the Susitna River (Figure 4.2-1). A detailed description of the justification and distribution for each Focus Areas is presented in ISR Study 8.5, Part A, Section 4.2 (AEA 2014a). During 2013, HSC sampling was conducted at seven of the ten Focus Areas (FA-104 [Whiskers Slough], FA-113 [Oxbow 1], FA-115 [Slough 6A], FA-128 [Slough 8A], FA-138 [Gold Creek], FA-141 [Indian River], and FA-144 [Slough 21]). In 2014, HSC sampling was conducted in all ten MR Focus Areas and in the Trapper-Birch and Sheep-Caswell Creek complexes in the LR (Figure 4.2-2). Because of the spatial clustering of spawning activities, HSC spawning surveys in 2014 were only conducted at those locations (within and outside of Focus Areas) where spawning was observed during the 1980s and 2013 surveys.

Winter HSC sampling in the MR occurred during two winter periods (2012-2013 and 2013-2014) (SIR Study 8.5, Appendix A, *2014 Instream Flow Winter Studies*, submitted to the FERC November 2015 [R2 2015b]). Data collection primarily occurred within three Focus Areas: FA-104 (Whisker Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek); however, opportunistic sampling also occurred within FA-141 (Indian River) (Figures 4.2-3). These Focus Areas were selected for the 2012-2014 sampling effort because they contain a diversity of habitat types with GW influence, they have documented fish utilization by multiple fish species and life stages, and they could be safely accessed during the winter. Candidate sampling locations were identified prior to sampling such that the relative data collection effort was similar among FA-104 (Whisker Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek). However, adjustments to proposed sampling locations were made during each field effort based upon known fish distributions (e.g., spawning), logistical considerations (e.g., site access, ice cover), and site hazards and personal safety.

A detailed description of the random sampling approach used for HSC sampling is presented in ISR Study 8.5, Part A, Section 4.5.1.3 (AEA 2014a). In summary, the stratification approach splits macrohabitat into linear habitat units of 500-meter (main and side-channels) and 200-meter-long (off-channel) segments. These units were then stratified into areas of known fish use versus unknown fish use based on studies conducted in the 1980s. Individual sample sites (100-meter and 50-meter) were then placed within the habitat units, in areas that visually appeared to have the greatest diversity of microhabitat types (i.e., fast and slow, deep and shallow water) and could be safely surveyed.

4.2.2 Summer Surveys

Summertime surveys were completed in 2013 and 2014 to collect site-specific information on microhabitat use and availability for development of multivariate HSC. Collection of summer 2014 HSC data closely followed the methods utilized during the summer 2013 sampling. The only notable differences between the summer 2013 and 2014 sampling methods were the frequency of sampling (approximately every 2 weeks in 2013, approximately monthly in 2014) and the increased intensity of measurements to detect positive or negative intergravel flow using a minipiezometer were completed in 2014 for the detection of GW upwelling or downwelling (vertical hydraulic gradient [VHG[). A detailed description of the 2013 sampling methods is presented in ISR Study 8.5, Part A, Section 4.5.1.4 (AEA 2014a). The remainder of this Section provides a summary of the HSC data collection methods.

To ensure the accurate detection of microhabitat use of rearing and holding fish, a combination of active and passive fish observation methods were employed during both the 2013 and 2014 surveys. These methods included snorkel surveys, pole/beach seining single-pass backpack electrofishing, and backpack electrofishing combined with a mobile downstream block seine. For schooled-fish observations (schools categorized by life stage and species) only one observation of microhabitat use was recorded for each species of fish observed regardless of the number present.

The following information and microhabitat use measurements were recorded at each fish observation point:

- Fish species
- Fish length (millimeters [mm])
- Number of fish observed
- Fish location
- Water depth
- Mean column velocity
- Presence (within 3 feet) of habitat structure/cover
- Distance to water’s edge (feet)
- Substrate composition (dominant, sub-dominant, percent dominant, and percent embedded)
- Water temperature (ºC)
- Dissolved oxygen (DO) (ppm)
- Turbidity (Nephelometric Turbidity Units [NTU])

- Conductivity (μS)[1]

For spawning surveys, the presence of at least one actively spawning or guarding fish of known species was required to qualify as an individual fish-use spawning site or redd. If a redd was observed without a fish either spawning on or guarding a specific channel location, it was not used as an HSC/HSI fish spawning site.

After fish sampling was complete, habitat availability measurements were completed within each sampled site. Cross-channel transects were marked every 10 meters (32.8 feet) along the edge of the sampling site so that there would be 10 transects in each 100-meter (328-foot) site and 5 transects in each 50-meter (164-foot) site. At each transect, microhabitat measurements were collected at three random stations across the sampled width of the channel. The following measurements were made at each station across the transect:

- Water depth
- Mean column velocity
- Substrate composition
- Habitat structure or cover types present
- Water quality (temperature, DO, and conductivity)
- Presence of upwelling or downwelling (one measurement on each transect) using a minipiezometer to detect the presence of GW upwelling or downwelling (United States Geological Survey [USGS] 2000 Fact Sheet [USGS 2000]).

4.2.3 Winter Surveys

Winter surveys were conducted to better understand habitat utilization by fish species and life stages during ice cover conditions and to determine if there were sufficient differences in microhabitat use (depth, velocity, and substrate) between seasons to warrant the development of seasonal HSC. The winter period is an ecologically important time for salmonids in that stream flows are typically at their lowest, relegating fish to areas suitable as overwintering habitats.

The 2012-2013 and 2013-2014 winter surveys were conducted during February, March, and April. Methods utilized during the 2013-2014 study were initially developed during the 2012-2013 pilot winter study conducted at FA-104 (Whiskers Slough) and FA-128 (Slough 8A) (Figure 4.2-3). Detailed descriptions of the 2012-2013 and 2013-2014 winter surveys are provided in the ISR Study 8.5, Part C, Appendix L, *2012-2013 Instream Flow Winter Studies* submitted to the FERC June 3, 2014 (R2 2014c), the Technical Memorandum, *2013-2014 Instream Flow Winter Studies* submitted to the FERC September 17, 2014 (R2 2014d), and in SIR Study 8.5, Appendix A (R2 2015b), and are only summarized here. Winter surveys were conducted using electrofishing methods at open-water sites to capture fish and collect site-specific HSC/HSI data. Habitat utilization data (e.g., water depth, velocity, substrate

[1] Although conductivity values were collected during HSC surveys, predicted changes to conductivity levels in response to proposed Project operations are not included as part of water quality modeling and therefore conductivity is not included as part of HSC model development.

composition, water quality) were collected at each point of fish capture. Water depth and velocity measurements were made using a wading rod and Price AA water velocity meter. Water temperature, DO, and specific conductance were recorded at the locations of fish observations using a hand-held water quality meter. Due to sampling constraints (e.g., ice cover, limited daylight hours, and exposure time) no habitat availability data were collected during the winter surveys.

4.3 Habitat Utilization Summary

Frequency histograms were developed using the 2013-2014 HSC data to visually compare habitat utilization (velocity, depth, and substrate type) between the LR and MRs, seasonal habitat use within the MR, and HSC developed during the 1980s studies. Although a visual comparison is helpful in identifying significant segment, seasonal or period scale differences in microhabitat selection, this analysis does not take into account habitat availability and should not be assumed to predict habitat preference or suitability. Additionally, no adjustment or normalization of the data has been completed to account for significant differences in the number of habitat use measurements between samplings. Summary statistics such as median values and percentile ranges (i.e., 25-75th percentile) are provided to compare distributions of observations with a reduced influence of outliers.

4.3.1 River Segment Comparison

Using summer 2013 and 2014 habitat utilization data collected from the MR and LR, frequency distributions were generated for each species and life stage with sufficient numbers of mean velocity, depth, and substrate type observations (>10). For comparison purposes, a bin size of 0.2 feet was used for depth and mean column velocity histograms. The frequency of fish observations in each of the bins was then normalized by dividing by the maximum value observed, to create probability histograms with values between 0 and 1. The utilization histograms for each variable were then displayed together on a single plot to enable direct comparison.

4.3.2 Seasonal Comparison

For the comparison between summer and winter microhabitat use, only those observations collected from within sample areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], FA-138 [Gold Creek], and FA-141 [Indian River]) common to both surveys were included. Similar to the summer surveys, frequency distribution histograms were only developed for those species and life stages with sufficient number of observation to display a general trend in microhabitat use. Along with the histogram plots, the range and median habitat utilization are also reported.

4.3.3 1980s and 2013-2014 Comparison

An extensive set of HSC developed as part of the 1980s Su-Hydro instream flow studies. These criteria were developed using a combination of site-specific data collected through fish sampling and literature sources, and through refinement based on the professional judgment of project biologists. These curves are presented exactly as reported in their respective source references and have not been modified. Substrate curves are one exception; to allow comparability between 1980s substrate curves and those collected during the current studies, adjusted substrate codes were used to standardize the curves for this habitat parameter. A summary of the number of observations and methods used to develop the 1980s HSC is presented within Section 6 (Habitat Suitability Curve Development Studies for the Susitna River) of R2 2013.

Using the HSC developed as part of the 1980s studies, a comparison was made between the 1980s curves and the habitat utilization data collected in 2013-2014 for six species/life stages: Chinook and coho juvenile, adult grayling, spawning pink salmon *(O. gorbuscha)*, and adult rainbow trout *(O. mykiss)* and whitefish. These species and life stages had either an insufficient number of 2013-2014 site-specific habitat utilization measurements to develop multivariate HSC models or had unique HSC (clear and turbid water, MR and LR) developed during the 1980s studies that could be used to compare habitat use between the two studies.

4.4 Other Microhabitat Variables

In response to the April 1, 2013 FERC Study Plan Determination (SPD) (FERC 2013), a detailed evaluation of fish abundance measures and eight additional habitat variables (surface flow and GW exchange flux, surface and intergravel DO and temperature, macronutrients, pH, dissolved organic carbon [DOC], alkalinity, and chlorophyll-a) was completed to determine whether relationships were evident and if additional HSC curve development was warranted. A Technical Memorandum, *Evaluation of Relationships Between Fish Abundance and Specific Microhabitat Variables* (R2 2014e), describing the results of the evaluation was submitted to the FERC on September 17, 2014.

Most of the analyses used in the evaluation involved comparisons between habitat data collected by various studies and fish abundance data collected by the FDAML (Study 9.6) and FDAUP (Study 9.5). Fish abundance data collected at random sites in the Upper, MR, and LR using electrofishing, seining, and snorkeling were used for these comparisons. Subsets of this main dataset were used where synoptic data were available for each microhabitat parameter.

When synoptic data for named microhabitat parameters were not available from these studies, then habitat use data from other studies (e.g., Baseline Water Quality Study (Study 5.5), the River Productivity Study (Study 9.8), the GW Study (Study 7.5), and the IFS Winter Study (Study 8.5) were considered if they were collected within the same macrohabitat unit, and within two weeks of relevant fish abundance data.

To increase the number of samples with observed fish and to avoid conflicting results for multiple species, fish counts were summed by species/life stage groups for the analyses, as follows:

1. Anadromous salmon fry (Chinook, chum, coho, sockeye)
2. Anadromous salmon juvenile fish (Chinook, coho, sockeye)
3. Resident salmonids (juvenile or adult; whitefish, Arctic grayling, rainbow trout, Dolly Varden *[Salvelinus malma]*)
4. Resident non-salmonids (juvenile or adult; burbot *[Lota lota],* longnose sucker)

Adult anadromous species were not included in the analysis because they were not targeted by FDAML (Study 9.6) and FDAUP (Study 9.5) sampling, and some sampling methods (i.e., electrofishing) were interrupted when anadromous adults were encountered.

4.5 Data Considerations and Threshold Values

Prior to analysis all 2013 and 2014 microhabitat data were entered into spreadsheet format and subsequently checked for data entry accuracy. Any necessary edits or corrections were then made to the database and checked by a senior staff member for completeness. A database of all 2013 and 2014 HSC utilization and availability data has been completed (SIR Study 8.5, Section 5).

Although site-specific observations were used to define habitat preference for all species and life stages with sufficient site-specific observations, limits or thresholds have been proposed for certain variables to help define the minimum and maximum range of habitat preference predictions within the HSC models. Threshold values proposed for use in the HSC models are based on either: minimum and maximum habitat use values observed in the HSC database, ranges of habitat use reported in literature, water quality standards set by the Alaska Department of Environmental Conservation (ADEC 2012), or limitations in sampling.

As an example, a minimum depth of 0.25 feet was proposed for the adult life stage of resident fish species (non-anadromous) as that was the shallowest depth observed for that particular life stage. Without setting a minimum depth, the HSC model would initiate depth preference predictions at 0.0 feet deep. It is assumed that 0.25 feet is the minimum depth suitable for adult resident fish.

Other data considerations or adjustments are described in Section 5.6.

4.6 HSC Modeling

The ISR Study 8.5, Part C, Appendix M (R2 2014a) provided a detailed description of the methods being used for HSC curve development, and two example analyses based on 2013 data only. The methods are repeated here for convenience, and all results include 2013 and 2014 data combined. There is only one notable change to the methods since the ISR Study 8.5, Part C, and that change is in regards to the handling of upwelling/VHG observations for the multivariate HSC spawning curves as described in Section 5.5.1.

The habitat suitability modeling provides information on which habitat variables (of those collected synoptic with HSC) are most predictive of fish presence, as well as final predictive multivariate HSC models to be used to assess Project effects. Multivariate HSC models for 12 individual species and life stages are presented in this report and represent the models proposed for application in the habitat-flow analysis for evaluating operational effects. However, these models will be subject to agency and stakeholder review and therefore should be viewed as draft Final HSC models. The same general model development process was followed for all species and life stages for which sufficient observations for model development have been attained. For those species and life stages with insufficient numbers of site-specific observations, additional data collection efforts may be warranted or alternative methods for HSC development will need to be developed.

4.6.1 General Approach

Habitat suitability was determined based on the likelihood of habitat use by each fish species-life stage. Habitat parameters were measured where fish have been observed (utilization data) and at additional stratified random locations at each selected sampling site (availability data). The probability of fish presence as a function of these habitat variables was modeled with univariate and multivariate logistic regression, using availability measurements as a "0" response and utilization measurements as a "1" response (Manly et al. 1993). Logistic regression is a generalized linear model used for non-normally distributed (e.g., binomial) dependent variables. The candidate models included polynomial effects when non-linear relationships were reasonable ecological hypotheses. For example, an intermediate depth may be optimal for some species and life stages, suggesting a quadratic, rather than a linear relationship between depth and suitability.

For practical sampling reasons, observation locations were comprised of sampling site blocks sampled at different times, which are viewed as clusters of fish utilization and availability measurements. Generally, clusters (site/date sampling events) are included as random effects in statistical models, to prevent bias based on unequal sampling probabilities. Mixed effects models (with a random effect for sampling event) are used to account for differences among blocks without fitting a separate mean response for each block. In some cases, there is little difference in utilization among utilized clusters, and the random effect is dropped from the model to increase statistical power.

Because of the ephemeral nature of spawning and the vast spatial scale of the Susitna River, it was unlikely that randomly selected sites alone would provide enough spawning information for development of HSC/HSI models. To ensure sufficient numbers of spawning observations, non-randomly selected known spawning locations (i.e., 1980s surveys) were also sampled as time allowed in 2013 (heretofore labeled "select" spawning sites). In 2014, spawning surveys were limited to sites where spawning was observed in 2013. The selected sites are likely to have higher overall percentages of observed spawning and they may also have different relationships with habitat variables. Because of this potential difference, a fixed two-level factor defining the sampling difference (random/select) was included in the set of potential "univariate" models as a main effect and as an interaction effect. Significant interactions were investigated and potential biases in the final model discussed.

4.6.2 Univariate Analysis

Although multivariate models are proposed for HSC, there are several issues related to model development that required consideration prior to forming the multivariate regression, including the large number of potential predictors (with polynomial relationships), concerns about correlation among predictors, and the lack of a priori knowledge regarding the nature of relationships between each predictor and habitat preference. These issues were addressed by fitting exploratory univariate models for each potential predictor variable prior to conducting the multivariate analysis. Models including only one habitat variable are referred to as "univariate" models, although fixed and random blocking variables were included in some places. Univariate models were attempted for:

- Depth
- Velocity
- Substrate (spawning)
- Cover/Turbidity (non-spawning)

- Upwelling (spawning; categorical)
- Surface water temperature
- Dissolved oxygen

Polynomial models up to order 3 were used, using the *glm* function in *R* (version 3.02; R Core Team 2013) for fixed effects models, and the *glmer* function in R package *lme4* (Bates et al. 2013) for models including random effects. Best fitting models were selected based on Akaike's Information Criteria (AIC). Models with the lowest absolute AIC and those within 2.0 of the best-fit model can be considered potential models (Burnham and Anderson 2002), while models outside of this range have weak to no evidence of relationships. Following Zuur et al. (2009), the inclusion of the random effect was evaluated first, comparing the full model allowing random means for each site with the full fixed effects model with no random effects for site. The full model in the univariate case included only the habitat variable polynomial; for spawning it also included the random/select site grouping factor, and interaction between the habitat variable and the grouping factor.

For spawning models only, if interaction between site group (random versus select sites) and the habitat variable was included in the best-fit model, the form of interaction was evaluated. Clear differences in the impact of the habitat variable at random versus select sites may indicate bias in the model that combines these sites. Although this bias cannot be avoided in the application of this model, the implication of potential bias is acknowledged.

Finally, the null model with the best random structure (random effect or no random effect) was compared to polynomial models with the habitat variable in question. If no models containing the habitat variable were superior to the null model using the AIC criteria, then there is no or weak evidence that the habitat variable has predictive value for this fish species-life stage. If any model containing the habitat variable had lower AIC than the null model, the variable was considered predictive and retained for the multivariate analysis.

4.6.3 Multivariate Models

For instream flow models, suitability indices from univariate HSC/HSI curves based on depth, velocity, and substrate are typically multiplied together to form a composite suitability index. Other methods include using the arithmetic or geometric average, the minimum, or a weighted product of the univariate indices (Ahmadi-Nedushan et al. 2006). However, all of these methods of combining variables are based on an assumption of the relative importance of each predictor (e.g., equal importance) as well as independence among the predictors.

Instead, a multiple regression approach has been used to combine all significant predictors (identified during univariate modeling) into a combined index of preference or suitability. Interactions among variables (e.g., the impact of velocity depends on substrate type) may be important, and were examined using multiple regression. Multiple regression candidate models included all combinations of main effects for which univariate models were found to be predictive. The multivariate models were compared using the AIC criterion, and models within AIC of 2.0 of the best-fit model (Burnham and Anderson 2002) were considered potential final models.

4.6.3.1 Multicollinearity

Correlation or lack of independence among predictors in a multiple regression is labeled multicollinearity, and it impacts the precision of individual regression coefficients and their interpretation. It does not impact the strength or predictive capabilities of the model if the prediction space is in the range of data used to fit the model, and if the correlations among variables also remain the same (Neter et al. 1990). However, the relative importance of collinear predictors cannot be interpreted based on the magnitude of the regression coefficients, which are subject to change depending on which variables are included in the model. For example, when two variables X1 and X2 are strongly collinear, the data contain little information about the impact of X1 when holding X2 constant, because in reality there is little variation in X1 when X2 is fixed.

Because HSC/HSI models are mainly concerned with prediction (e.g., which habitats are most suitable to spawning) as opposed to identification of the most important habitat covariates, collinearity is not an issue for the HSC/HSI analysis. However, actions to reduce collinearity are taken when possible, and collinearity is measured and reported for each multivariate model. Although some authors recommend centering continuous variables (i.e., subtracted from the mean value) to reduce collinearity (Neter et al. 1990), this will not produce an HSC/HSI curve that is useful for absolute habitat values, and centering is not used here. Collinearity in categorical variables (e.g., upwelling) is reduced by fitting them without an overall mean (i.e., intercept) and including multiple categorical variables as combined categories when possible (e.g., sites with upwelling and gravel substrates is one category) rather than as two separate variables.

Variance inflation factors (VIFs) are used as a formal check of collinearity. The square-root of the VIF is an estimate of the multiplicative inflation of the confidence interval around the coefficient estimates. When some predictors are categorical with more than two levels (i.e., more than one degree of freedom), the generalized VIFs are used with a similar interpretation (Fox and Monette 1992). If there are *p* degrees of freedom in a term, then $GVIF^{1/2p}$ is a one-dimensional expression of the decrease in the precision of estimation due to collinearity. Polynomials of the same variable are inherently correlated, but do not need to be interpreted separately. The VIF is estimated for the model without random effects because it is unclear how to estimate the VIF for mixed effects models. Some authors recommend that VIF>10 indicates a problem with collinearity (Ahmadi-Nedushan et al. 2006; Neter et al. 1990). If the VIF or generalized VIF were found to be greater than 10 for one of the included variables in the multiple regression, alternative models would be considered.

4.6.3.2 Interaction

It is possible that some environmental habitat variables interact in their relationship to fish habitat selection. However, interactions are seldom considered in multivariate habitat suitability modeling. One reason for this may be generally low numbers of fish observations. Even when there are large numbers of observations (as for chum salmon spawning), there may be insufficient replication of environmental conditions to properly infer interaction relationships in most cases. For example, high velocity sites with fine sediments have not been observed, so there cannot be inference on whether suitability at high velocity sites would differ among substrate types.

In addition to the main effects multivariate model, all possible models with a single two-way interaction in the original candidate set were also considered. If there was strong evidence that one of these interactions improved model predictions, the interaction term was further evaluated using graphical methods, and retained if the interaction relationship is well-defined. In this case, well-defined means there is sufficient replication at the combinations of variables that are driving the interaction effect, and also that the observed interaction effect is ecologically reasonable.

5. RESULTS

5.1 Selection of Priority Species and Development of Species Periodicity Information

A priority ranking of the 19 fish species to be considered for site-specific HSC was developed in collaboration with TWG during Q2 2013 (Table 5.1-1). The high and moderate ranked species are generally considered the most sensitive to habitat loss through manipulation of flows and the most widely distributed in the Susitna River. Five of the original 19 species (lake trout *[S. namaycush]*, northern pike *[Esox lucius]*, sculpin *(Cottid)*, Arctic lamprey *[Lethenteron japonicum]*, and threespine stickleback *[Gasterosteus aculeatus]*) were considered a low priority for development of site-specific HSC due to low numbers within the study area or that their habitat needs were similar to other species.

The priority species list was further refined during a March 21, 2014 Technical Team Meeting (AEA 2014b; R2 2014f) during which the remaining species were once again ranked using results of the 2013 HSC surveys, management status, and perceived sensitivity to changes in habitat due to potential Project operations (Table 5.1-2). Although no direct effort was made to collect site-specific microhabitat use information for low-priority ranked species during the 2013-2014 effort, incidental observations of these species were noted. During the 2013 and 2014 HSC surveys, sufficient microhabitat use observations were collected for development of draft final multivariate preference curves for all seven high priority species (Table 5.1-2). Of the moderate priority ranked species (pink salmon spawning and adult Arctic grayling, rainbow and Dolly Varden trout) only pink salmon spawning had sufficient site-specific observation to enable comparison with 1980s HSC and consideration for univariate HSC development. With the low number of site-specific observations for Dolly Varden and rainbow trout over the two-year sampling period, it is recommended that these species be moved to the low priority ranking.

5.2 HSC Sampling

5.2.1 Study Site Selection

During the 2014 HSC sampling effort, 72 additional sites were selected and sampled. For the combined 2013-2014 HSC sampling, a total of 129 sites were sampled (including both 50- and 100-meter sampling sites [164 and 328 feet, respectively]) for collection of site-specific data to define microhabitat use and availability by spawning and freshwater 'rearing' (juvenile resident or anadromous fish) or adult (resident fish) life stages. Both microhabitat utilization and availability data were collected during each sampling event. Microhabitat availability data was combined with habitat utilization data for developing species and life stage habitat preference.

Collection of habitat availability data allows modeling of fish presence/absence as a function of single or multiple parameters (e.g., water depth, velocity, cover, water quality, temperature, and GW upwelling) using availability measurements at locations where fish were not observed, and utilization measurements as locations where fish were observed (Manly et al. 1993).

5.2.2 Summer Surveys

Summertime HSC data collection was completed during eight separate sampling sessions from June through September 2013 and May through September 2014 (Table 5.2-1). The sampling occurred over a range of river flows from approximately 11,300 cubic feet per second (cfs) to 36,200 cfs as measured at the Gold Creek gage (USGS Gage No. 15292000). Habitat measurements were collected for four life history stages (spawning, juvenile, fry, and adult) and twelve fish species: Chinook, sockeye, chum, coho, and pink salmon; rainbow trout; Arctic grayling; Arctic lamprey; Dolly Varden char; whitefish (round *[Prosopium cylindraceum]* and humpback *[Coregonus pidschian]*); longnose sucker; and burbot.

As previously described in Section 4.2.1, the selection of summer HSC/HSI sampling sites relied on both stratified random and non-random sampling approaches based on macrohabitat composition and known fish use. Combined 2013 (n=57) and 2014 (n=72) sampling included 129 individual habitat segments representing ten different habitat types (Table 5.2-1). Of the ten habitat types sampled, side slough habitat had the most (30) segments sampled followed closely by upland slough (25). Although a significant number of the 2014 sampling sites were located in the LR (16 sites) the majority of the sites (78%) were located in the MR (56 sites). Fifteen of the MR sample sites were located within the three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex], FA-184 [Watana Dam]) that only sampled in 2014 (Table 5.2-1). Each of the selected habitat segments was sampled a minimum of once and in many cases twice, resulting in a total of 267 unique sampling events. The location of each sampling event within each of the ten Focus Areas and the LR is presented in Figures 5.2-1 through Figure 5.2-12.

A total of 2,799 observations of site-specific habitat use were used in development of the HSC models. A summary of the 2013-2014 HSC observations is presented by species and life stage in Table 5.2-2. Of the 2,799 utilization observations collected, approximately 80 percent were from MR Focus Areas (Table 5.2-2). Side slough (30.5%), side channel (19.8%), and upland slough (15.5%) macrohabitat types contained the largest percentage of HSC observations. Chum, sockeye, pink, and coho salmon were the only species observed spawning during the 2013-2014 surveys. Nearly half (44.7%) of all spawning observations were in side slough macrohabitat types with the next highest percentage (35.6%) of spawning observed in side channel habitat (Table 5.2-2).

5.2.3 Winter Surveys

Winter 2012-2013 HSC sampling was conducted in open-water areas of FA-104 (Whiskers Slough) and FA-128 (Slough 8A). Winter 2013-2014 HSC sampling was expanded to open-water areas within FA-104 (Whiskers Slough), FA-128 (Slough 8A) and FA-138 (Gold Creek) (Figures 5.2-13 through Figure 5.2-15) (R2 2014c; R2 2014d); with one additional opportunistic sampling event conducted in FA-141 (Indian River). Selection of winter sampling sites was non-random and relied on fish utilization information obtained during summer surveys, the availability of open-water areas, and safety concerns. Using these criteria, 8 open-water sites were selected for sampling during 2012-2013 and expanded to 18 sites for the 2013-2014 sampling. One additional site was located in FA-141 (Indian River), but was only sampled once during the winter sampling. Like the summer sampling, many of the winter sites were visited multiple times throughout the winter resulting in 45 unique sampling events.

A total of 59 electrofishing surveys were conducted during the winter HSC data collection efforts in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River). Although several different methods (minnow trapping, trot lines, under ice video) were used to determine fish habitat use during winter surveys (FDAML [Study 9.6] and IFS [Study 8.5]) only fish habitat utilization data collected during electrofish sampling were used for comparison. Electrofishing surveys are considered to provide a more direct and effective means of recording fish habitat use compared to passive trapping methods (e.g., minnow trapping), which can introduce capture biases related to fish size and sampling area (Bryant 2000). Fish species captured during electrofishing surveys consisted of Chinook, sockeye, chum and coho salmon, rainbow trout, Arctic grayling, longnose sucker, and Arctic lamprey; sculpin were also captured, though these individuals were not identified to species (Table 5.2-3). During the opportunistic survey of a main channel site in FA-141 (Indian River), 1 Chinook and 3 coho salmon juveniles were captured.

Over both winter survey years, a total of 291 site-specific HSC observations were recorded for eight fish species during winter electrofishing surveys (Table 5.2-3). Most HSC observations were of fry and juvenile salmonids (coho salmon (126 observations), sockeye salmon (68 observations), and chum salmon (42 observations). A detailed description of results of the 2012-2014 winter studies surveys is provided in the SIR Study 8.5, Appendix A (R2 2015b). The distribution of winter observations within FA-104 (Whiskers Slough), FA-128 (Slough 8A), and FA-138 (Gold Creek) was nearly equal with 38.5 percent, 26.1 percent, and 34.0 percent of the total respectively.

5.3 Habitat Utilization Summary

The following Section summarizes results of summer and winter habitat utilization data collection efforts and the resulting frequency histograms for depth, velocity and substrate use. Additionally, a comparison is made between 1980s HSC and utilization histograms developed from the 2013-2014 data. As previously stated, this comparison is only intended to identify significant segment, seasonal or period scale differences in microhabitat use and should not be used to infer habitat preference or suitability.

Attachment 1 presents histogram plots developed from summer surveys comparing microhabitat use by species and life stage for the LR and MR. Attachment 2 presents plots comparing habitat use between the summer and winter surveys. Attachment 3 presents plots comparing 1980s HSC and the distribution of habitat utilization observed during the current HSC surveys. Attachment 4 presents percentile ranges of habitat utilization for each species and life stage with sufficient number of site-specific observations (>10).

Statistical tests have not been completed to identify differences between various data distributions. As such, any of the following distinctions drawn between data groupings do not necessarily reflect statistical significance but simply differences in microhabitat use.

5.3.1 River Segment Comparisons

Results of the summer HSC surveys are organized and reported by species and are limited to those species and life stages with sufficient number of observations (approximately 10) to generalize microhabitat use. Comparisons of habitat utilization between MR and LR are included for each species and life stage.

5.3.1.1 Chinook Salmon

During the summer HSC surveys, no Chinook salmon were observed spawning in the mainstem Susitna River. A total of 217 Chinook fry and 67 Chinook juvenile microhabitat utilization measurements were recorded (Table 5.2-2). Chinook fry observations were widely distributed across macrohabitat types with side slough, tributary, tributary mouth, main channel, and upland slough habitat each providing between 10 and 24 percent of the total (Table 5.2-2). Fifty percent of the Chinook salmon rearing observations occurred during the late-May to June sampling period.

Observed depths utilized by Chinook fry in LR habitats were slightly greater compared to the MR (Figure D1-1); median depth was 1.0 feet in the LR and 0.8 feet in the MR. However, the 75^{th} percentile (1.3 feet) was the same in both river segments (Attachment 4). Velocities used by Chinook fry were greater in the LR (median=0.5 feet per second [fps]) compared to the MR (median = 0.3 fps); the $25\text{-}75^{th}$ percentile ranged from 0.1 to 0.8 fps in the LR but only from 0.1-0.5 fps in the MR. Chinook juveniles were more frequently observed in shallower water in the LR (median=0.7 feet) compared to the MR (median=1.4 feet) (Figure D1-2); the $25\text{-}75^{th}$ percentile ranged from 0.4-0.9 feet in the LR and 0.8-2.0 feet in the MR. Median velocities used by Chinook juveniles in the LR (0.5 fps) were greater than in the MR (0.2 fps), as was the $25\text{-}75^{th}$ percentile range (LR=0.3 to 0.9 fps; MR = 0.1-0.7 fps). Although substrate utilization for both fry and juvenile Chinook was slightly higher for smaller substrate sizes in the LR, the substrate composition (availability) of the LR is generally smaller than in the MR.

5.3.1.2 Chum Salmon

During the 2013-2014 spawning surveys, there were 397 observations of chum salmon spawning. All of the observations were located in the MR of the Susitna River, primarily in side channel, side slough, and upland slough macrohabitat types (Table 5.2-2). Chum salmon fry observations were significantly higher in 2014 (n=239) compared to the 2013 surveys (n=14). The primary factor for the large difference in the number of observations between the two years is assumed to be the timing of the surveys. In 2013, the first surveys did not begin until late-June (ISR Study 8.5 [AEA 2014a]), while in 2014, the surveys were started in late-May. Chum salmon fry were observed in all Focus Areas downstream of FA-151 (Portage Creek) and in all habitat types except multi-split main channel, with the largest numbers found in main channel, side channel, and side sloughs (Table 5.2-2). Although chum fry were observed in both the LR and MR, nearly seventy percent of observations were in the MR sample sites. Chum salmon fry were captured during their outmigration and HSC measurements likely reflect active outmigration rather than rearing activity.

For spawning chum salmon, the median depth utilization was 1.2 feet, with a $25\text{-}75^{th}$ percentile range of 0.8-1.6 feet. For velocity, the median spawning utilization was 0.2 fps, with the $25\text{-}75^{th}$ percentile ranging 0.1-0.5 fps (Figure D1-3). Spawning chum were generally observed in macrohabitat areas (side channel, side slough, upland slough) with low mean column velocities. Substrate utilization ranged from fines to large cobble with the majority of spawning observed in small or large gravel. A small number (n=17) of the chum spawning observations were found in areas with fines as the dominant (>50%) substrate type. Although presented here for comparison, spawning observations with fines classified as the dominant substrate type were not used as part of HSC model development (Section 5.5). For chum fry, median depth utilization was 0.7 feet and the 25-75th percentile ranged from 0.5-1.0 feet (Figure D1-4). Velocity utilization for chum fry was centered around a median of 0.3 fps and the 25-75th percentile ranged from 0.1-0.7 fps. Substrate utilization for chum fry ranged from fines to boulder-sized substrate with small and large cobble having the highest overall frequencies.

5.3.1.3 Coho Salmon

Only three coho salmon spawning observations were made during the 2013-2014 HSC surveys, all of which were located in MR side channel macrohabitat (FA-128 [Slough 8A]). A total of 274 coho fry and 87 juvenile microhabitat measurements were recorded (Table 5.2-2). Coho fry and juvenile observations were collected in nearly every habitat type with the exception of bar island complex and multi-split main channel areas. The largest numbers of fry measurements were collected in side slough (36%), upland slough (24%), and tributary (13%) habitat areas (Table 5.2-2). For juvenile coho, 70 percent of the observations were made in side and upland sloughs. Coho rearing observations were made in all Focus Areas downstream of Devils Canyon. FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam) are located upstream of Devils Canyon and are generally considered outside the distribution of coho salmon in the Susitna River. Approximately 11 percent of the coho rearing observations were located in the LR.

Microhabitat depth measurements for coho fry utilization in the LR were centered around a median of 1.2 feet (25-75th percentile = 0.9-1.7 feet); none were observed in depths less than 0.6 feet (Figure D1-5). In the MR, utilized depths were slightly less, with a median of 0.9 feet (25-75th percentile = 0.6-1.4 feet) (Attachment 4). For velocity, fry utilization was comparable in both river segments, where the median was 0.1 fps, although the 25-75th percentile range was slightly broader in the MR (0.0-0.3 fps) compared to the LR (0.0-0.2 fps).

Fewer observations of juvenile coho salmon were collected in the LR (n=7) compared to the MR (n=87) (Table 5.2-2). The median depth utilized by juvenile coho was 1.6 feet in the MR (25-75th percentile = 0.9-2.0 feet) while in the LR, the median utilized depth was 1.3 feet (25-75th percentile = 1.1-1.6 feet). The velocities used by juvenile coho were similar in the MR (median = 0.1 fps; 25-75th percentile = 0.0-0.3 fps) and LR (median = 0.2 fps; 25-75th percentile = 0.1-0.2 fps) (Figure D1-6). Substrate utilization for juvenile coho in the LR was higher for small particle sizes compared to the MR. This is not surprising given the smaller substrate sizes generally observed in the LR.

5.3.1.4 Pink Salmon

The 2014 HSC spawning survey occurred in mid- to late-September, which is outside the period when most pink salmon spawning occurs in the Susitna River. Therefore, there were no observations of pink salmon spawning during the 2014 survey. However, 53 pink salmon spawning observations were made in 2013 at FA-141 (Indian River) (n=17) and other non-focus-areas (n=36) within the MR (Table 5.2-2). All of these observations were made in either tributary or tributary mouth macrohabitat areas. Pink spawning depth utilization was centered around a median of 0.8 feet, while the 25-75th percentile ranged from 0.5-1.2 feet (Figure D1-7) (Attachment 4). The median velocity in which spawning was observed was 1.5 fps (25-75th percentile=1.2-2.3 fps). The relative high median velocity used by spawning pink salmon (when compared to both chum and sockeye spawning) is not surprising given that all habitat utilization measurements were made in high velocity tributary and tributary mouth macrohabitats. Large gravel represented the median substrate size as well as the 25-75th percentile of utilized substrate sizes.

A total of 39 pink salmon fry were observed during the surveys. All but one of the pink salmon fry observations were located in the MR and 87 percent were found in tributary and tributary mouth habitat types within FA-141 (Indian River) (Table 5.2-2).

Depth utilization for pink salmon fry was centered around a median of 0.5 feet while the 25-75th percentile ranged from 0.3-0.9 feet (Figure D1-8). For velocity, fry utilization was centered around a median of 0.4 fps and the 25-75th percentile ranged from 0.2-0.6 fps. Substrate utilization ranged from fines to large cobble while small cobble had the highest overall frequency.

5.3.1.5 Sockeye Salmon

A total of 244 sockeye spawning utilization measurements were collected during the 2013-2014 surveys, with 92 percent of the observations occurring in side slough, side channel, and upland slough habitats (Table 5.2-2). Spawning observations were concentrated in four Focus Areas, FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), and FA-144 (Slough 21). Sockeye spawning depth utilization was centered around a median of 1.2 feet (25-75th percentile=0.9-1.5 feet) (Figure D1-9). For velocity, spawning utilization was centered around a median of 0.1 fps (25-75th percentile=0.1-0.3 fps (Attachment 4). This is very similar to the median velocity used by spawning chum salmon and is consistent with the low velocity habitat areas (side channel, side slough, upland slough) used by spawning sockeye and chum salmon. Large gravel substrate had the highest frequency of utilization, although utilized substrates ranged from fines to large cobble.

Microhabitat use observations were collected for 357 sockeye salmon fry and 21 sockeye juveniles. Measurements for fry were made in all Focus Areas except FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam). These Focus Areas are located upstream of Devils Canyon and are generally considered outside the distribution of sockeye salmon in the Susitna River. Although sockeye fry observations were made in a wide variety of habitat types, the highest concentrations were in side slough (46%), upland slough (18%) and side channel (13%) habitat types; these were also the only habitat types in which juvenile observations were made (Table 5.2-2). Approximately 12 percent of the fry and 10 percent of juvenile observations were made in the LR.

Sockeye fry microhabitat depth measurements were slightly different between river segments, centered around a median of 0.9 feet (25-75th percentile=0.7-1.2 feet) in the LR and a median of 0.7 feet (25-75th percentile=0.4-1.1 feet) in the MR (Figure D1-10). Utilized velocities for fry in the MR were centered around a median of 0.2 fps (25-75th percentile=0.0-0.3 fps) and were less than in the LR which were centered around a median of 0.1 fps (25-75th percentile=0.0-0.6 fps)

(Attachment 4). Although substrate utilization for fry occurred over a wide range of particle sizes, fine substrate had the highest frequency of use in the LR, whereas small cobble had the highest frequency of use in the MR.

For juvenile sockeye, depth utilization centered around a median of 1.3 feet with the 25-75th percentile ranging from 1.0-1.7 feet (Figure D1-11). The median velocity utilized by juvenile sockeye was 0.1 fps with the 25-75th percentile ranging from 0.0-0.2 fps. Similar to fry, juvenile sockeye were observed in areas with a wide range of dominant substrate sizes, with the greatest frequency of observations occurring where fines were the dominant substrate.

5.3.1.6 Arctic Grayling

Observations of Arctic grayling were limited to the adult, juvenile, and fry life stages as no spawning was observed. Arctic grayling were observed in each of the surveyed Focus Areas, although most observations were made in FA-141 (Indian River; 25 percent), FA-173 (Stephan Lake Complex; 16 percent), and FA-128 (Slough 8A; 14 percent). Although Arctic grayling were observed in seven of the ten habitat types, most were in main channel (28 percent), side channel (23 percent), side slough (23 percent), and upland slough (14 percent) habitat (Table 5.2-2). Of the 213 Arctic grayling observations, 120 were for fry, 78 were for juvenile, and 15 were for adult life stages. There were no Arctic grayling observed in the LR.

Depth utilization by Arctic grayling fry was centered around a median of 0.5 feet (25-75th percentile=0.3-0.8) (Figure D1-12). For velocity, the median fry utilization was 0.1 fps with a 25-75th percentile range from 0.1-0.2 fps. Areas dominated by fine substrate comprised the majority of fry utilization observations, although fry were observed over a broad range of dominant substrate sizes.

For Arctic grayling juveniles, the median depth utilization was slightly greater than for fry, with a median of 0.6 feet and a 25-75th percentile range from 0.5-1.1 feet (Figure D1-13). Juveniles also utilized greater velocities compared to fry, with a median of 0.5 fps and a 25-75th percentile range of 0.2-0.8 fps. Juveniles also utilized areas with larger substrates with small cobble representing the median substrate size used; although, like fry, juveniles were observed over a broad range of dominant substrate sizes

Depth utilization by Arctic grayling adults was greater than depths used by earlier life stages; median adult depth utilization was 0.9 feet with a 25-75th percentile range of 0.8-1.2 feet (Figure D1-14). Similarly, adults used faster velocities; median velocity utilization was 1.2 fps with a 25-75th percentile range of 0.5-1.6 fps. Dominant substrates were also slightly larger; the median size of dominant substrate was large cobble, although adult observations were made over a similarly broad range of substrate sizes.

5.3.1.7 Burbot

A total of 28 burbot observations were made in 2013-2014, although the majority of these observations were for adult burbot (n=22). Only 1 burbot fry and 5 burbot juvenile observations were made, and no spawning burbot were observed. Thus, only microhabitat utilization for adult burbot is discussed here. Adult burbot were observed in all but two of the ten Focus Areas and except for one observation in the LR, all were observed in the MR (Table 5.2-2). Depth utilization for adult burbot was centered around a median of 1.4 feet, with a 25-75th percentile range of 0.9-2.3 feet (Figure D1-15). For velocity, the median observation was 0.2 fps and the

25-75th percentile range was 0.0-1.1 fps. Dominant substrate utilization for adult burbot ranged from fines to boulder, although fines had the highest frequency.

5.3.1.8 Dolly Varden

A total of 26 Dolly Varden observations were made in 2013-2014, although the majority of these observations were for fry (n=21). Only 2 juvenile and 3 adult Dolly Varden observations were made, and no spawning Dolly Varden were observed. Thus, only microhabitat utilization for Dolly Varden fry is discussed here. Fry were observed in six of the ten Focus Areas and all observations were in the MR (Table 5.2-2). Depth utilization for Dolly Varden fry was centered around a median of 0.7 feet, with a 25-75th percentile range of 0.3-1.0 feet (Figure D1-16). For velocity, the median observation was 0.2 fps and the 25-75th percentile range was 0.1-0.5 fps. Dominant substrate utilization for Dolly Varden fry ranged from fines to boulder, with the highest frequencies observed for fines, large cobble, and boulder.

5.3.1.9 Longnose Sucker

Observations of longnose sucker in 2013-2014 were limited to the adult, juvenile, and fry life stages; no spawning fish were observed. Longnose sucker were observed in each of the ten Focus Areas and in eight of the ten habitat types, with tributaries the lone exception (Table 5.2-2). Of the 256 longnose sucker observations, 88 were for the fry life stage, 97 for juvenile, and 71 adult. Approximately eight percent of the longnose sucker microhabitat use measurements were completed in the LR (Table 5.2-2).

Median depth utilization by longnose sucker fry (0.95 feet) was slightly deeper than for juveniles (0.8 feet), although the 25-75th percentile ranges were similar for fry (0.6-1.3 feet) and juveniles (0.5-1.4 feet (Figures D1-17 and D1-18). Depth utilization by fry was similar in the LR and MR, with the same median value (0.95 feet) in both river segments. For fry, velocity utilization was slightly greater in the LR (median=0.3 fps; 25-75th percentile=0.1-0.5 fps) compared to the MR (median=0.1 feet; 25-75th percentile=0.0-0.4 fps) (Attachment 4). For juveniles, velocity utilization was similar to that of fry, with a median of 0.2 fps and a 25-75th percentile range of 0.1-0.5 fps. Utilization of dominant substrate sizes for both fry and juvenile sucker ranged from fines to boulder, with fines having the highest frequency.

Adult longnose sucker utilized greater depths than earlier life stages; the median of depth observations was 1.3 feet with a 25-75th percentile range of 0.9-2.0 feet (Figure D1-19). However, adult velocity utilization was more similar to the other life stages, with observations having a median velocity of 0.2 fps and a 25-75th percentile range of 0.1-0.6 fps. Substrate utilization for adults was similar to other life stages, also ranging from fines to boulder, with fines having the highest frequency.

5.3.1.10 Whitefish

Due to the difficulty in distinguishing between early life stages (fry and juvenile) of round and humpback whitefish, all microhabitat use observations for the two species were lumped into a generic grouping of "whitefish." Observations of whitefish were limited to the adult, juvenile, and fry life stages; no spawning was observed. Whitefish were found in each of the 10 Focus Areas and in eight of the ten habitat types (Table 5.2-2). Of the 241 whitefish observations, 105 were for fry, 101 were for juvenile, and 35 were for adult life stages. Fifteen percent of the 2013-2014 whitefish observations were located in the LR.

Depths utilized by whitefish fry were slightly greater in the MR (median=1.0 feet; 25-75th percentile=0.7-1.3 feet) compared to the LR (median=0.8 feet; 25-75th percentile=0.6-1.0 feet) (Figure D1-20). Utilized velocities, were slightly lower in the MR (median=0.3 fps; 25-75th percentile=0.1-0.6 fps) compared to the LR (median=0.5 fps; 25-75th percentile=0.0-0.7 fps). Substrate utilization by whitefish fry ranged from fines to boulder, with fines having the highest frequency.

For juvenile whitefish, the median depth utilized was 0.6 feet, with a 25-75th percentile range of 0.4-1.0 feet (Figure D1-21). Velocities utilized by juveniles had a median of 0.3 fps and a 25-75th percentile range of 0.1-0.6 fps, which was similar to the velocity utilization exhibited by whitefish fry. A similar range of substrate utilization was also observed, although small cobble had the highest overall frequency for juveniles.

Whitefish adult utilized slightly greater depths compared to earlier life stages; the median depth was 1.0 feet and the 25-75th percentile ranged from 0.7-1.5 feet (Figure D1-22). Utilized velocities were also slightly higher for adults at 0.4 fps and a 25-75th percentile range of 0.1-0.8 feet per second (Attachment 4). Like other whitefish life stages, substrate utilization ranged from fines to boulder, although like only fry, the highest overall frequency was for fines.

5.3.1.11 Rainbow Trout and Arctic Lamprey

HSC measurements in 2013-2014 were limited to 19 observations for rainbow trout and 1 observation for Arctic lamprey; an additional observation of an undifferentiated lamprey species was also made (Table 5.2-2). Rainbow trout observations included four fry, seven juveniles, and eight adults, while both lamprey observations were juveniles. No spawning observations were made for either species. Rainbow trout observations were all within the MR, including six of the ten Focus Areas and in six of the ten macrohabitat types (Table 5.2-2). The lone Arctic lamprey observation was in FA-104 (Whiskers Slough) in side slough habitat, while the undifferentiated lamprey observation was in the LR in tributary habitat. Due to the limited number of observations, no attempt was made to develop frequency histograms for these species.

5.3.2 Seasonal Comparisons

Similar to the summer surveys, results of HSC surveys during the winter 2012-2013 and 2013-2014 are organized and reported by species and are generally limited to those species and life stages with a sufficient number of observations (approximately 10) to display a general trend in microhabitat use. Comparisons of habitat utilization between winter and summer surveys are included for each species and life stage.

5.3.2.1 Chinook Salmon

During winter HSC surveys in 2012-2013 and 2013-2014, a total of 17 Chinook fry and 28 Chinook juvenile microhabitat measurements were recorded (Table 5.2-3). Fewer winter observations were made compared to the total number of Chinook fry (n=217) and juvenile (n=67) observations made during summer surveys (Table 5.2-2). Both fry and juvenile winter observations were made in FA-104 (Whiskers Slough) and FA-128 (Slough 8A) while only a single fry observation and a single juvenile observation were made in FA-141 (Indian River) and FA-138 (Gold Creek), respectively.

The observed range of depths utilized during the winter by Chinook fry was narrower than summer utilization (Figure D2-1). The median winter depth utilization (0.6 feet) was slightly less than the median summer utilization (0.8 feet). The 75th percentile for depth utilization was also less for winter (1.0 feet) than for summer (1.3 feet) observations. Similarly for velocity, the median winter fry utilization (0.2 fps) was less than the median summer utilization (0.3 fps); the 75th percentile for winter velocity utilization (0.2 fps) was also less than summer utilization (0.5 fps).

For juvenile Chinook, a similar trend was observed in which shallower depths and slower velocities were utilized in winter compared to summer (Figure D2-2). The median depth utilized by juveniles was 0.9 feet in winter and 1.2 feet in summer. The winter 25-75th percentile range was 0.6-1.2 feet while the summer 25-75th percentile range was 0.7-1.9 feet. For velocity utilization, the winter median was 0.1 fps while the summer median was 0.3 fps; the winter 25-75th percentile range was 0.1-0.2 fps while the summer 25-75th percentile range was 0.1-0.7 fps.

A variety of dominant substrate sizes were utilized by both fry and juvenile Chinook during both seasons. However, the range of dominant substrates observed was somewhat broader during summer for both life stages.

5.3.2.2 Chum Salmon

During winter HSC surveys, a total of 42 chum salmon fry microhabitat measurements were recorded (Table 5.2-3). These observations were made exclusively during the 2013-2014 winter season. Fewer winter observations were made compared to the total number of chum fry (n=253) observations made during summer surveys. All winter chum salmon fry HSC observations were collected within FA-128 (Slough 8A) and FA-138 (Gold Creek) (Table 5.2-3). This was not surprising given the large concentration of chum spawning within these two Focus Areas.

The observed range of depths utilized during the winter by chum fry was narrower and generally shallower than summer utilization (Figure D2-3). The median winter depth utilization (0.5 feet) was slightly less than the median summer utilization (0.7 feet). The 25-75th percentile range for depth utilization was also less for winter observations (0.3-0.8 feet) than for summer observations (0.5-1.0 feet). Similarly for velocity, the median winter fry utilization (0.2 fps) was less than the median summer utilization (0.3 fps); the 75th percentile for winter velocity utilization (0.5 fps) was also less than that for summer utilization (0.7 fps) (Attachment 4).

The range of dominant substrate utilized by chum fry was similar between the two seasons, ranging from fines to boulder-sized substrate, although summer observations showed a more frequent use of areas where fines were the dominant substrate.

5.3.2.3 Coho Salmon

During winter HSC surveys in 2012-2013 and 2013-2014, a total of 36 coho fry and 88 coho juvenile microhabitat measurements were recorded (Table 5.2-3). Fewer winter fry observations were made compared to the total number of summer fry observations (n=274), whereas the number of winter juvenile observations was nearly identical to the number of summer juvenile observations (n=87). Both fry and juvenile winter observations were made in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), and FA-141 (Indian River). However, most measurements were made in FA-104 (Whiskers Slough) and FA-138 (Gold Creek).

The observed depths utilized during the winter by coho fry were generally shallower than depths utilized during summer (Figure D2-4). The median winter depth utilization was (0.7 feet) slightly less than the median summer utilization (0.9 feet). The 25-75th percentile range for depth utilization was also less for winter observations (0.4-0.9 feet) than for summer observations (0.6-1.4 feet). Velocity use for coho fry showed greater similarities between seasons. The median velocity utilized by fry was 0.2 fps for winter observations and 0.1 fps for summer observations. The 25-75th percentile ranges were also similar for winter (0.1-0.3 fps) and summer (0.0-0.3 fps) observations. Coho fry utilized similar dominant substrate sizes across seasons, with areas dominated by fines having the highest frequency.

For coho juveniles, observed depths utilized during the winter were shallower than depths utilized during summer (Figure D2-5). The median winter depth utilization (0.8 feet) was less than the median summer utilization (1.5 feet). Likewise, the 25-75th percentile range for depth utilization was also less for winter observations (0.4-0.9 feet) than for summer observations (0.6-1.4 feet). Velocities utilized by coho juveniles were more similar across seasons. The median velocity utilized by juvenile coho was 0.1 fps in both seasons, while the 25-75th percentile ranges for winter (0.1-0.2 fps) and summer (0.0-0.3 fps) utilization were also similar. Dominant substrates utilized by juvenile coho during winter and summer were similar as well, with areas dominated by fines having the highest frequency.

5.3.2.4 Sockeye Salmon

During winter HSC surveys, a total of 35 sockeye salmon fry and 33 sockeye salmon juvenile microhabitat measurements were recorded (Table 5.2-3). These observations were made exclusively during the 2013-2014 winter season. Fewer winter fry observations were made compared to the total number of summer fry observations (n=357), whereas the number of winter juvenile observations was greater than the number of summer juvenile observations (n=21). Winter fry observations were made in FA-104 (Whiskers Slough), FA-128 (Slough 8A), FA-138 (Gold Creek), although most observations were in FA-128 (n=30). Winter juvenile observations were limited to FA-138 (Gold Creek).

The observed range of depths utilized during the winter by sockeye fry was narrower and generally shallower than summer utilization (Figure D2-6). The median winter depth utilization (0.6 feet) was slightly less than the median summer utilization (0.7 feet). The 25-75th percentile range for depth utilization was also less for winter observations (0.4-0.8 feet) than for summer observations (0.5-1.2 feet). Velocity utilization showed greater similarity between seasons. The median velocity utilized by sockeye fry was 0.1 fps for both seasons, while the 25-75th percentile ranges were also similar for winter (0.1-0.3 fps) and summer (0.0-0.3 fps) observations. Sockeye fry utilized similar substrate sizes across seasons, with areas dominated by fines having the highest frequency.

For sockeye juveniles, observed depths utilized during the winter were shallower than depths utilized during summer (Figure D2-7). The median winter depth utilization (1.0 feet) was less than the median summer utilization (1.3 feet). Likewise, the 25-75th percentile range for depth utilization was also less for winter observations (0.6-1.3 feet) than for summer observations (1.0-

1.7 feet) (Attachment 4). Velocities utilized by sockeye juveniles were more similar across seasons. The median velocity utilized by juvenile coho was 0.0 fps in winter and 0.1 fps in summer, while the 25-75th percentile ranges were 0.0-0.1 fps in winter and 0.0-0.2 fps in summer. Although the juvenile sockeye showed a broad range of dominant substrate utilization in both winter and summer, areas dominated by fines had the highest frequency in summer whereas areas with large cobble had the highest frequency in winter.

5.3.2.5 Rainbow Trout, Arctic Grayling, Longnose Sucker and Lamprey

A combined total of nine HSC measurements were made for rainbow trout, Arctic grayling, longnose sucker, and an undifferentiated lamprey species during the winter 2014 surveys (Table 5.2-3). No one species had more than four observations, limiting the usefulness of histogram development. All but two of the winter HSC measurements for these species were made in FA-104 (Whiskers Slough). Due to the limited number of observations, no attempt was made to develop winter frequency histograms for these four species.

5.3.3 1980s and 2013-2014 Comparison

The number of HSC utilization measurements collected during 2013-2014 surveys varied by species and life stage. For species and life stages with fewer (<75) 2013-2014 observations, reviewing HSC curves developed during the 1980s Susitna River studies offers a means to compare and cross-validate the recent utilization data, which is the focus of the following Section. Descriptions of the 1980s HSC curves are presented in the 2012 baseline environmental report summarizing aquatic and instream flow studies conducted in the 1980s (R2 2013). Additional information regarding the field and analytical techniques used to develop the 1980s curves can be found therein. For certain species and life stages (i.e., Chinook salmon juvenile), separate HSC curves were developed in the 1980s by river segment (i.e., LR versus MR) and turbidity level. In such cases, the 2013-2014 data presented below reflect the same set of conditions for which the 1980s HSC curves were developed. The comparisons provided below focus exclusively on summer observations and not winter observations. HSC curves from the 1980s and recent utilization results are discussed for depth and velocity. However, because 1980s HSC curves integrated cover and substrate for rearing suitability, substrate is only discussed below as it relates to spawning.

5.3.3.1 Chinook Salmon Juvenile

During the 1980s licensing studies, a total of 4,395 juvenile Chinook salmon were captured from 1,260 sample cells during efforts to collect juvenile salmon HSC data in the MR (Suchanek et al. 1984a). Sampling effort was targeted at sites where rearing fish were numerous based on knowledge of seasonal movements. Backpack electrofishing and beach seines were the primary sampling methods with beach seining typically used in turbid water areas and electrofishing in clear water areas. Sampling cells 50 feet long by six feet wide (300 ft^2) were delineated in areas with known high fish use and positioned along the shoreline and mid-channel areas.

Chinook salmon were the only juvenile salmon captured in sufficient numbers to develop separate suitability curves based on turbid vs. clear-water conditions and observations from electrofishing (clear-water) and seining (turbid-water) were therefore analyzed separately. Additional sampling was conducted in the LR during the 1980s (Suchanek et al. 1985) which allowed for separate HSC curves to be developed by river segment for appropriate parameters. Catches from a total of 1,155 sample cells in the LR were used to analyze habitat suitability. Of these cells, 400 were sampled in water with a turbidity of 30 NTU or less while the remainder had turbidity levels between 30 and 350 NTU. As with sampling in the MR, 30 NTU was used as the breakpoint between turbid and clear water. Sampling in 2013-2014 collected a total of 67 juvenile Chinook observations, in both the MR (n=49) and LR (n=18). Turbidity levels were also recorded in 2013-2014, allowing for some comparisons with the 1980s curves by both turbidity and river segment. The 67 total juvenile Chinook observations from 2013-2014 included MR observations in turbid-water (n=18) and clear-water (n=31), and LR observations in turbid-water (n=17) and clear-water (n=1).

Based on MR observations from the 1980s, the effect of depth on the distribution of juvenile salmon was not considered limiting beyond a minimum threshold, and the inclusion of depth in composite weighting factors showed only minimal improvement in the correlation with catch. Depths greater than or equal to 0.15 ft were assigned a suitability index of 1.0 in the MR HSC curve for all juvenile salmon species (Figure D3-3). Depths less than 0.15 were assigned a suitability index of 0.0 based on professional judgment. Although separate depth curves were not developed for clear- vs. turbid-water conditions, Suchanek et al. (1984a) did suggest that juvenile Chinook may prefer shallower depths in turbid water. The distribution of juvenile Chinook utilization observations from 2013-2014 in the MR all fall within this broad range of optimal depth values reflected by the 1980s HSC curve for depth in the MR.

In the 1980s, comparisons between MR and LR data were made independently for clear-water and turbid-water conditions. While MR efforts suggested that depth in clear water had little effect on juvenile Chinook catch relative to other habitat parameters, LR efforts suggested a more frequent use of greater depths. Based on this finding, 1980s clear-water LR depth curve was developed using professional judgment in which only depths greater than 2.1 feet were assigned a suitability index of 1.0 (Figure D3-1). Because only one juvenile Chinook observation from 2013-2014 was collected in clear-water conditions in the LR, a comparison to the 1980s HSC curve for the clear-water in the LR is not possible. For turbid-water conditions, the LR depth curve was developed by adjusting the MR curve such that optimum depths ranged from 0.3-1.5 feet. A depth of 0.1 feet was also modified to have a suitability >0.0 based on observations of limited Chinook use at this depth. A total of 17 juvenile Chinook observations were collected in 2013-2014 in turbid-water within the LR and offer some comparison to the 1980s HSC curve for LR turbid-water. The median depth utilized in LR turbid-water in 2013-2014 was 0.7 feet and the 25-75th percentile ranged from 0.4-0.9 feet, generally within the optimal range identified by the 1980s curve.

In the 1980s, separate velocity HSC curves were developed for clear- versus turbid-water in the MR. Under clear-water conditions in the MR, velocities between 0.35 and 0.65 fps were found to be optimal for juvenile Chinook salmon and were assigned a suitability index of 1.0 (Figure D3-3). Velocities greater than 0.65 fps were assigned decreasing suitability indices, reaching 0.0 at velocities of 2.60 and greater. For comparison, 2013-2014 utilization observations from clear-water in the MR had a median of 0.1 fps and a 25-75th percentile range of 0.0-0.5 fps, slightly lower than the 1980s HSC curve optima.

Under turbid-water conditions in the MR, the 1980s results indicated that juvenile Chinook appeared to prefer slower velocities than in clear-water; velocities between 0.05 and 0.35 fps were found to be optimal and were assigned a suitability of 1.0 (Figure D3-4). Velocities greater than 0.35 fps were assigned decreasing suitability indices, and like the clear-water curve, reached 0.0 at velocities of 2.60 fps and greater. Suchanek et al. (1984a) suggested that the preference for slower velocities in turbid water may be attributable to the absence of velocity breaks to rest behind when turbidity is used for cover rather than objects. For comparison, 2013-2014 utilization observations from turbid-water in the MR had a median of 0.3 fps and a 25-75th percentile range of 0.1-0.8 fps, which is slightly higher than the both the 1980s HSC curve for MR turbid-water optima, and the distribution of observations from 2013-2014 in MR clear-water.

During the 1980s, the distribution of juvenile Chinook catch in clear-water in the MR showed peak catches at velocities ranging from 0.1 to 0.3 fps. This range suggested that under clear-water conditions, Chinook used lower velocities in the LR compared to the MR. The MR clear-water distribution of catch by velocity interval was more similar to the LR turbid-water suitability criteria. Thus, the MR turbid-water velocity HSC curve was selected to represent the clear-water curve for the LR (Figure D3-1). Under turbid-water conditions, velocities used by juvenile Chinook were similar in the LR and MR and the turbid-water MR velocity criteria was considered appropriate for the LR. Thus, the selected velocity criteria for the LR was identical for both turbid- and clear-water conditions, with velocities between 0.05 and 0.35 fps considered optimal and assigned a suitability of 1.0 (Figure D3-1, Figure D3-2).

Juvenile Chinook observations from the LR in 2013-2014 were insufficient to offer a comparison of turbid- versus clear-water conditions. However, the combined LR observations from 2013-2014 had a median velocity of 0.5 fps and a 25-75th percentile range of 0.3-0.9 fps, which is slightly higher than the optima selected by the 1980s curves for velocity in the LR.

5.3.3.2 Coho Salmon Juvenile

HSC curves developed for juvenile coho salmon in the 1980s were based on a total of 2,020 juvenile coho observations from 1,260 sample cells in the MR (Suchanek et al. 1984a). Sampling was also conducted in a total of 345 sample cells the LR, although few coho were captured in habitat types other than tributary mouths and only tributary mouth data were used to compare suitability criteria across river segments (Suchanek et al. 1985). Sample sizes were also insufficient to develop separate suitability curves based on turbid vs. clear-water conditions. Juvenile coho catches were low in turbid water while electrofishing (clear-water) data were deemed sufficient for criteria development. Thus, juvenile coho criteria were developed based exclusively on catches under clear-water conditions. By comparison, a total of 87 juvenile coho observations were collected in 2013-2014 in both the MR (n=80) and LR (n=7) segments.

Analysis of variance of the 1980s data from the MR indicated that depth was significantly related to juvenile coho catch. However, the effect of depth was not considered limiting beyond a minimum threshold. Therefore, the 1980s HSC for juvenile coho and all other juvenile salmon species considered, depths greater than or equal to 0.15 feet were assigned a suitability of 1.0 (Figure D3-5). Depths less than 0.15 feet were assigned a suitability of 0.0 based on professional judgment. The distribution of depth observations during the 1980s surveys of the LR were very different compared to the MR. However, after adjusting for the effects of velocity, percent cover, and cover type there was no trend in depth suitability. Therefore, the 1980s depth suitability criteria for the LR was not changed from that developed for the MR. Due to the broad range of depths with a suitability of 1.0 in the 1980s curve, all depth utilization observed in 2013-2014 fell within the range considered suitable.

For the 1980s HSC curve developed based on MR observations, velocities between 0.05 and 0.35 fps were considered optimal for juvenile coho salmon and were assigned a suitability of 1.0 (Figure D3-5). Velocities greater than 0.35 fps were assigned decreasing suitability, reaching 0.0 at velocities of 2.10 fps and greater. The 1980s catch distribution from the LR matched closely with the suitability curve derived for the MR so the MR velocity suitability curve was chosen as representative for both the LR and MR. Velocity utilization observed in 2013-2014 also matched closely with the 1980s MR curve, with a median velocity of 0.1 fps and a 25-75th percentile range of 0.0-0.3 fps.

5.3.3.3 Pink Salmon Spawning

During the 1980s, utilization data were not collected for pink salmon spawning in the MR. Rather, Vincent-Lang et al. (1984) developed depth, velocity, and substrate HSC for pink salmon spawning based solely on previously published information as modified by the opinions of project biologists familiar with Susitna River pink salmon stocks. HSC developed in the Terror Lake environmental assessment (Wilson et al. 1981) were chosen as the basis for modification. Because the Terror River has hydraulic and physical characteristics similar to many of the larger clear water tributaries of the MR, the curves developed for pink salmon depth, velocity, and substrate spawning suitability were considered an appropriate basis for modification by Vincent-Lang et al. (1984). Efforts in 2013-2014 were able to collect 53 pink salmon spawning observations, all of which were collected in the MR.

The 1980s depth suitability criteria curve developed for pink salmon spawning was similar to that developed for the Terror Lake system in which assigned a suitability of 1.0 at a depth of 1.0 feet. However, one modification was that a suitability of 0.0 was extended from 0.1 to 0.3 feet because it was assumed that depths less than 0.3 feet would not be suitable (Figure D3-6). An additional modification was to extend a suitability of 1.0 out to 4.0 feet based on the opinion of field biologists that depths greater than 2.5 ft (the depth at which suitability in the Terror Lake curves begins to decline) would not likely limit pink salmon spawning in tributaries of the MR. Although many of the 2013-2014 velocity observations fell within the range of maximum suitability defined in the 1980s curve, the median depth observed was 0.8 feet and 75 percent of the observations were in depths of 1.2 feet or less.

The 1980s velocity suitability criteria curve developed for pink salmon spawning assigned a maximum suitability of 1.0 at velocities of 1.0-2.0 fps. The curve generally matched that developed for the Terror Lake system, except that velocities ranging from 2.0 to 5.0 fps were assigned slightly higher suitability indices (Figure D3-6). This modification was based on the opinions of project biologists that these velocities are utilized to a greater degree by spawning pink salmon in tributaries of the MR. With a median of 1.5 fps and a 25-75th percentile range of 1.2-2.3 fps, observations of velocity utilization from 2013-2014 closely matched the 1980s curve (Figure D3-6).

The substrate suitability criteria curve developed for pink salmon spawning in the Terror Lake system was considered representative of substrate suitability for pink salmon spawning in the MR and adopted in its entirety for the 1980s curve. The 1980s curve assigned a suitability of 1.0 for large gravel substrate, with lower suitability for small gravel (0.75) and small cobble (0.5). Observations of substrate utilization in 2013-2014 closely matched this suitability curve, with large gravel having the highest frequency of utilization, followed by small gravel, and then small cobble (Figure D3-6).

5.3.3.4 Arctic Grayling Adult

HSC were developed in the 1980s based on a total of 140 adult Arctic grayling observations collected by boat electrofishing (n=138) and hook-and-line sampling (n=2) in the MR (Suchanek et al. 1984b). All of the 15 adult Arctic grayling observations collected in 2013-2014 were also from the MR. For the 1980s HSC and as with other adult resident species, depth was only thought to limit the distribution of adult Arctic grayling as a minimum. Therefore, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 feet, and to 0.0 for depths less than 0.5 feet (Figure D3-7). Results from 2013-2014 indicated similar depth utilization, with 75 percent of the observations occurring at depths of 0.8 feet or greater.

During the 1980s, adult Arctic grayling were often found to use areas with high velocity compared to adults of other resident species (Suchanek et al. 1984b). The 1980s HSC curves assigned a suitability of 0.04 at 0.0 fps, which gradually increased to a suitability of 1.0 for velocities of 3.05-4.30 fps; a suitability of 0.0 was assigned to velocities of 4.5 fps and greater (Figure D3-7). Although 2013-2014 observations indicated more frequent utilization of higher velocities from 1.0-2.0 fps compared to adults of other resident species, all adult Arctic grayling observations were in velocities of 2.5 fps or less.

5.3.3.5 Rainbow Trout Adult

A total of 143 adult rainbow trout observations were collected by boat electrofishing (n=44) and hook-and-line sampling (n=99) in the MR to develop HSC curves in the 1980s (Suchanek et al. 1984b). Results of hook-and-line sampling suggested that adult rainbow trout preferred pools with depths greater than 2.0 feet. As with other adult resident species, however, depth was only thought to limit the distribution of adult rainbow trout as a minimum. Therefore, for all adult resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 feet, and to 0.0 for depths less than 0.5 feet (Figure D3-8). Adult rainbow trout captured by boat electrofishing were typically found in cells with water velocities less than 1.5 fps, whereas results of hook-and-line sampling suggested that adult rainbow trout preferred pools with velocities less than 0.5 fps. Because electrofishing data were collected at more cells in a wider variety of habitat types compared to hook-and-line sampling, velocity HSC were fit to the boat electrofishing data. Based on this information, velocities between 0.05 and 1.05 fps were assigned a suitability of 1.0, with decreasing suitability values up to 4.5 fps, which was assigned a suitability of 0.0.

Only eight adult rainbow trout observations were collected in 2013-2014. This total was deemed insufficient to warrant the development of utilization summary statistics or histograms for comparison with the 1980s HSC.

5.3.3.6 Whitefish Adult

HSC curves developed in the 1980s for adult whitefish were based on a total of 138 adult round whitefish observations collected by boat electrofishing in the MR (Suchanek et al. 1984b). Most of the 35 whitefish observations collected in 2013-2014 were also from the MR. For the 1980s HSC curve, depth was only thought to limit the distribution of adult round whitefish as a minimum. Therefore, for adult round whitefish and all other resident species, depth suitability was conservatively set to 1.0 for all depths greater than 0.6 feet, and to 0.0 for depths less than

0.5 feet (Figure D3-9). Results from 2013-2014 indicated similar depth utilization, with 75 percent of the observations occurring at depths of 0.7 feet or greater.

The 1980s HSC for velocity were developed by fitting suitability values to catch distributions. Although velocity did not appear to have a strong effect on distribution, observations most frequently occurred at velocities of 2.0-3.0 fps (Suchanek et al. 1984b). In contrast, 75 percent of the observations from 2013-2014 were at velocities of 0.8 fps or less and few observations were within the 2.0-3.0 fps range identified as having the highest suitability in the 1980s HSC. Suchanek et al. (1984b) indicate that turbidity influenced round whitefish distribution as a cover source, which may have been a greater determinant in distribution compared to velocity.

5.4 Other Microhabitat Variables

HSC and HSI models have been utilized by natural resources scientists for over two decades to assess the effects of habitat changes on biota. HSC for fish typically describe the instream suitability of habitat variables (depth, velocity, substrate and cover) related to stream hydraulics and channel structure. HSC curves can also be developed for other microhabitat variables influenced by flow including water quality (temperature, DO, turbidity, pH) and presence of GW upwelling or downwelling.

In response to the April 1, 2013 FERC SPD [FERC 2013], a detailed evaluation of fish abundance measures and eight additional habitat variables (surface flow and GW exchange flux, surface and intergravel DO and temperature, macronutrients, pH, DOC, alkalinity, and chlorophyll-a) was completed to determine whether relationships were evident and if additional HSC curve development was warranted (R2 2014e).

There were three crucial requirements to be met for habitat variables to be included in HSC development. The first is that there is a predictive and direct relationship between the habitat variable and fish presence; second, that changes to the habitat variable as a function of flow can be spatially and quantitatively predicted at the Focus Area scale; and third, that predicted changes in the variable are observable at a temporal scale (hours to days) similar to changes in flow conditions in response to Project operations. If any of these criteria cannot be met, then the individual variable was not considered as part of site-specific HSC curve development.

Of the eight variables requested by the FERC for further investigation of possible HSC development, three (VHG as a surrogate for surface and GW exchange flux, surface water DO, and temperature) are included as part of the HSC suitability curve development process. Intergravel DO and temperature continue to be collected, but this data will be used to develop threshold (highs and lows) that can be applied as part of the effective spawning habitat analysis.

For the five remaining variables (pH, DOC, alkalinity, macronutrients, and chlorophyll-a), statistical analysis was completed to estimate the probability that these variables are "strong" predictors of habitat use by the target species and life stages (R2 2014e). A summary description of the predictive value of each of these five variables is presented below along with a recommendation regarding inclusion in future HSC development activities (Table 5.4-1).

5.4.1 Macronutrients

It is widely believed that the concentration of N and P does not relate directly to fish abundance because it must first be assimilated into the food web before utilized by fish (Nakano and

Murakami 2001, Meyer et al. 2007). Furthermore, the rate of P and N assimilation varies over space and time making it unrealistic to believe that the water quality model can predict changes to total N and P concentrations within all macrohabitat types of a Focus Area on an hourly or daily time-step in response to changes in Project operations. Considering these facts, it is AEA's recommendation that macronutrients are not added as a variable to predict fish habitat use as part of the HSC curve development process, and that no additional data collection efforts are required.

5.4.2 pH

The pH of water can directly affect not only the habitat selection of fish but fish health as well. Although pH was not collected as part of the HSC surveys, it was largely collected as part of FDAML (Study 9.6) and FDAUP (Study 9.5) surveys (AEA 2014a). Results of this assessment show no clear evidence of a relationship between pH and abundance of resident, non-salmonid fish in the Susitna River. However, there is strong evidence that salmonids (resident and anadromous fry and juvenile) are found most commonly in areas with pH near 7 in the MR and LR of the Susitna River. The analysis shows that 90-100% of salmonids are selecting habitats in the range of 6.2-8.7, which is very similar to the ADEC (2012) determined preference range. Therefore, it is recommended that a pH range of 6.5-8.5 be used as a threshold by which to evaluate the loss or gain in habitat area.

5.4.3 Dissolved Organic Carbon

There is no evidence that DOC can be used as a predictor of fish abundance or habitat use in the Susitna River. Levels of DOC can show considerable spatial and temporal variability depending on sample location and assimilation into the trophic food web. As such, it is recommended that DOC not be added as a variable to predict fish habitat use as part of the HSC model development process.

5.4.4 Alkalinity

Alkalinity samples were not collected within MR Focus Areas during the Baseline Water Quality Study (ISR Study 5.5). As a result, there were only 19 samples (where Baseline Water Quality Study alkalinity samples and FDAML samples overlapped) from which to evaluate a relationship between alkalinity and fish abundance. Although in most stream-fish populations, alkalinity of stream water alone is not known to have a significant, direct effect on fish, results of the statistical analysis did show a weak relationship between alkalinity levels and both resident and non-resident salmonids abundance. Since alkalinity levels are not being collected or modeled on a Focus Area scale and the generally weak relationship between alkalinity and fish abundance, it is recommended that alkalinity not be added as a variable to predict fish habitat use as part of the HSC model development process.

5.4.5 Chlorophyll-a

In 2013, chlorophyll-a samples were collected by both the Baseline Water Quality Study (5.5) and River Productivity Study (9.8). Unfortunately, the samples were collected from two different sources (mid-water column and river substrate) and could not be combined as part of this analysis. Similar to DOC, chlorophyll-a levels are generally not considered a direct indicator of fish abundance (particularly for salmonids) or habitat use, but rather an indicator of overall water quality and productivity.

Benthic chlorophyll-a data are being analyzed as part of the River Productivity Study (Study 9.8) (AEA 2014a) to evaluate and model benthic macroinvertebrates and algal communities. To reduce duplication of effort, it is recommended that chlorophyll-a not be included in development of HSC curves for the IFS but to rely on the results of the River Productivity Study to evaluate potential Project impacts on chlorophyll-a.

5.5 Data Considerations and Threshold Values

Environmental conditions (e.g., high water velocity), sometimes restricted the areas that could be safely sampled to determine the extent of fish utilization. Field conditions under Existing Conditions may not present the full range of parameters to evaluate fish utilization of habitats. For example, water temperatures in the glacially-fed Susitna River are generally cold and the extent of fish utilization under a range of water temperatures cannot be sampled under field conditions. In this case, threshold values are needed in order to limit extrapolation of models beyond observed ranges and prevent ecologically unreasonable results near the outer extent of observed ranges. Proposed restrictions and thresholds applied to the HSC model are presented in Table 5.5-1. The threshold values are life stage- and season-specific and based on one of three factors; 1) the observed range of habitat use by a particular life stage, 2) biological needs or limits established during similar studies, and 3) water quality standards established by the ADEC (2012).

Completing the statistical analysis for a diverse data set collected over approximately 120 river miles for a wide range of habitat conditions required the grouping or consolidation of some data for specific habitat variables and the expansion or interpretation of habitat conditions within a sample site for other variables. A general summary of the life stage-specific data considerations and thresholds is provided in Section 5.1.1 and Section 5.2, while those specific to particular species are detailed in Section 5.6.

Because both habitat utilization and availability measurements are necessary for development of multivariate HSC, only those data collected concurrently in space and time at the site level (i.e., for the HSC/HSI program) were used as part of the model development. During the 2013 sampling, some variables (water temperature, DO, conductivity, turbidity, and VHG) were not collected at every availability and utilization sampling point but were collected within the sampling site and were assumed to be equivalent to those sampled at the nearest measurement point. If multiple measurements were equidistant from the unmeasured location, the average of the measured locations was used. During the 2014 sampling, habitat measurements were taken at all utilization locations, and along each availability transect.

For all species and life stages, only those sampling events that included fish observations were used for developing the HSC curves. It is reasonable to assume that the relatively large number of sampling events with no fish is at least partially due to the wide spatial dispersion of fish in the Susitna River, rather than to unsuitable habitat conditions in most sampled locations. Therefore, if all availability data from all sampling events were to be included in the analysis of habitat preference, the HSC model may not reflect true habitat selection. Further, an important assumption of random effects models is that the random intercept term across sites has a normal distribution. Models based on the full availability dataset may fit poorly because the random effect distribution will be badly skewed with a large spike at zero.

5.5.1 Spawning Life Stage

Spawning adult salmon were assumed to require a minimum water depth of 0.3 feet to remain upright and successfully spawn. A small number (7 of 553) of measurements in the vicinity of spawning salmonids recorded water depths less than 0.3 feet. It is assumed these redd measurements were taken following a drop in stage and while adult salmon exhibited site fidelity, they were not actively digging or spawning.

Mean column velocities greater than 4.5 feet per second were assumed to be unsuitable for spawning (Table 5.5-1). This threshold is similar to the maximum velocity applied to spawning HSC developed during the 1980s studies. Daily average minimum and maximum water quality thresholds are also proposed for pH, DO, and water temperature (Table 5.5-1). Each of the minimum and maximum values matches water quality standards for designated uses proposed by the ADEC (2012).

Exploratory review of spawning substrate data determined that the largest differences among substrates for spawning could be found when substrate groups were formed as follows:

- Group 1: 100% large and small gravel dominant
- Group 2: Gravel dominant mixed substrate
- Group 3: Gravel subdominant mixed substrate
- Group 4: No gravel, but large or small cobble dominant
- Group 5: Bedrock, boulder or all fine substrate

Substrates included in Group 5 were considered unsuitable for spawning, and were removed from the spawning analysis for all predictor variables. Differences among the remaining four substrate groups were used for testing in the HSC model.

Adjustment to VHG (used to detect GW upwelling or downwelling) within spawning sites were made to match the anticipated scale of the GW mapping. First, samples were classified into three categories: 1) Upwelling if the measured VHG was positive; 2) Downwelling if the measured VHG was negative; and 3) Neutral if the VHG was 0. VHG measurement within 50-meter sampling sites were consistently identified as upwelling or downwelling sites if all measurements within the site were a mix of upwelling and neutral or a mix of downwelling and neutral. All neutral VHG and unsampled locations within these sites were assigned as upwelling or downwelling according to the site designation. There were four sites that had a mixture of positive and negative VHG measurements. Each of these sites was divided into a predominately downwelling and/or upwelling segment based on where the transition occurred longitudinally in the segment.

5.5.2 Fry, Juvenile and Adult Life Stages

Minimum water depths for suitable habitat were set to 0.05 feet for fry, 0.2 feet for juvenile, and 0.25 feet for adults (Table 5.5-1). These minimum depth values match site-specific observations collected during 2013-2014 HSC surveys. A maximum velocity threshold of 3.0 feet per second was also applied to both the fry and juvenile life stages for the summer period (May-September). Although this maximum velocity value is somewhat higher than the preference range reported in the 1980s studies, it defines the highest velocity observations made during the 2013-2014 surveys. No maximum velocity is proposed for the adult life stage. Daily average minimum and maximum water quality thresholds are proposed for pH, DO, and water temperature (Table 5.5-1). Each of the minimum and maximum values matches water quality standards for designated uses proposed by the ADEC (2012).

All substrate size classes are assumed to be suitable for fry, juvenile, and adult life stages and as such are not included in the HSC model for these life stages. Because there are often multiple cover types (boulder, wood debris, aquatic vegetation, undercut bank and overhead vegetation) present in the same location, the full mix of individual cover types could not be assessed in the same model. Instead, the types of cover showing increased utilization were combined into one factor – cover or no cover. Turbidity can also be utilized as cover by juvenile fish, or there may be decreased utilization of cover in turbid water. Habitat use studies completed during the 1980s Susitna River Study reported an inflection point at approximately 30 NTU for juvenile Chinook salmon use of turbidity as cover (Schmidt et al. 1984). The 2013-2014 survey data suggests a similar break point of 30 NTU to define clear (<30 NTU) and turbid (>30 NTU) water. Locations are defined as turbid and non-turbid based on this NTU level, and this turbidity factor is included in the analysis of cover for each species and life stage. In order to get the strongest predictive model of fish preference, cover and turbidity were generally combined into a 3-level factor: No cover in turbid water (lowest preference); cover in clear water (highest preference); and the combined category of cover in turbid water or no cover in clear water (moderate preference). For each "univariate" comparison, the models with cover alone, turbidity alone, and the combined factor were compared and the best fit model was integrated into the habitat preference model.

5.6 HSC Modeling

This Section presents the draft Final multivariate HSC models developed for the 12 high priority species and life stages proposed for application in the habitat-flow analysis for evaluating Project operational effects. The HSC models will be subject to agency and stakeholder review which may result in some model refinements.

Univariate preference histograms for the four continuous predictor variables (depth, velocity, temperature, and DO) are provided in Attachment 5. These plots show the distribution of total sampled habitat split into utilization (blue bars) and availability (white bars) and normalized to a maximum bar height of one. The histograms are overlaid with the proportion of habitat utilized for each bin in the histogram. The models discussed below are modeling this proportion on a continuous basis using logistic regression, as described in Section 4.7 HSC Modeling.

As discussed previously, models are compared using AIC in tables accompanying the analysis for each species and life stage. Models with the lowest absolute AIC and those within 2.0 of the best-fit model can be considered potential models (Burnham and Anderson 2002), while models outside of this range have weak to no evidence of relationships. Modeled HSC curves are displayed as functions of final predictor variables for each species and life stage. Note that the height at optimal suitability for these curves varies by species and life stage; the curves would need standardization if comparisons across species and life stage were necessary.

5.6.1 2013-2014 HSC Model for Chinook Salmon Fry

5.6.1.1 Univariate Analysis

The utilization of cover by Chinook salmon fry, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-1. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the types of cover showing increased utilization were combined into one factor – cover or no cover. For Chinook salmon fry, aquatic vegetation is not included as a utilized cover type (Table 5.6-1). There is some apparent interaction with turbidity – cover is utilized mainly in non-turbid water.

The univariate regression models are displayed with AIC results in Table 5.6-2. The random effects model improves the fit for all univariate models, and is used for the HSC analyses in this Section. Cover interacting with turbidity, depth (quadratic), and velocity (linear) are selected to include in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-1).

5.6.1.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, and presence/absence of cover interacting with turbidity were included in multivariate modeling. The interaction factor is included by creating a three-level factor with levels of "turbid" for locations with NTU>30, and locations with cover vs. no cover split for non-turbid sites. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.01, indicating that confidence intervals around predicted coefficients may be 1 percent inflated.

The best-fit main effects model included the cover/turbidity factor, a quadratic relationship with depth, and a linear decreasing relationship with velocity (Table 5.6-3). The interaction between depth and velocity further reduced the AIC by 5.4. However, including this interaction would predict high suitability in deep, fast water (depths>1.5 feet, velocity>.5 fps), and appears to be ecologically unreasonable. This interaction may be caused by relatively few observations in deep fast water.

The draft final HSC model for Chinook salmon fry is:

$$\log\left(\frac{p}{1-p}\right) = C_k + 1.80 * depth - 0.613 * depth^2 - 1.15 * vel + \gamma_{site} + \varepsilon,$$

where:

C_k is a constant depending on cover and turbidity:

C_{CNT} = -1.02 for locations with cover and NTU≤30

C_{NCNT} = -2.31 for locations with no cover and NTU≤30

C_T = -2.69 for locations with no cover and NTU>30,

p is the probability of Chinook salmon fry presence,

γ_{site} is the random effect for site, and

ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and all other sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft final HSC model for Chinook fry is displayed as a function of depth and velocity in Figures 5.6-1 and 5.6-2.

5.6.2 2013-2014 HSC Model for Chinook Salmon Juvenile

5.6.2.1 Univariate Analysis

The utilization of cover by juvenile Chinook salmon, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-4. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. Undercut bank cover was only observed once, so the result is unclear and undercut bank is retained as a cover type. Because wood cover shows increased utilization in non-turbid water, it is also retained. There is some apparent interaction with turbidity – cover is utilized mainly in non-turbid water.

The univariate regression models are displayed with AIC results in Table 5.6-5. The random effects model did not improve the fit for any univariate models, so the fixed effects model was used for the HSC analyses in this Section. The original depth analysis showed that the best fit was a 3^{rd}-order polynomial with a steep increase and high preference for the deepest observed locations (3.5-5 feet deep; Figure D5-2). There are only a small number of utilization and availability observations with depths greater than 3.5 feet, mainly in small deep pools in otherwise wadeable areas. These results were having undue influence on the model, so the analysis was re-fit on observations with depths less than 3.5 feet. This selection was revisited during the multivariate analysis. Cover, depth (linear), and velocity (linear) are selected to include in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-2).

5.6.2.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, and presence/absence of cover were included in multivariate modeling. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.03, indicating that confidence intervals around predicted coefficients may be 3 percent inflated.

Table 5.6-6 displays the AIC results for multivariate models. When all data are included, the best-fit main effects model with fixed effects included a third-order polynomial relationship with depth as previously discussed, and a linear decreasing relationship with velocity. Including the interaction between depth and velocity did not reduce the AIC for this model. As discussed previously, the third order polynomial relationship is not ecologically reasonable and is based on a small number of observations in deeper water. The model with a linear depth relationship is within AIC of 2 of the best model, so it is a valid alternative. Table 5.6-6 also displays the results for the model fit only on observations with depth measurements <3.5 feet (four utilization observations removed). Because the observations > 3.5 feet in depth appear to be exerting undue influence on model results, the HSC model fit to the reduced dataset is proposed.

The draft final HSC model for Juvenile Chinook salmon is:

$$\log\left(\frac{p}{1-p}\right) = -2.72 + 0.325 * depth - 0.388 * vel + \varepsilon,$$

where:

p is the probability of juvenile Chinook salmon presence,

and ε is random error (assumed normally distributed).

The random error term is included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. Non-modeled sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft final HSC model for Chinook juvenile is displayed as a function of depth and velocity in Figures 5.6-3 and 5.6-4.

5.6.3 2013-2014 HSC Model for Chum Salmon Spawning

5.6.3.1 Univariate Analysis

Utilization of available substrate and upwelling locations by chum salmon spawning is summarized in Table 5.6-7. Model AIC results comparing fixed and random effects models and models with interaction between spawning site type and predictors are displayed in Table 5.6-8. Random effects models fit better in all cases. There were some differences between random and select spawning sites in the preference for depth. Spawning at the select sites was not obviously selective for depth, whereas there was more spawning at deeper locations for the random sites. Therefore, the inclusion of select sites in the model may cause an overestimate of preference for shallow sites.

The models showing the best predicted univariate relationships for each predictor are compared using AIC in Table 5.6-9. For depth, the linear model (increasing) had the lowest AIC, but the quadratic model had similar AIC and has a better ecological interpretation, with the beginning of a decline in preference near 3 feet deep. For DO, the linear model had similar AIC to the null model, but the linear relationship was decreasing, indicating a reduction in preference for higher DO levels (Figure D5-3). The predictors tested in the multivariate model below are depth (quadratic), velocity (quadratic), water temperature (linear), upwelling (2-level factor) and substrate (3-level factor).

5.6.3.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, substrate, upwelling, and water temperature were included in the multivariate modeling. Using all of these variables, the highest adjusted VIF is 1.40, indicating that confidence intervals around predicted coefficients may be 18 percent wider than they would be with uncorrelated predictors. This VIF (1.4) was well below the threshold of 10 typically used to indicate a concern for multicollinearity.

Including upwelling and substrate as separate factors in the model is not possible because of the low sample sizes retained in 8 different groups (e.g., six downwelling sites with all-gravel substrate). Thus, the full model was first tested with three options, 1) upwelling only, 2) substrate only, or 3) a combined upwelling substrate group, consisting of all downwelling sites as one level of the factor, then the four substrate groups with upwelling as four additional levels. When these three options were compared, the AICc (AIC corrected for sample size) values were 1) 1000.6; 2) 969.4; and 3) 971.3. Thus, the categorical substrate factor was the best predictor of chum spawning preference than any use of upwelling in the model. Therefore, upwelling was not included in further multivariate comparisons.

The multivariate AIC results are compared in Table 5.6-10. The best fit main effects model includes substrate, linear effects for depth and temperature, and quadratic effects for velocity. All two-way interaction terms were tested with the best-fit main effects model and with the model including a quadratic effect rather than a linear effect for depth. The interaction between velocity and temperature improved the fit for both of these models, and no other interaction did. This interaction allows for a different velocity preference depending on surface water temperature, and is included in the HSC model. The second best-fit model, with AIC 1.2 greater than the best fit model is proposed for the HSC because it is within 2.0 of the top model, and the relationship with depth is more ecologically reasonable. This model matches expected and common relationships between depth and velocity and selection of spawning sites for chum salmon.

The draft Final HSC multivariate model for chum salmon spawning is:

$$\log\left(\frac{p}{1-p}\right) = C_k + 0.999depth - 0.155depth^2 + 0.408vel - 1.23vel^2$$
$$-0.225temp + 0.247(vel * temp) + \gamma_{site} + \varepsilon,$$

where:

p is the probability of chum salmon spawning,

k indexes eight intercept values for substrate/upwelling combinations:

$C_1 = 0.811$ (all gravel substrate)

$C_2 = 0.382$ (gravel dominant mixed substrate)

$C_3 = -0.131$ (gravel subdominant mixed substrate)

$C_4 = -0.999$ (no gravel, but cobble dominant),

γ_{site} is the random effect for site, and

ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and all other sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the level of spawning that will occur in a particular location.

The above model applies only to sites with dominant or subdominant gravel or dominant cobble substrates, and with depths of at least 0.30 feet; other sites are assigned a suitability of zero. This model also applies only to the ranges of all variables that were observed during HSC sampling. Locations on the river with habitat values outside of the observed ranges are assigned a suitability based on threshold values (Table 5.5-1). HSC for temperatures, depths and velocities outside of these observed ranges but within the allowed ranges displayed in Table 5.5-1 are set on a linear trajectory from the last modeled point to the zero suitability endpoint, as displayed in Figure 5.6-5, Figure 5.6-6, and Figure 5.6-7.

5.6.4 2013-2014 HSC Model for Coho Salmon Fry

5.6.4.1 Univariate Analysis

The utilization of cover by Coho salmon fry, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-11. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. Although the preference is not increased for boulder cover overall, it is increased in non-turbid water, so boulder is retained as a cover type. There is some apparent interaction with turbidity – cover is utilized mainly in non-turbid water.

The univariate regression models are displayed with AIC results in Table 5.6-12. The random effects model improves the fit for all univariate models, and is used for the HSC analyses in this Section. Cover interacting with turbidity, depth (quadratic), and velocity (linear) are selected to include in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-4).

5.6.4.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, and presence/absence of cover interacting with turbidity were included in multivariate modeling. The interaction factor is included by creating a three-level factor with levels of "turbid" for locations with NTU>30, and locations with cover vs. no cover split for non-turbid sites. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.01, indicating that confidence intervals around predicted coefficients may be 1 percent inflated.

The best-fit model included the cover/turbidity factor, a quadratic relationship with depth, and a linear decreasing relationship with velocity (Table 5.6-13). Two interactions reduced the AIC, depth:velocity and depth:cover/turbidity. The depth:velocity interaction is related to a higher preference for deep, fast water than the main effects model captures. This relationship is based on a relatively low number of observations in deep, fast water, and may be due to fry captured during migration rather than rearing. This interaction is not included in the final draft model. The interaction between cover/turbidity and depth is included, however, as the data suggest a preference for a more shallow depth when there is no cover or when the water is turbid.

The draft final model for coho salmon fry is presented below in three equations, one for each cover/turbidity group:

With Cover and NTU ≤ 30:

$$\log\left(\frac{p}{1-p}\right) = -1.91 + 2.51 * depth - 0.744 * depth^2 - 1.08 * vel + \gamma_{site} + \varepsilon,$$

With No Cover and NTU ≤ 30:

$$\log\left(\frac{p}{1-p}\right) = -1.97 + 1.34 * depth - 0.744 * depth^2 - 1.08 * vel + \gamma_{site} + \varepsilon,$$

With NTU > 30:

$$\log\left(\frac{p}{1-p}\right) = -3.33 + 2.46 * depth - 0.744 * depth^2 - 1.08 * vel + \gamma_{site} + \varepsilon,$$

where:

p is the probability of coho salmon fry presence,

γ_{site} is the random effect for site, and

and ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and all other sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft final HSC model for coho salmon fry is displayed as a function of depth and velocity in Figure 5.6-8 and Figure 5.6-9, respectively.

5.6.5 2013-2014 HSC Model for Coho Salmon Juvenile

5.6.5.1 Univariate Analysis

The utilization of cover by juvenile coho salmon, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-14. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. Because there was no increase in utilization observed for boulder cover nor turbidity greater than 30 NTU, these types of cover were not included in the cover factor. Thus, boulders and turbidity were not considered as types of cover in the HSC model for juvenile coho salmon.

The univariate regression models are displayed with AIC results in Table 5.6-15. For coho juvenile salmon, there are not large differences in utilization among sites where fish are observed. The random effects model does not improve the fit in this case, and a fixed effects model is used for the HSC analyses in this Section. Non-boulder cover, depth (quadratic), velocity (linear), and water temperature (linear) are selected to include in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-5).

5.6.5.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, temperature, and presence/absence of non-boulder cover were included in multivariate modeling. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.08, indicating that confidence intervals around predicted coefficients may be 8 percent inflated.

The best-fit main effects model included the cover factor and the quadratic effect for depth only (Table 5.6-16). There was strong evidence that depth and cover impact habitat preference for juvenile coho salmon. The effects of velocity and temperature were weaker as evidenced by the lower AIC for including them in the main effects model. Although there is some evidence of interaction between cover type and both temperature and velocity (i.e., the relationship between temperature and velocity preference differs depending on the availability of cover), the differences between these models was very small (AIC within 1), so the main effects model including cover and depth only was selected for HSC for parsimony.

The HSC model for juvenile coho salmon is:

$$\log\left(\frac{p}{1-p}\right) = C_k + 1.17 * depth - 0.228 * depth^2 + \varepsilon,$$

where:

p is the probability of juvenile coho salmon presence,

k indexes two intercept values for presence/absence of non-boulder cover types:

$C_0 = -3.37$ (non-boulder cover absent)

$C_1 = -2.72$ (non-boulder cover present),

and ε is random error (assumed normally distributed).

The random error term is included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. Non-modeled sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The model is displayed as a function of depth and cover in Figure 5.6-10.

5.6.6 2013-2014 HSC Model for Sockeye Salmon Spawning

5.6.6.1 Univariate Analysis

Utilization of available substrate and upwelling locations by sockeye salmon spawning is summarized in Table 5.6-17. Model AIC results comparing fixed and random effects models and models with interaction between spawning site type and predictors are displayed in Table 5.6-18. Random effects models fit better in all cases. There were some differences between random and select spawning sites in the preference for substrates. For select spawning sites, there is greater spawning in substrates with no gravel than in subdominant gravel sites. This is a finding contrary to expectations, and is most likely due to small sample sizes and other interacting factors. To increase sample sizes and ensure there is no conflict among the site types, we further reduced the substrate groups for the sockeye salmon HSC model by combining Group 3 (Gravel subdominant mixed substrate) and Group 4 (cobble dominant with no gravel) in the substrate factor. With this three-level factor, the interaction effect is not significant (Table 5.6-18, Revised Substrate Group).

There was also some evidence of differing relationships with velocity between random and select spawning sites. At select spawning sites, there is an apparent preference for lower velocities than at random sites, where there is more spawning selection at higher velocities. The impact of including the select sites in this analysis is a potential bias in the velocity relationship; our model including all sites may over-predict the selectivity for slower moving water based on the non-random selection of select sites.

The models showing the best predicted univariate relationships for each predictor are compared using AIC in Table 5.6-19. The predictors selected for the multivariate model were depth (quadratic), velocity (linear), water temperature (linear), and substrate (3-level factor) analysis (Figure D5-6). Upwelling was not significant, but it should be pointed out that there was only one site with downwelling and observed sockeye salmon spawning, so the sample size was very imbalanced for testing this impact. We do not infer that upwelling is not important to sockeye salmon here, but only that we do not have sufficient information to properly model its impact.

5.6.6.1 Multivariate Analysis

Based on the univariate model results, depth (quadratic), velocity, substrate, and water temperature were included in multivariate modeling. Using all of these variables, there is no evidence that multicollinearity is an issue of concern based on generalized variance inflation factors. The highest VIF is 1.08, indicating that standard errors for predicted coefficients may be up to 4% inflated (square root of 1.08 is approximately 1.04).

The AIC model results are displayed in Table 5.6-20. The best fit main effects model includes the substrate factor, and linear terms for velocity and water temperature. The three two-way interaction terms each reduced AIC, but the temperature:velocity interaction was very similar to the main effects model (AIC difference = 0.1). The interaction between the substrate and velocity is related to an apparent increase in site selection with water velocity for gravel-dominant mixed substrates. Although it is not clear what the interpretation may be for this, the interaction effect is very strong and appears important for accurately modeling the data. The interaction between substrate and temperature relates to some mitigation of the reduction in preference for temperature in some substrates, but this effect is relatively minor. The impact of not including this interaction is possible under-predicted preference at sites with water temperatures near 8 degrees C for some substrate types.

The draft final HSC model for sockeye salmon spawning is represented by three equations below.

For Group 1 (All Gravel) Substrates:

$$\log\left(\frac{p}{1-p}\right) = 4.16 + 0.146vel - 0.463temp + \gamma_{site} + \varepsilon,$$

For Group 2 (Gravel Dominant Mixed) Substrates:

$$\log\left(\frac{p}{1-p}\right) = 2.10 + 2.45vel - 0.463temp + \gamma_{site} + \varepsilon,$$

For Group 3+4 (Gravel Subdominant and/or Cobble Dominant) Substrates:

$$\log\left(\frac{p}{1-p}\right) = 0.994 + 2.18vel - 0.463temp + \gamma_{site} + \varepsilon,$$

where

p is the probability of sockeye salmon spawning,

γ_{site} is the random effect for site, and

ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and other variance is included in the random error term. It is important to note that this model is not intended to be predictive of the level of spawning that will occur in any particular location.

The above model applies only to sites with dominant or subdominant gravel or dominant cobble substrates, and with depths of at least 0.30 feet; other sites are assigned a suitability of zero. This model also applies only to the ranges of all variables that were observed during HSC sampling. Locations on the river with habitat values outside of the observed ranges are assigned a suitability based on ecological theory (Table 5.5-1).

The draft final HSC model for sockeye salmon spawning as a function of velocity and water temperature is displayed in Figures 5.6-11 and 5.6-12.

5.6.7 2013-2014 HSC Model for Arctic Grayling Fry

5.6.7.1 Univariate Analysis

The utilization of cover by Arctic grayling fry, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-21. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. There may be interaction with turbidity.

The univariate regression models are displayed with AIC results in Table 5.6-22. The random effects model improves the fit for all univariate models, and is used for the HSC analyses in this Section. Cover, depth (quadratic), velocity (linear), and temperature (linear) were selected to be included in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-7).

5.6.7.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, water temperature, and presence/absence of cover were included in multivariate modeling. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.02, indicating that confidence intervals around predicted coefficients may be 2 percent inflated.

The AIC model results are displayed in Table 5.6-23. The best-fit main effects model included cover, a quadratic relationship with depth, a linear decreasing relationship with velocity, and an increasing linear relationship with temperature. Although an increasing relationship with water temperature is not intuitive, it is reasonable for Arctic grayling fry in this temperature range. One interaction reduced the AIC, interaction between temperature and depth. The interaction is related to a preference for deeper water when the temperatures are higher, and it is retained and included in the final model. Note that the coefficient for the main effect of temperature in the model displayed below is negative, but the interaction with depth makes it a positive relationship for temperature for all depths > 0.13 feet.

The draft final HSC model for Arctic grayling fry:

$$\log\left(\frac{p}{1-p}\right) = C_k + 0.767depth - 0.641depth^2 - 0.696vel$$

$$-0.0164temp + 0.133(depth * temp) + \gamma_{site} + \varepsilon,$$

where:

k indexes two intercept values for presence/absence of cover:

C_0 = -3.26 when cover is absent

C_1 = -2.70 when cover is present,

p is the probability of Arctic grayling fry presence,

γ_{site} is the random effect for site, and

ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and other variance is included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in any particular location.

The draft final HSC model for Arctic grayling fry is displayed in Figure 5.6-13, Figure 5.6-14, and Figure 5.6-15.

5.6.8 2013-2014 HSC Model for Arctic Grayling Juvenile

5.6.8.1 Univariate Analysis

The utilization of cover by juvenile Arctic grayling, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-24. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. For juvenile arctic grayling *(Thymallus arcticus)*, wood and aquatic vegetation cover do not show increased preference, so a cover factor using only boulder, overhanging vegetation, and undercut bank was used. There is also increased utilization in turbid water, so turbidity is also included as a factor in the cover analysis.

The univariate regression models are displayed with AIC results in Table 5.6-25. The random effects model improves the fit for some univariate models, and is used for all HSC analyses in this Section. The original model for depth was influenced heavily by a single utilization observation at 3.5 feet. There were no utilization observations between 2 and 3.5 feet, so this single observation was exerting strong influence over the model predictions. This observation was therefore not used in further HSC analysis.

Cover and depth (quadratic) were selected to include in multivariate analysis based on the model results. Although there is an apparent linear decreasing relationship with water temperature, this relationship is not ecologically reasonable over this temperature range, and this relationship is not included in the multivariate analysis (Figure D5-8).

5.6.8.2 Multivariate Analysis

Based on the univariate model results, depth and presence/absence of three types of cover were included in multivariate modeling. Using these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.01, indicating that confidence intervals around predicted coefficients may be 1 percent inflated.

The multivariate AIC results are compared in Table 5.6-26. The best-fit main effects model included cover and a quadratic relationship with depth. Interaction between cover and depth did not reduce AIC.

The draft final HSC model for juvenile Arctic grayling is:

$$\log\left(\frac{p}{1-p}\right) = C_k + 2.91 * depth - 1.36 * depth^2 + \gamma_{site} + \varepsilon,$$

where:

k indexes two intercept values for presence/absence of cover:

C_0 = -3.41 when boulder, overhanging vegetation, or undercut bank cover is absent

C_1 = -2.78 when boulder, overhanging vegetation, or undercut bank cover is present,

p is the probability of juvenile Arctic grayling presence,

γ_{site} is the random effect for site, and

and ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and other variance is included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in any particular location.

The draft final HSC model for juvenile Arctic grayling is displayed in Figure 5.6-16.

5.6.9 2013-2014 HSC Model for Whitefish Fry

5.6.9.1 Univariate Analysis

The utilization of cover by whitefish fry, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-27. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. Although boulder cover does not increase preference overall, it does in clear water, so boulder is retained as a cover type. There may be interaction with turbidity – cover does not appear as important in turbid conditions.

The univariate regression models are displayed with AIC results in Table 5.6-28. The random effects model does not improve the fit for the univariate models, so the fixed model is used for the HSC analyses in this Section. The original best fit model for velocity was concave up, based on fitting two utilization observations that were in velocity greater than 2.4 fps (Figure D5-9). All other velocities utilized were < 1.5 fps. Because these two unique velocity observations were exerting undue influence on the model results, they were removed from further HSC analysis. Depth (quadratic), velocity (quadratic), and temperature (quadratic) were selected to include in multivariate analysis based on the model results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-9).

5.6.9.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, and water temperature were included in multivariate modeling. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.04, indicating that confidence intervals around predicted coefficients may be 4 percent inflated.

The multivariate model AIC results are displayed in Table 5.6-29. The best-fit main effects model included quadratic relationships with depth, velocity, and temperature. The models were fit without the two extreme velocity observations > 2.4 fps. One interaction reduced the AIC, interaction between depth and velocity. The interaction is related to a preference for slower water as depth increases, and it is retained and included in the final model as interaction between velocity and the quadratic term for depth.

The draft final HSC model for whitefish fry is:

$$\log\left(\frac{p}{1-p}\right) = -7.21 + 2.00depth - 0.540depth^2 + 2.84vel - 2.07vel^2$$
$$+0.691temp - 0.0292temp^2 - 0.837(vel * depth^2) + \varepsilon,$$

where:

p is the probability of whitefish fry presence,

and ε is random error (assumed normally distributed).

The random error term is included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. Non-modeled sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft Final HSC model for whitefish fry is displayed as a function of depth, velocity, and temperature in Figure 5.6-17, Figure 5.6-18, and Figure 5.6-19, respectively.

5.6.10 2013-2014 HSC Model for Whitefish Juvenile

5.6.10.1 Univariate Analysis

The utilization of cover by juvenile whitefish, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-30. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. Although some cover types do not show increased preference by whitefish juveniles, they do in clear water, so all are retained as a cover type. There is no apparent interaction with turbidity, but turbidity may be utilized as cover (i.e., proportionately more observations in turbid water).

The univariate regression models are displayed with AIC results in Table 5.6-31. The random effects model improves the fit for the univariate models, so it was used for the HSC analyses in this Section. The original best fit model for velocity was the null model, based on one utilization observations in water depth of 2.94 feet. All other depths utilized were < 2.2 feet. Because this single velocity observation was exerting undue influence on the model results, it was removed from further HSC analysis. Linear relationships for temperature and velocity, and the turbidity factor were selected to include in multivariate analysis based on the model results. Although turbidity had AIC slightly greater than the null model, the values were very close so it was retained. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-10).

5.6.10.2 Multivariate Analysis

Based on the univariate model results, turbidity, velocity, and water temperature were included in multivariate modeling. Using all of these variables, there was no evidence that multicollinearity was an issue of concern based on variance inflation factors. The square root of the highest VIF was 1.04, indicating that confidence intervals around predicted coefficients may be 4 percent inflated.

The AIC comparison for multivariate whitefish juvenile models is displayed in Table 5.6-32. The best-fit main effects model included linear relationships with temperature and velocity, but the model including the turbidity factor had AIC only 0.41 higher than this model. The models were fit without the influential velocity observations (2.9 fps). Two-way interactions for the models with and without turbidity were tested. One interaction reduced the AIC, interaction between turbidity and temperature. The preference for turbid locations is mainly in lower temperatures, so the linear decreasing relationship between preference and temperature is more pronounced in turbid sites. This model with the turbidity factor and the interaction with temperature had AIC 2.5 lower than the best main effects model, and was selected as the draft final model.

The draft final HSC model for juvenile whitefish is:

For NTU ≤30 NTU:

$$\log\left(\frac{p}{1-p}\right) = -1.80 - 0.564vel - 0.0295temp + \gamma_{site} + \varepsilon,$$

For NTU > 30 NTU:

$$\log\left(\frac{p}{1-p}\right) = 0.0537 - 0.564vel - 0.240temp + \gamma_{site} + \varepsilon,$$

where:

p is the probability of juvenile whitefish presence,

γ_{site} is the random effect for site, and

and ε is random error (assumed normally distributed).

The random site effect and the random error term are included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. The non-modeled differences among sites are included in the random site effect, and other variance is included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in any particular location.

The draft Final HSC model for juvenile whitefish is displayed as a function of temperature and velocity in Figure 5.6-20 and Figure 5.6-21.

5.6.11 2013-2014 HSC Model for Longnose Sucker Juvenile

5.6.11.1 Univariate Analysis

The utilization of cover by juvenile longnose sucker, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-33. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model. Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. The overhanging vegetation cover type does not show increased proportionate utilization, so it is deleted as a cover type. There is no apparent interaction with turbidity, or utilization of turbidity as cover.

The univariate regression models are displayed with AIC results in Table 5.6-34. The random effects model does not improve the fit for the univariate models, so the fixed effects model is used for the HSC analyses in this Section. There was no apparent relationship with depth when all observations are included. This is mainly due to a small number of utilizations in rarely sampled deep habitats. Without the observations in depths > 2.9 feet, a quadratic depth model is superior to the null model (Table 5.6-34). All other depths utilized were < 2.3 feet. Multivariate models with and without the deep habitat observations are discussed below. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-11).

5.6.11.2 Multivariate Analysis

Based on the univariate model results, depth and velocity were included in multivariate modeling for depth data < 3 feet. If all data are included, only velocity is included. There was no evidence that multicollinearity was an issue of concern for the depth and velocity model based on variance inflation factors. The square root of the highest VIF was 1.001, indicating that confidence intervals around predicted coefficients may be 0.1 percent inflated.

The multivariate model AIC results are displayed in Table 5.6-35. The best-fit main effects model for depths < 3 feet included a quadratic relationship with depth, and a linear relationship with velocity. The depth:velocity interaction slightly reduced the AIC, but the interaction was related to middle depths and velocities, and did not appear to be ecologically reasonable. The interaction was not retained for the draft final model.

The draft final HSC model for juvenile longnose sucker for depths < 3 ft:

$$\log\left(\frac{p}{1-p}\right) = -2.75 + 1.75depth - 0.77depth^2 - 0.517vel + \varepsilon.$$

If all depths are included, only velocity is retained (see Table 5.6-34 for AIC results):

$$\log\left(\frac{p}{1-p}\right) = -2.04 - 0.475vel + \varepsilon,$$

where:

p is the probability of juvenile longnose sucker presence,

and ε is random error (assumed normally distributed).

The random error term is included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. Non-modeled sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft final HSC models for juvenile longnose sucker are displayed as a function of depth and velocity in Figure 5.6-22 and Figure 5.6-23.

5.6.12 2013-2014 HSC Model for Longnose Sucker Adult

5.6.12.1 Univariate Analysis

The utilization of cover by adult longnose sucker, including turbidity as a cover type and a potential interacting factor, is summarized in Table 5.6-36. Because there are often multiple cover types at the same location, individual cover types cannot be assessed in a single model.

Instead, the forms of cover showing increased utilization were combined into one factor – cover or no cover. The overhanging vegetation cover type does not show increased proportionate utilization, but the sample size is very small, so it is retained as a cover type. There is increased utilization with turbidity, and possible interaction with turbidity.

The univariate regression models are displayed with AIC results in Table 5.6-37. The random effects model does not improve the fit for the univariate models, so the fixed effects model is used for the HSC analyses in this Section. A quadratic relationship with depth, a quadratic relationship with velocity, and a turbidity factor are retained for the multivariate analysis based on these results. A decreasing relationship between DO and preference improves predictions, but it is not an ecologically reasonable relationship and is therefore not included in multivariate analysis (Figure D5-12).

5.6.12.2 Multivariate Analysis

Based on the univariate model results, depth, velocity, and turbidity were included in multivariate modeling. There was no evidence that multicollinearity was an issue of concern for the depth and velocity model based on variance inflation factors. The square root of the highest VIF was 1.01, indicating that confidence intervals around predicted coefficients may be 1 percent inflated.

The multivariate model AIC results are displayed in Table 5.6-38. The best-fit main effects model included the turbidity factor, a quadratic relationship with depth, and a linear relationship with velocity. No interactions reduced the AIC.

The draft final HSC model for adult longnose sucker is:

$$\log\left(\frac{p}{1-p}\right) = C_k + 3.05depth - 0.843depth^2 - 0.708vel + \varepsilon,$$

where:

k indexes two intercept values for presence/absence of turbidity:

C_0 = -4.64 for non-turbid water (<30 NTU)

C_1 = -3.83 for turbid water (>30 NTU),

p is the probability of adult longnose sucker presence,

and ε is random error (assumed normally distributed).

The random error term is included in the above displayed model to highlight the intention of the model, which is to discriminate among habitats based on physical features. Non-modeled sources of variance are included in the random error term. It is important to note that this model is not intended to be predictive of the number of fish that will occur in a particular location.

The draft final HSC model for adult longnose sucker is displayed as a function of depth and velocity in Figure 5.6-24 and Figure 5.6-25.

6. DISCUSSION

The goal of the HSC Development Study was to collect sufficient habitat utilization and availability data to develop site-specific HSC models to support the evaluation of Project effects. The HSC models represent an assumed functional relationship between an independent variable, such as depth, velocity, substrate, GW upwelling, water temperature, cover, etc., and the response of a specific species and life stage to a gradient of the independent variable (suitability or preference). As part of the IFS, the HSC models will be used to translate hydraulic and channel characteristics into measures of overall habitat preference for individual species and life stages during specific time periods. Results of the HSC modeling provides information on which habitat variables are most predictive of fish presence, as well as predictive multivariate HSC/HSI models for those species and life stages with sufficient site-specific observations.

This SIR Study 8.5, Appendix D presents the statistical approach used for developing draft final HSC models for the priority species and life stages of fish found in the Susitna River using site-specific habitat utilization and availability data. For species and life stages with some, but not enough site-specific observation to construct HSC models, additional data collection may be warranted. Development of site-specific empirical HSC/HSI data will not be attainable for some species and life stages due to their low abundance or primary use of tributary rather than mainstem habitats. In those cases, alternative HSC development methods (literature based, enveloping, guilding, expert opinion/roundtable discussions, and Bayesian statistical) will be evaluated for HSC development.

6.1 2013-2014 HSC Sampling

Both summer (May-September) and winter (October-April) HSC data were collected to determine if significant differences in seasonal microhabitat use were evident. Summer 2014 field data collection was expanded to include all ten MR Focus Areas and two LR tributary complexes. Summertime data collection occurred during eight separate surveys from mid-May through late-September at 129 sample sites. Many of the sites were sampled more than once resulting in 267 unique sampling events. A total of 2,799 microhabitat use measurements were collected for 12 different species of fish from within ten different macrohabitat types. Sampling in the LR, and the three upstream most Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex], FA-184 [Watana Dam]) that were unsampled in 2013, accounted for just over 19 percent of the total number of summer observations.

Winter 2012-2013 and 2013-2014 HSC data collection was concentrated within three MR Focus Areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], and FA-138 [Gold Creek]) during three separate sampling events (February, March, and April). Winter habitat use measurements for rearing Chinook, coho, chum, and sockeye salmon made up over 96 percent of the total number of observations (n=291). For salmon species, there were a similar number of HSC measurements for the fry (n=131) and juvenile (n=151) life stages. The distribution of observations within the three Focus Areas was similar with 38.5 percent collected at FA-104 (Whiskers Slough), 26.1 percent at FA-128 (Slough 8A), and 34 percent at FA-138 (Gold Creek). There were 4 observations of habitat use in FA-141 (Indian River) that accounted for the remainder of the winter HSC measurements.

6.2 Habitat Utilization Frequency Histograms

Frequency distributions (i.e., histograms) have been generated for mean velocity, depth, and substrate utilization for each species. Frequency bin widths of 0.2 were used to evaluate the mean velocity and depth utilization distributions. Histogram plots of depth and mean column velocity utilization were then produced for each species and life stage for which sufficient field observations were recorded. Summer HSC data were plotted for the LR and MR, and as a combined dataset. Winter HSC were plotted for summer and winter observations. Additionally, a comparison of microhabitat use observed during the 2013-2014 surveys and the 1980s HSC curves was completed.

6.2.1 River Segment Comparison

Although there were some minor differences in the depth and velocity of water utilized by fish in the LR and MRs, the range (percentiles) of microhabitat use was generally similar between the segments for most species and life stages.

Of the 12 high priority species/life stages, Chinook fry and juvenile, coho fry and juvenile, longnose sucker juvenile, and whitefish fry were observed during HSC surveys of both the LR and MRs of the Susitna River (Table 5.2-2). A side by side comparison of the range of habitat use for these species/life stages shows that Chinook fry and juvenile, longnose sucker fry, and whitefish fry had slightly higher use of faster velocity water in the LR. These results should be viewed with caution as major differences in habitat availability between the two segments (more off-channel/lower water velocity habitat in the MR) and sample size differences (up to 7x more observations in the MR) may explain most of the limited variability between the segments. A visual assessment of the range of microhabitat use by high priority species and life stages common to both the LR and MRs of the Susitna River would indicate that there is very little difference in utilization of water depth and velocity between the two segments.

6.2.2 Seasonal Comparison

A comparison of summer and winter microhabitat use observations was completed to determine if difference in microhabitat (water depth and velocity) selection between seasons justifies development of separate (summer and winter) HSC models. The comparison could only be made for those species and life stages with sufficient (>10) habitat use observations between the two seasons. Only Chinook fry and juvenile, coho fry and juvenile, chum fry, and sockeye fry and juvenile had enough observations between the seasons to draw any conclusions regarding difference in habitat. Of those seven species/life stages, only the fry and juvenile life stages of Chinook and coho salmon are considered high priority species/life stages. It is assumed that sockeye and chum salmon fry migrate out of the Susitna River shortly after breakup and so comparisons of microhabitat use or selection between summer and winter seasons may not be appropriate.

For the fry and juvenile life stages of Chinook and coho salmon, habitat use between seasons was significantly different in both the overall range (0-100 percentile) and median (50^{th} percentile) depth and velocity use (Attachment 4). When compared to summer habitat use, maximum (100 percentile) velocity and depth use during the winter was 1-3 times lower for both species and life stages. The use of lower velocity areas during the winter is not surprising given that nearly all fish species exhibit physiological and/or behavioral responses to the seasonal change in habitat from summer to winter, such as movement to off-channel and low velocity habitat. The dramatic shift in use of lower velocity areas by fry and juvenile Chinook and coho, during the winter, appears to justify an adjustment of the velocity preference model between seasons.

Although it is not possible to construct a unique winter habitat preference model without wintertime habitat availability data, a reduction in the maximum velocity threshold from 3.0 feet per second in the summer to 1.5 feet per second in the winter is recommended. This reduction or limitation in the range of suitable velocities would increase the sensitivity of the habitat modeling to detect changes in suitable habitat for overwintering Chinook and coho salmon.

6.2.3 1980s and 2013-2014 Comparison

A comparison of HSC developed from the 1980s studies and habitat use data collected as part of the 2013-2014 data collection effort was completed for a select number of species and life stages including Chinook and coho salmon juvenile, pink salmon spawning, Arctic grayling adult, rainbow trout adult, and whitefish adult (Attachment 3). Two of the six species/life stages (Chinook and coho juvenile) had sufficient site-specific observations for the development of multivariate HSC and those models will be used to assess habitat changes in response to proposed Project operations. The remaining four species/life stages had insufficient site-specific observations and were designated as moderate priority for development of HSC models using habitat utilization data and comparison with 1980s HSC.

Pink salmon spawning and whitefish adult were the only two species/life stages with a large enough number of 2013-2014 site-specific observation (>30) to provide a meaningful comparison to the 1980s HSC. A visual comparison of the 2013-2014 pink salmon spawning data (n=53) and the 1980s HSC appears to indicate strong similarities in habitat utilization. Even though the 1980s pink salmon spawning HSC were not developed from Susitna River but were transferred from site-specific data collected from the Terror River (Alaska), the 1980s HSC should be considered as a potential source of HSC for the current effort.

Similarities between the 1980s HSC and 2013-2014 habitat use data for Arctic grayling, rainbow trout, and whitefish adult was not nearly as evident. There were only 8 habitat use observations of rainbow trout adult during the 2013-2014 surveys making it difficult to draw any conclusion from a comparison of the data. Additionally, differences in data collection methods between the 1980s and 2013-2014 surveys make comparison of results questionable. During the 1980s HSC surveys, boat electrofishing and hook and line sampling were used extensively for capturing adult species. The use of these sampling techniques during the 1980s surveys, allowed for sampling of deeper and faster water that could not be sampled during the 2013-2014 surveys due to permitting and safety restrictions. In short, a comparison of habitat use between the two studies is not recommended for Arctic grayling, rainbow trout, and whitefish adult.

6.3 HSC Models

Multivariate HSC models have been developed from 2013-2014 HSC sampling data for Chinook salmon fry and juvenile, chum salmon spawning, coho salmon fry and juvenile, sockeye salmon spawning, Arctic grayling fry and juvenile, whitefish fry and juvenile, and longnose sucker juvenile and adult. Completing the statistical analysis for a diverse data set collected over a wide range of habitat conditions required certain model assumptions, data grouping or consolidations and applying threshold to set minimum and/or maximum ranges within the HSC models. Some of the more significant model assumptions, data considerations, and variable thresholds include:

- Priority ranking for development of HSC models was given to those species and life stages that are assumed to select and utilize specific microhabitat areas for rearing or spawning purposes. Life stages (e.g., fry life stage of chum and pink salmon) that are known to outmigrate from the Susitna River soon after breakup were not included as part of HSC model development.
- Because both habitat utilization and availability measurements are necessary for development of multivariate HSC, only those data collected concurrently were used as part of the model development.
- The models have included a possible random effect for each visit to each site to account for wide variability in fish use among sites.
- Each species and life stage of fish were observed in only a small fraction of the total sampling events. Only those sampling events that included fish observations were used for developing the multivariate HSC curves for each species and life stage.
- Macrohabitat type has not been included in HSC modeling, although differences in habitat preference among macrohabitat types are possible.
- Due to the large number of categories and combination of substrate and cover types the full suite of data could not be assessed within the same model. To address this, the variables were simplified into groups of similar classes to test the best fit of the HSC model.
- Threshold values have been proposed for many of the variables to set minimum and/or maximum ranges within the HSC models. The threshold values are life stage and time period (seasonal) specific.
- Although numerous authors (e.g., Mouw et al.; 2014, Burril et al. 2010; Wilson 2006; Lorenz and Eiler 1989; 1980s Susitna Studies) have identified a strong relationship between GW upwelling and site selection by spawning chum and sockeye salmon, characterization of this relationship in the Susitna River has not provided clear results. Given the strength of the scientific argument that a correlation between GW and spawning site selection does exist, evaluation of the scale and specific influence of GW upwelling/downwelling in habitat selection by spawning chum and sockeye salmon will continue.
- Limits within the sampling methods (high water velocity), sometimes restricted the areas that could be safely sampled to determine the outmost extent of fish utilization. To compensate for this fact, proposed restriction and thresholds were applied to limit the use of HSC model to those portions of the Susitna River that fall within the range of sampled conditions or thresholds. Habitat areas that fall outside of the sampling or threshold ranges (e.g., maximum depth, velocity, distance from water's edge) will be assumed to have no preference or suitability for a particular species or life stage.

All of these assumption and constraints are considered preliminary and will need to be reviewed in consultation with the resource agencies. Further modification to the HSC model will be completed after reviewing comments from the resource agencies and the FERC. Final HSC model assumptions and data considerations will be presented in the Updated Study Report (USR).

7. NEXT STEPS

This report summarizes the 2013-2014 data collection and provides a detailed description of the statistical process that was applied in development of the draft final HSC models for 12 species/life stage combinations. Draft final HSC models are presented for all high priority species and life stages; however, additional data collection remains for some species/life stages. There are several activities remaining that need to be completed before final HSC can be developed for all priority species and life stages. These include the following:

- Finalization of priority species: The priority ranking of species for HSC development was proposed during a Technical Team Meeting on 21 March 2014. That list is subject to stakeholder review and may be modified based on comments.
- Finalize species and life stage periodicity: Detailed interim periodicity tables were developed for twelve of the priority species and life stages and presented in the June ISR Study 8.5. The interim periodicity tables were developed from site-specific data (list) and in general are consistent with periodicity information developed in the 1980s. Additional site-specific information will be developed during analysis of the results of FDAML (Study 9.6) and may modify the draft periodicity values for some life stages. Final species and life stage periodicity will be developed as part of the USR.
- For moderate and low priority species and life stages, select alternative HSC development method(s). Alternative methods were described in the FERC-approved Study Plan for developing HSC including site specific curves. Alternative curve development methods will be identified for all species lacking the requisite numbers of site specific measurements. These methods will be presented to the agency and stakeholders representatives during subsequent TWG or Technical Team Meetings. Complete development of HSC using alternative methods for those species and life stages with insufficient numbers of site-specific observations (i.e., Adult Arctic grayling, Bering Cisco *[Coregonus laurettae]*, burbot, and eulachon *[Thaleichthys pacificus]*).
- Two years of HSC sampling has been completed in the MR Focus Areas below Devils Canyon, and one year of study has been completed in MR Focus Areas downstream of FA-151 (Portage Creek) and in the LR. An additional year of study will be completed in MR FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam) and in the LR.
- Conduct additional HSC surveys to collect site-specific habitat use observations for pink salmon spawning and adult whitefish and rainbow trout. Sample site selection, timing, and survey methods would be directed towards maximizing the number of observations for each species/life stage. It is assumed that three, 5-day sampling events (one each in July, August, and September) focused in macrohabitat types with the highest number of past observations (HSC, FDAML, 1980s surveys) would be sufficient.

- Continue to review potential relationships between spawning habitat selection/preference and GW upwelling or downwelling. Although this study did not identify upwelling/downwelling as a strong predictor of habitat preference, additional evaluation of the scale and specific influence of GW upwelling/downwelling in habitat selection by spawning chum and sockeye salmon will continue.
- Complete multivariate HSC modeling utilizing new/additional observations for moderate priority species and life stages with sufficient numbers and diversity of observations to develop site-specific HSC.
- Review and evaluate both univariate and multivariate HSC modeling results and proposed HSC based on alternative methods with agency and stakeholder representatives.
- Develop final HSC models for all priority species and life stages for use in the IFS habitat modeling. Final HSC will be proposed in the USR.

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9. TABLES

Table 1-1. Status of Habitat Suitability Criteria development for the Susitna River, Alaska.

Species [1]	Life Stage	Number of Microhabitat Measurements	Multivariate Preference HSC Model	Univariate Utilization HSC	Non-site Specific HSC	Field Data Collection Complete?	Targeted Future Data Collection
High Priority Species							
Chinook salmon	Fry-summer	217	X			Yes	
	Fry-winter	17		X			X
	Juv-summer	67	X			Yes	
	Juv-winter	28		X			X
Chum salmon	Fry [2]	253	N/A	N/A	N/A	Yes	
	Spawning	397	X			Yes	
Coho salmon	Fry-summer	274	X			Yes	
	Fry-winter	36		X			X
	Juv-summer	87	X			Yes	
	Juv-winter	88		X			X
	Spawning	3			X	Yes	
Pink salmon	Fry[2]	39	N/A	N/A	N/A	Yes	
	Spawning	53		X			X
Sockeye salmon	Fry-summer[2]	357	N/A	N/A	N/A	Yes	
	Fry-winter	35		X			X
	Spawning	244	X			Yes	
Arctic grayling	Fry	120	X			Yes	
	Juv	78	X			Yes	
	Adult	15		X			X
Rainbow trout	Fry	4			X	Yes	
	Juvenile	7			X	Yes	
	Adult	8		X			X
Moderate Priority Species							
Burbot	Fry	1			X	Yes	
	Juvenile	5			X	Yes	
	Adult	22		X			X
Dolly Varden	Fry	21			X	Yes	
	Juvenile	2			X	Yes	
	Adult	3			X	Yes	
Eulachon	Spawning			X			X [3]
Longnose sucker	Fry[4]	88		X		Yes	
	Juvenile	97	X			Yes	
	Adult	71	X			Yes	
Whitefish (undiff)	Fry	105	X			Yes	
	Juvenile	101	X			Yes	
	Adult	35		X			X

Notes:
Juv=Juvenile, undiff=undifferentiated
1 HSC will not be developed for low priority species northern pike, round whitefish, sculpin, three-spine stickleback, Arctic lamprey, Bering cisco, and lake trout.
2 N/A – Not applicable since HSC will not be developed for fry that outmigrate shortly after emergence.
3 Data collection activities will be conducted under Study 9.16 (Eulachon Run timing, Distribution, and Spawning in the Susitna River).
4 Considered for multivariate model development.

Table 5.1-1. Priority ranking of fish species for development of site-specific Habitat Suitability Curves for the Susitna River, Alaska. (Presented to TWG during Q2 2013 meeting)

Common Name	High	Moderate	Low
Chinook salmon	X		
Chum salmon	X		
Coho salmon	X		
Pink salmon	X		
Sockeye salmon	X		
Arctic grayling	X		
Arctic lamprey			X
Bering cisco			X
Burbot		X	
Dolly Varden		X	
Eulachon		X	
Humpback whitefish		X	
Lake trout			X
Longnose sucker		X	
Northern pike			X
Rainbow trout	X		
Round whitefish			X
Sculpin			X
Threespine stickleback			X

Table 5.1-2. Updated priority ranking of fish species and life stages for development of Habitat Suitability Criteria for the Susitna River, Alaska. (Presented to Technical Team during Q2 2014 meeting.)

	Priority Ranking		
	High	Moderate	Low
Life Stage	Multivariate Preference Curves	Univariate Utilization / 1980s Curves	Literature Based / Expert Panel
Spawning	Chum		
	Sockeye		
	Pink		
Adult	Whitefish[1]	Rainbow trout	Bering cisco
	Arctic grayling	Dolly Varden	Eulachon
	Longnose sucker	Burbot	
Juvenile	Coho	Arctic grayling	
	Chinook		
	Longnose sucker		
Fry	Coho	Whitefish[1]	
	Chinook	Arctic grayling	
	Sockeye	Longnose sucker	

Notes:

1 To eliminate potential for miss identification, no distinction was made between whitefish species (humpback and round).

Table 5.2-1. Number of individual sampling events by Focus Area, habitat type, and sampling session during 2013 - 2014 HSC sampling in the Middle and Lower River segments of the Susitna River, Alaska.

Focus Area	Number of Sample Sites	Habitat Type[1]	Number of Sample Sites	Sample Session	Number of Sampling Events
Lower River[2]	16	Bar Island Complex	3	June 18-22, 2013	12
FA-104 (Whiskers Slough)	17	Main Channel	21	July 10-30, 2013	49
FA-113 (Oxbow 1)	9	Split Main Channel	6	Aug 6-27, 2013	64
FA-115 (Slough 6A)	5	Multi-Split Main Channel	1	Sep 10-29, 2013	42
FA-128 (Slough 8A)	13	Side Channel	27	May 20-31, 2014	30
FA-138 (Gold Creek)	15	Side Channel Complex	2	June 1-7, 2014	20
FA-141 (Indian River)	10	Side Slough	30	July 15-22, 2014	27
FA-144 (Slough 21)	8	Upland Slough	25	Sep 17-24, 2014	23
FA-151 (Portage Creek)	3	Tributary Mouth	8		
FA-173 (Stephan Lake)	9	Tributary	6		
FA-184 (Watana Dam)	3				
Outside Focus Area	21				
Total	**129**		**129**		**267**

Notes:

1 Habitat types defined in ISR Study 9.9 (AEA 2014a).

2 Lower River (Susitna River downstream of Talkeetna including the Trapper-Birch and Sheep-Caswell complexes).

Table 5.2-2. Number of microhabitat use measurements used in HSC model development by Focus Area and habitat type for all species and life stages observed during 2013 - 2014 HSC surveys of the Middle and Lower River segments of the Susitna River, Alaska.

	Life	Lower	Middle River Focus Areas												Habitat Type[2]											
Species	**Stage**	**River[1]**	**104**	**113**	**115**	**128**	**138**	**141**	**144**	**151**	**173**	**184**	**NFA**	**Total**	**MC**	**SC**	**SS**	**SMC**	**MSMC**	**Trib**	**TM**	**US**	**BIC**	**SCC**	**Total**
Chinook	Fry	32	51	15	7	14	13	45	3	35			2	217	33	17	52	15		38	35	21	5	1	**217**
	Juv	18	11	2	3	8	10	5		7			3	67	13	18	16	2		1	4	9	2	2	**67**
Chum	Fry	77	65	36	8	18	4	30	15					253	48	59	52	27		16	11	14	14	12	**253**
	Juvenile					1							1	2	1	1									**2**
	Spawning					71	71	19	76				160	397	51	129	124	25			7	61			**397**
Coho	Fry	33	119	22	7	21	15	42	4	3			8	274	8	21	98	17		36	28	65		1	**274**
	Juv	7	30	10	16	3	6	3	2	5			5	87	4	6	16	2		10	3	45		1	**87**
	Spawning					3								3		3									**3**
Pink	Fry	1	1			2		34	1					39		4	1			23	11				**39**
	Spawning							17					36	53						17	36				**53**
Sockeye	Fry	44	69	26	15	71	46	56	20	2			8	357	8	46	166	13		32	18	65	7	2	**357**
	Juv	2	6	2		1	6	2					2	21		5	13					3			**21**
	Spawning					51	68	19	82				24	244		65	123			7	12	37			**244**
Arctic Grayling	Fry		10	6	11	21	11	35	11		6	1	8	120	14	22	37	3		1	17	26			**120**
	Juv		4	3		9	3	15	4	1	26	9	4	78	36	21	12	3		1	1	4			**78**
	Adult		1					4			3	7		15	10	5									**15**
Arctic lamprey juv			1											1			1								**1**
Lamprey (undiff) juv		1												1						1					**1**
Burbot	Fry			1										1				1							**1**
	Juv		1	3				1						5	2			3							**5**
	Adult	1	7	1	5	2	2		1	2	1			22	6	8	1	1				5		1	**22**
Dolly Varden	Fry		2	7				10		1			1	21	1					10	4	6			**21**
	Juv						1				1			2			1					1			**2**
	Adult						1			1	1			3	1		2								**3**
Longnose sucker	Fry	12	13	20	6	1		9	1	1	22	1	2	88	6	17	33	4			8	18	2		**88**
	Juv	7	16	7	6	3	10	7	1	3	31	2	4	97	15	20	45	2	1			12	1	1	**97**
	Adult	2	16	8	4	7	14	6	3		1		10	71	19	22	13	7	2			7		1	**71**
Rainbow trout	Fry			2						2				4	1					2	1				**4**
	Juv		4	2				1						7	1	1				2		3			**7**
	Adult		4			1			1	1			1	8	2	2	1					3			**8**
Whitefish	Fry	25	5	5	5	3	12	8	1	1	21	15	4	105	24	30	29				2	14	4	2	**105**
	Juv	9	5	6	2	9	5	8	1	2	23	28	3	101	46	23	14	4			1	11	2		**101**
	Adult	2	2	3	1	6	5	6	1	4		1	4	35	19	8	2	3				3			**35**
TOTAL		**273**	**443**	**187**	**96**	**326**	**303**	**382**	**228**	**71**	**136**	**64**	**290**	**2,799**	**369**	**553**	**852**	**132**	**3**	**197**	**199**	**433**	**37**	**24**	**2,799**

Notes:

1 Lower River: Susitna River downstream of Talkeetna including the Trapper-Birch and Sheep-Caswell complexes.

2 Habitat Types defined in ISR Study 9.9 (AEA 2014a): MC=Main Channel, SC=Side Channel, SS=Side Slough, SMC=Split Main Channel, Multi-Split Main Channel, Trib=Tributary, TM=Tributary Mouth, US=Upland Slough, BIC=Bar Island Complex, SCC=Side Channel Complex.

Table 5.2-3. Total number of HSC observations recorded during electrofish sampling in each winter season of 2012-2013 and 2013-2014, by fish species and life stage.

Winter Season	Species	Life stage[1]	FA-104 (Whiskers Slough)	FA-128 Slough 8A)	FA-138 (Gold Creek)	FA-141 (Indian River)	Total
2012-2013	Chinook salmon	Fry	1	2	0	0	**3**
		Juvenile	13	10	0	0	**23**
	Coho salmon	Fry	2	0	0	0	**2**
		Juvenile	1	0	0	0	**1**
2013-2014	Chinook salmon	Fry	13	0	0	1	**14**
		Juvenile	2	3	1	0	**6**
	Sockeye salmon	Fry	1	30	4	0	**35**
		Juvenile	0	0	33	0	**33**
	Chum salmon	Fry	0	17	25	0	**42**
	Coho salmon	Fry	25	7	2	1	**35**
		Juvenile	47	7	32	2	**88**
	Rainbow trout	Juvenile	2	0	2	0	**4**
	Arctic grayling	Juvenile	1	0	0	0	**1**
	Longnose sucker	Juvenile	2	0	0	0	**2**
	Arctic lamprey	Juvenile	2	0	0	0	**2**
2012-2013 Total			**17**	**12**	**0**	**0**	**29**
2013-2014 Total			**95**	**64**	**99**	**4**	**262**
Cumulative Total			**112**	**76**	**99**	**4**	**291**

Notes:

1 Fry consist of fish less than 60 mm fork length; juvenile life stage represents fish between 60 mm and 150 mm fork length.

Table 5.4-1. Evaluation of FERC requested variables and recommendations for inclusion in future HSC curve development.

Variable	Relationship with Fish Abundance Measures (Strong, Weak, None)	Direct Link to Fish Habitat Use	Modeled at Focus Area Scale	Recommended for Future HSC Analysis
Macronutrients: Total Phosphorus, Total Nitrogen	Insufficient Data	Unknown	No	No
pH	Strong	Yes	Yes	Yes
Dissolved Organic Carbon	None	No	Yes	No
Alkalinity	Weak	No	No	No
Chlorophyll-a	Strong	No	Yes	No

Table 5.5-1. Proposed minimum and maximum threshold values for use with individual HSC/HSI model variables and life stages.

Variable	Life Stage	Time Period	Threshold Range Minimum	Threshold Range Maximum	Comments
Depth	Fry	All Year	0.1 ft	Model/non-limiting	If descending limb does not extend to zero preference, set probability constant from last (deepest) utilization point to outer extend of depth range
	Juv.	All Year	0.2 ft	Model/non-limiting	If descending limb does not extend to zero preference, set probability constant from last (deepest) utilization point to outer extend of depth range
	Adult	All Year	0.25 ft	Model/non-limiting	If descending limb does not extend to zero preference, set probability constant from last (deepest) utilization point to outer extend of depth range
	Spawning	Summer	0.3 ft	Model/non-limiting	If descending limb does not extend to zero preference, set probability constant from last (deepest) utilization point to outer extend of depth range
Velocity	Fry	Summer	0.0 fps	Model or 3.0 fps	If descending limb does not extend to zero preference, use maximum threshold to set upper extent of velocity preference. Last utilization point at 2.9 fps
	Juv.	Summer	0.0 fps	Model or 3.0 fps	If descending limb does not extend to zero preference, use maximum threshold to set upper extent of velocity preference. Last utilization point at 2.9 fps
	Adult	Summer	0.0 fps	Model	Last utilization point at 2.9 fps
	Spawning	Summer	0.0 fps	Model or 4.5 fps	Last utilization point at 3.47 fps, similar to maximum spawning velocity used in 1980s HSC study
	Fry	Winter	0.0 fps	1.5 fps	Last utilization point at 0.93 fps (winter)
	Juv.	Winter	0.0 fps	1.5 fps	Last utilization point at 1.15 fps (winter)
pH	Fry	All Year	6.5	8.5	Alaska DEC (2012)
	Juv.	All Year	6.5	8.5	Daily minimum and maximum values
	Adult	All Year	6.5	8.5	
	Spawning	All Year	6.5	8.5	
DO	Fry	Winter	7 mg/l	17 mg/l	Daily minimum and maximum values
	Juv.	Winter	7 mg/l	17 mg/l	
	Adult	Winter	7 mg/l	17 mg/l	
	Incubation	Winter	7 mg/l	17 mg/l	Assume 2 mg/l depression for intergravel (Alaska DEC, 2012)
	Fry	Summer	7 mg/l	17 mg/l	If D.O. pre-project <7 mg/l, no greater than 2 mg/l reduction from background, but no lower than 3 mg/l regardless of pre-project level.
	Juv.	Summer	7 mg/l	17 mg/l	
	Adult	Summer	7 mg/l	17 mg/l	
	Spawning	Summer	7 mg/l	17 mg/l	

Variable	Life Stage	Time Period	Threshold Range		Comments
			Minimum	Maximum	
Temp.	Fry	Summer	3.0°C	20.0°C	Alaska DEC (2012)
	Juv.	Summer	3.0°C	20.0°C	Daily minimum and maximum values
	Adult	Summer	3.0°C	20.0°C	
	Spawning	Summer	3.0°C	13.0°C	Aug. 15 – Sep. 30; applied to only those areas with >0.0 spawning preference
Distance to Water's Edge	Fry	Summer	none	75.0 ft	Based on maximum distance from bank observed during 2013-2014 surveys
	Juv.	Summer	none	75.0 ft	Based on maximum distance from bank observed during 2013-2014 surveys
	Adult	Summer	none	None	
	Spawning	Summer	none	None	

Table 5.6-1. Utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns).

Type of Cover		All		Turbidity≤30		Turbidity>30	
		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	1082	186	731	125	334	61
	Percent Utilization	16%	24%	18%	32%	9%	7%
Wood	Number of Observations	1107	132	768	88	326	40
	Percent Utilization	16%	31%	18%	43%	10%	5%
Aquatic Vegetation	Number of Observations	1136	103	763	93	359	7
	Percent Utilization	18%	12%	21%	9.7%	9%	14%
Overhead Vegetation	Number of Observations	1193	46	818	38	358	8
	Percent Utilization	16%	46%	19%	55%	9%	0%
Undercut Bank	Number of Observations	1224	15	841	15	366	0
	Percent Utilization	17%	73%	19%	73%	9%	na
Any (Non-Turbidity)	Number of Observations	839	431	544	312	285	112
	Percent Utilization	14%	23%	15%	29%	9.8%	6.3%
Turbidity (>30 NTU)	Number of Observations	856	397				
	Percent Utilization	20%	9%				

Note:
na = not applicable

Table 5.6-2. Chinook salmon fry univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	1311.8	0		Lowest AIC
	Linear Depth	1312.1	0.3		
	Quadratic Depth	1291.2	-21	**	
	3rd order Depth	1292.2	-20		
	Fixed effects: 3rd order Depth	1330.3	19		
Velocity	Null (No covariates)	1311.8	0		Lowest AIC
	Linear Velocity	1284.7	-27	**	
	Quadratic Velocity	1286.7	-25		
	3rd order Velocity	1288.7	-23		
	Fixed effects 3rd order Velocity	1318.6	6.8		
Water Temperature	Null (No covariates)	1304.5	0	**	Null model has lowest AIC
	Linear Temperature	1306.5	2.0		
	Quadratic Temperature	1306.9	2.4		
	Fixed effects quadratic Temperature	1347.9	43		
Non-Aquatic Vegetation Cover and Turbidity	Null (where turbidity available)	1261	0		Lowest AIC
	Non-Aquatic Vegetation Cover	1205.4	-56		
	Non-Aquatic Vegetation Cover:Turbidity	1194.6	-66	**	
	Fixed effects Non-Aquatic Vegetation Cover:Turbidity	1229.2	-32		
Dissolved Oxygen	Null (sites with DO measured)	1291.7	0	**	Decreasing preference with increasing DO is not ecologically reasonable
	Linear DO	1268.5	-23		
	Quadratic DO	1270.4	-21		
	Fixed effects quadratic DO	1308.0	16		

Note:

1 Displayed models are mixed/random effects models except where noted.

Table 5.6-3. AIC results for Chinook salmon fry multivariate models.

Intercept	Cover/ Turbidity	Depth	Depth²	Velocity	Cover: Depth	Cover: Velocity	Depth: Velocity	Degrees of Freedom	AICc	deltaAIC[1]	Notes[2]
x	x	x	x	x			x	8	1151.0	0	
x	x	x	x	x				7	1156.4	5.4	BME,S
x	x	x	x	x	x			9	1157.6	6.6	
x	x	x	x	x		x		9	1158.4	7.4	
x								2	1261.0	110	NULL

Notes:

1 Models other than the null model with deltaAIC > 15 are not displayed for brevity.

2 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-4. Juvenile Chinook salmon utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns)

Type of Cover		All		Turbidity≤30		Turbidity>30	
		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	776	121	362	56	414	65
	Percent Utilization	7%	8%	7%	11%	7%	6%
Wood	Number of Observations	799	67	398	20	401	47
	Percent Utilization	8%	6%	8%	10%	7%	4%
Aquatic Vegetation	Number of Observations	787	79	348	70	439	9
	Percent Utilization	7%	8%	7%	8.6%	7%	0%
Overhead Vegetation	Number of Observations	828	38	389	29	439	9
	Percent Utilization	7%	13%	7%	10%	7%	22%
Undercut Bank	Number of Observations	865	1	417	1	448	0
	Percent Utilization	7%	0%	8%	0%	7%	na
Any (Non-Turbidity)	Number of Observations	624	275	267	151	357	124
	Percent Utilization	7%	9%	5%	12%	7.6%	6.5%
Turbidity (>30 NTU)	Number of Observations	418	481				
	Percent Utilization	8%	7%				

Note:

na = not applicable

Table 5.6-5. Juvenile Chinook salmon univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc[2]	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	456.9	0		Lowest AIC
	Linear Depth	454.6	-2.3	**	
	Quadratic Depth	456.3	-0.6		
	3rd order Depth	457.1	0.2		
	Mixed effects: 3rd order Depth	459.1	2.2		
Velocity	Null (No covariates)	478.8	0		Lowest AIC
	Linear Velocity	475.2	-3.6	**	
	Quadratic Velocity	476.2	-2.6		
	3rd order Velocity	478.1	-0.7		
	Mixed effects 3rd order Velocity	480.1	1.3		
Water Temperature	Null (No covariates)	478.8	0	**	Null Model has lowest AIC
	Linear Temperature	480.7	1.9		
	Quadratic Temperature	482.4	1.7		
	Mixed effects quadratic Temperature	484.5	2.0		
Non-Aquatic Vegetation Cover and Turbidity	Null (where turbidity available)	478.8	0		Lowest AIC
	Non-Aquatic Vegetation Cover	478.6	-0.2	**	
	Non-Aquatic Vegetation Cover:Turbidity	478.8	0.0		
	Mixed effects Non-Aquatic Vegetation Cover:Turbidity	480.9	2.1		
Dissolved Oxygen	Null (sites with DO measured)	469.0	0	**	Linear decrease with DO not ecologically reasonable
	Linear DO	464.5	-4.5		
	Quadratic DO	466.5	2.0		
	Mixed effects quadratic DO	468.5	2.0		

Notes:

1 Displayed Models are fixed effects models except where noted.

2 Displayed AICc results for depth are for depths <3.5 feet only.

Table 5.6-6. AIC results for juvenile Chinook salmon multivariate models.

Dataset	Intercept	Cover	Depth	Depth[2]	Depth[3]	Velocity	Depth: Velocity	Degrees of Freedom	AICc[1]	deltaAIC	Notes[2]
All Data	x		x	x	x	x		5	466.7	0	BME
	x		x			x		3	467.9	1.2	
	x	x	x	x	x	x		6	468.3	1.6	
	x		x	x	x	x	x	6	468.5	1.8	
	x		x	x	x			4	469.1	2.4	
	x	x	x			x		4	469.1	2.4	
	x		x					2	469.3	2.6	
	x		x	x		x		4	469.4	2.7	
	x	x	x					3	470	3.3	
	x	x	x	x	x			5	470.3	3.6	
	x		x	x				3	470.3	3.6	
	x	x	x	x		x		5	470.8	4.1	
	x	x	x	x				4	471.4	4.7	
	x					x		2	475.2	8.5	
	x	x				x		3	475.9	9.2	
	x	x						2	478.6	11.9	
	x							1	478.8	12.1	NULL
Depth < 3.5 feet	x		x			x		3	453.4	0	BME, S
	x		x					2	454.6	1.2	
	x					x		2	454.9	1.5	
	x	x	x			x		4	455.0	1.6	
	x		x			x	x	4	455.3	1.9	
	x	x	x					3	455.8	2.4	
	x	x				x		3	456.5	3.1	
	x							1	456.9	3.6	NULL
	x	x						2	458.1	4.7	

Notes:

1 AICc for different datasets is not directly comparable.

2 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-7. Utilization of categorical habitats as a percent of total samples (including availability) for chum salmon spawning.

Factor	Group	Number of Samples[1]	Percent Utilization
Substrate	All Gravel	159	63%
	Gravel Dominant Mix	293	58%
	Gravel Subdominant Mix	226	45%
	Cobble Dominant / No Gravel	103	23%
Upwelling	Upwelling	722	52%
	Downwelling	32	28%

Note:
1 Number of samples includes availability + utilization observations.

Table 5.6-8. AIC model comparisons testing random effects and interaction between spawning site type (random vs. select) and each predictor variable.

Predictor	Model[1,2]	AICc	deltaAIC	Conclusion
Depth	3rd order Depth with Site Type	1051.9	3.4	Some evidence that select sites have no depth preference; potential impact would be that relationship with depth is understated by including select sites.
	3rd order Depth with Site Type and Interaction	1048.5	0.0	
	Fixed Model: 3rd order Depth with Site Type and Interaction	1067.0	18	
Velocity	3rd order Vel with Site Type	1052.7	0.0	No evidence of interaction.
	3rd order Vel with Site Type and Interaction	1053.7	1.0	
	Fixed Model: 3rd order Vel with Site Type and Interaction	1062.0	9.3	
Water Temperature	Quadratic Temp with Site Type	1063.7	0.0	No evidence of interaction.
	Quadratic Temp with Site Type and Interaction	1064.6	0.9	
	Fixed Model: quadratic Temp with Site Type and Interaction	1083.0	19	
Substrate Group	Substrate Group with Site Type	1024.6	0.0	No evidence of interaction.
	Substrate Group with Site Type and Interaction	1024.7	0.1	
	Fixed effects: Substrate Group with Site Type and Interaction	1048.4	24	
Upwelling	Upwelling with Site Type	1026.6	0.0	No evidence of interaction.
	Upwelling with Site Type and Interaction	1028.3	1.7	
	Fixed effects: Upwelling with Site Type and Interaction	1044.1	18	
Dissolved Oxygen	Quadratic DO with Site Type	1052.8	0	No evidence of interaction.
	Quadratic DO with Site Type and Interaction	1054.2	1.5	
	Fixed effects: quadratic DO with Site Type and Interaction	1071.1	18	

Notes:

1 Displayed models are mixed/random effects models unless noted.

2 Interaction is added to the univariate model including all predictors.

Table 5.6-9. Chum salmon spawning univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	1065	0		Linear and quadratic have similar AIC
	Linear Depth	1049.2	-16	**	
	Quadratic Depth	1050.1	-15	**	
	3rd order Depth	1051.5	-14		
Velocity	Null (No covariates)	1065	0		Lowest AIC
	Linear Velocity	1066.1	1.1		
	Quadratic Velocity	1051.6	-13	**	
	3rd order Velocity	1053.6	-11		
Water Temperature	Null (No covariates)	1065	0		Lowest AIC
	Linear Temperature	1063.4	-1.6	**	
	Quadratic Temperature	1065.1	0.1		
Upwelling	Null (sites with upwelling measured)	1027.2	0		Lowest AIC
	Categorical	1025.8	-1.4	**	
Substrate Group	Null (No covariates)	1065	0		Lowest AIC
	Categorical	1024.1	-41	**	
Dissolved Oxygen	Null (sites with DO measured)	1049.7	0	**	Null has lowest AIC
	Linear DO	1050.2	0.50		
	Quadratic DO	1051.7	2.0		

Table 5.6-10. AIC results for chum salmon spawning multivariate models.

Intercept	Substrate	Depth	Depth[2]	Temp	Velocity	Velocity[2]	Substrate: Depth	Substrate: Velocity	Substrate: Temperature	Depth: Velocity	Depth: Temperature	Velocity: Temperature	Degrees of Freedom	AICc	Delta AIC[1]	Notes[3]
x	x	x		x	x	x						x	10	997.1	0.0	
x	x	x	x	x	x	x						x	11	998.3	1.2	S
x	x	x		x	x	x							9	999.1	2.0	BME
x	x	x		x	x	x	x						12	999.4	2.3	
x	x	x			x	x							8	1000.1	3.0	
x	x	x	x	x	x	x							10	1000.3	3.2	
x	x	x	x	x	x	x	x						13	1000.7	3.7	
x	x	x		x	x	x					x		10	1000.9	3.8	
x	x	x	x		x	x							9	1001.0	3.9	
x	x	x		x	x	x				x			10	1001.1	4.0	
x	x	x		x	x	x			x				12	1001.9	4.8	
x	x	x	x	x	x	x					x		11	1002.2	5.1	
x	x	x	x	x	x	x				x			11	1002.3	5.3	
x	x	x	x	x	x	x			x				13	1003.0	6.0	
x	x	x		x	x	x		x					12	1004.9	7.8	
x	x	x	x	x	x	x		x					13	1006.1	9.0	
x	x	x		x		x							8	1007.2	10.1	
x	x	x				x							7	1007.7	10.6	
x	x	x	x	x		x							9	1008.3	11.2	
x	x	x	x			x							8	1008.5	11.4	
x	x	x		x									7	1008.9	11.8	
x													2	1065.0	67.9	NULL

Notes:

1 Models other than the null model with deltaAIC > 12 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-11. Coho fry utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns).

Type of Cover		All		Turbidity≤30		Turbidity>30	
		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	1168	106	933	87	198	18
	Percent Utilization	22%	21%	23%	24%	11%	0%
Wood	Number of Observations	1143	131	913	107	199	17
	Percent Utilization	18%	50%	20%	55%	10%	12%
Aquatic Vegetation	Number of Observations	1006	268	778	242	199	17
	Percent Utilization	18%	34%	20%	36%	10%	12%
Overhead Vegetation	Number of Observations	1219	55	968	52	214	2
	Percent Utilization	20%	45%	22%	48%	10%	0%
Undercut Bank	Number of Observations	1246	28	992	28	216	0
	Percent Utilization	20%	75%	22%	75%	10%	na
Any (Non-Turbidity)	Number of Observations	760	514	576	444	165	51
	Percent Utilization	14%	33%	14%	36%	10.9%	7.8%
Turbidity (>30 NTU)	Number of Observations	1020	216				
	Percent Utilization	23%	10%				

Note:
na = not applicable

Table 5.6-12. Coho salmon fry univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	1284.9	0		Lowest AIC
	Linear Depth	1285.3	0.4		
	Quadratic Depth	1266	-19	**	
	3rd order Depth	1266.8	-18		
	Fixed effects: 3rd order Depth	1307.6	23		
Velocity	Null (No covariates)	1284.9	0		Lowest AIC
	Linear Velocity	1260.3	-25	**	
	Quadratic Velocity	1262.3	-23		
	3rd order Velocity	1264.3	-21		
	Fixed effects 3rd order Velocity	1296.6	12		
Water Temperature	Null (No covariates)	1277.5	0	**	Null model has lowest AIC
	Linear Temperature	1279.5	2.0		
	Quadratic Temperature	1280.1	2.5		
	Fixed effects quadratic Temperature	1323.7	46		
Cover and Turbidity	Null (where turbidity available)	1234	0		Lowest AIC
	Cover	1179.4	-55		
	Cover:Turbidity	1172.8	-61	**	
	Fixed effects Cover:Turbidity	1190.7	-43		
Dissolved Oxygen	Null (sites with DO measured)	1264.9	0	**	Linear decreasing relationship with DO is not ecologically reasonable
	Linear DO	1243.8	-21		
	Quadratic DO	1245.8	-19		
	Fixed effects quadratic DO	1286.9	22		

Notes:
1 Displayed Models are Mixed/Random effects models except where noted.

Table 5.6-13. AIC results for coho salmon fry multivariate models.

Intercept	Cover/ Turbidity	Depth	Depth[2]	Velocity	Cover/Turbidity: Depth	Cover/Turbidity: Velocity	Depth: Velocity	Degrees of Freedom	AICc	deltaAIC[1]	Notes[3]
x	x	x	x	x	x			9	1122.4	0	S
x	x	x	x	x			x	8	1129.6	7.2	
x	x	x	x	x				7	1133.6	11.2	BME
x	x	x	x	x		x		9	1134.3	11.9	
x	x	x	x					6	1151.7	29	
x	x			x				5	1155.8	33.4	
x	x	x		x				6	1157.6	35.2	
x	x							4	1170.9	48.5	
x	x	x						5	1172.5	50.1	
x								2	1234	111.6	NULL

Notes:

1 Models other than the null model with deltaAIC > 50 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-14. Coho salmon juvenile utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns).

		All		Turbidity≤30		Turbidity>30	
Type of Cover		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	1168	106	933	87	198	18
	Percent Utilization	22%	21%	23%	24%	11%	0%
Wood	Number of Observations	1143	131	913	107	199	17
	Percent Utilization	18%	50%	20%	55%	10%	12%
Aquatic Vegetation	Number of Observations	1006	268	778	242	199	17
	Percent Utilization	18%	34%	20%	36%	10%	12%
Overhead Vegetation	Number of Observations	1219	55	968	52	214	2
	Percent Utilization	20%	45%	22%	48%	10%	0%
Undercut Bank	Number of Observations	1246	28	992	28	216	0
	Percent Utilization	20%	75%	22%	75%	10%	na
Any (Non-Turbidity)	Number of Observations	760	514	576	444	165	51
	Percent Utilization	14%	33%	14%	36%	11%	7.8%
Turbidity (>30 NTU)	Number of Observations	1020	216				
	Percent Utilization	23%	10%				

Note:
na = not applicable

Table 5.6-15. Coho salmon juvenile univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	542.5	0		Lowest AIC
	Linear Depth	536.1	-6.4		
	Quadratic Depth	530.1	-12	**	
	3rd order Depth	531.9	-11		
	Mixed effects: 3rd order Depth	534.0	-8.5		
Velocity	Null (No covariates)	542.5	0		Lowest AIC
	Linear Velocity	541.3	-1.2	**	
	Quadratic Velocity	543.3	0.8		
	3rd order Velocity	546.8	4.3		
	Mixed effects 3rd order Velocity	544.78	2.3		
Water Temperature	Null (No covariates)	542.5	0		Lowest AIC
	Linear Temperature	541.2	-1.3	**	
	Quadratic Temperature	543.2	0.69		
	Mixed effects quadratic Temperature	545.2	2.7		
Non-Boulder Cover	Null (No covariates)	542.5	0		Lowest AIC
	Categorical	531.15	-11	**	
	Mixed effects Categorical	533.17	-9		
Dissolved Oxygen	Null (sites with DO measured)	542.5	0	**	Linear decreasing relationship with DO is not ecologically reasonable
	Linear DO	535.3	-7.2		
	Quadratic DO	537.3	-5.3		
	Mixed effects quadratic DO	539.3	-3.2		

Notes:

1 Displayed Models are fixed effects models except where noted.

Table 5.6-16. AIC results for coho salmon juvenile multivariate models.

Intercept	Non-Boulder Cover	Depth	Depth[2]	Temp	Velocity	Cover: Depth	Cover: Temperature	Depth: Temperature	Cover: Velocity	Depth: Velocity	Degrees of Freedom	AICc	Delta AIC[1]	Notes[3]
x	x	x	x		x				x		6	524.04	0	
x	x	x	x	x			x				6	524.29	0.25	
x	x	x	x								4	524.7	0.66	BME, S
x	x	x	x	x				x			6	525.82	1.8	
x	x	x	x	x							5	526.3	2.3	
x	x	x	x			x					5	526.41	2.4	
x	x	x	x		x						5	526.6	2.6	
x	x	x	x		x					x	6	528.07	4.0	
x	x	x	x	x	x						6	528.3	4.3	
x	x	x									3	529.1	5.1	
x		x	x								3	530.1	6.1	
x	x	x		x							4	530.6	6.6	
x	x	x			x						4	531	7.0	
x		x	x	x							4	531	7.0	
x	x										2	531.2	7.2	
x		x	x		x						4	531.3	7.3	
x	x			x							3	532.1	8.1	
x	x	x		x	x						5	532.5	8.5	
x	x				x						3	532.5	8.5	
x		x	x	x	x						5	532.6	8.6	
x	x			x	x						4	533.7	9.7	
x											1	542.5	18.5	NULL

Notes:

1 Models other than the null model with deltaAIC > 10 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-17. Utilization of categorical habitats as a percent of total samples (including availability) for sockeye salmon spawning.

Factor	Group	Number of Samples[1]	Percent Utilization
Substrate	All Gravel	130	72%
	Gravel Dominant Mix	160	56%
	Gravel Subdominant Mix	90	36%
	Cobble Dominant / No Gravel	75	40%
Upwelling	Upwelling	428	54%
	Downwelling	27	44%

Note:
1 Number of samples includes availability + utilization observations.

Table 5.6-18. AIC model comparisons testing random effects and interaction between spawning site type (random vs. select) and each predictor variable.

Predictor	Model[1,2]	AICc	deltaAIC	Conclusion
Depth	3rd order Depth with Site Type	603.1	0.0	Interaction is not significant
	3rd order Depth with Site Type and Interaction	605.2	2.1	
	Fixed Model: 3rd order Depth with Site Type and Interaction	630.7	28	
Velocity	3rd order Velocity with Site Type	598.1	2.4	Some evidence that historic sites have lower velocity preference; potential impact would be underestimated preference for higher velocity sites
	3rd order Velocity with Site Type and Interaction	595.7	0	
	Fixed Model: 3rd order Velocity with Site Type and Interaction	630.7	35	
Water Temperature	Quadratic Temperature with Site Type	598.3	0.0	Interaction is not significant
	Quadratic Temperature with Site Type and Interaction	600.3	2.0	
	Fixed Model: quadratic Temperature with Site Type and Interaction	618.8	21	
Substrate Group	Substrate Group with Site Type	548.7	5.0	Evidence of interaction. Substrate factor was revised to combine two groups without gravel dominant substrate.
	Substrate Group with Site Type and Interaction	543.8	0	
	Fixed effects: Substrate Group with Site Type and Interaction	583.4	40	
Revised Substrate Group[3]	Substrate Group with Site Type	550.0	0.0	Interaction is not significant
	Substrate Group with Site Type and Interaction	553.5	3.5	
Dissolved Oxygen	Quadratic DO with Site Type	561.9	0	Interaction is not significant
	Quadratic DO with Site Type and Interaction	562.2	0.31	
	Fixed effects: quadratic DO with Site Type and Interaction	572.6	11	

Notes:

1 Displayed models are mixed/random effects models unless noted.

2 Interaction is added to the univariate model including all predictors.

3 Substrate Group 3 and Group 4 combined due to low sample sizes.

Table 5.6-19. Sockeye spawning univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	601.6	0		Lowest AIC
	Linear Depth	603.3	1.7		
	Quadratic Depth	599.4	-2.2	**	
	3rd order Depth	601.2	-0.4		
Velocity	Null (No covariates)	601.6	0		Lowest AIC
	Linear Velocity	595.9	-5.7	**	
	Quadratic Velocity	597	-4.6		
	3rd order Velocity	596.1	-5.5		
Water Temperature	Null (No covariates)	601.6	0		Quadratic relationship not ecologically reasonable
	Linear Temperature	600.0	-1.6	**	
	Quadratic Temperature	597.6	-4		
Upwelling	Null (No covariates)	601.6	0	**	Null model has lowest AIC
	Upwelling	603.5	1.9		
Revised Substrate Group[1]	Null (No covariates)	601.6	0		Lowest AIC
	Substrate	547.9	-54	**	
Dissolved Oxygen	Null (sites with DO measured)	559.1	0	**	Null model has lowest AIC
	Linear DO	560.9	1.8		
	Quadratic DO	560.9	1.8		

Notes:
1 Substrate Group 3 and Group 4 combined due to low sample sizes.

Table 5.6-20. AIC results for sockeye salmon spawning multivariate models.

Intercept	Substrate	Depth	Depth2	Temp	Velocity	Substrate: Velocity	Substrate: Temperature	Temperature: Velocity	Degrees of Freedom	AICc	deltaAIC[1]	Notes[3]
x	x			x	x	x			8	532.2	0	S
x	x			x	x		x		8	539.3	7.1	
x	x			x	x			x	7	540.8	8.7	
x	x			x	x				6	541.0	8.8	BME
x	x	x		x	x				7	542.6	10	
x	x				x				5	544.7	13	
x	x	x			x				6	546.1	14	
x	x	x	x		x				7	546.3	14	
x	x			x					5	546.3	14	
x	x	x	x	x					7	547.6	15	
x	x								4	547.9	16	
x	x	x		x					6	548.3	16	
x	x	x	x						6	549	17	
x	x	x							5	549.9	18	
x									2	601.6	69	NULL

Notes:

1 Models other than the null model with deltaAIC > 20 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-21. Arctic grayling fry utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns)

Type of Cover		All		Turbidity≤30		Turbidity>30	
		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	813	49	469	19	308	30
	Percent Utilization	14%	14%	12%	26%	15%	7%
Wood	Number of Observations	820	42	465	23	325	13
	Percent Utilization	13%	21%	12%	17%	14%	15%
Aquatic Vegetation	Number of Observations	743	119	413	75	302	36
	Percent Utilization	13%	21%	12%	17%	12%	31%
Overhead Vegetation	Number of Observations	833	29	465	23	334	4
	Percent Utilization	13%	31%	11%	35%	14%	0%
Undercut Bank	Number of Observations	857	5	483	5	338	0
	Percent Utilization	14%	60%	12%	60%	14%	na
Any (Non-Turbidity)	Number of Observations	619	243	345	143	254	84
	Percent Utilization	12%	19%	10%	19%	13%	17%
Turbidity (>30 NTU)	Number of Observations	488	319				
	Percent Utilization	13%	14%				

Note:
na = not applicable

Table 5.6-22. Arctic grayling fry univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	684.7	0		Lowest AIC
	Linear Depth	683.2	-1.5		
	Quadratic Depth	662.9	-22	**	
	3rd order Depth	663.4	-21		
	Fixed effects: 3rd order Depth	672.0	-13		
Velocity	Null (No covariates)	684.7	0		Quadratic model is not ecologically reasonable
	Linear Velocity	681.8	-2.9	**	
	Quadratic Velocity	680.3	-4.4		
	3rd order Velocity	682	-2.7		
	Fixed effects 3rd order Velocity	685.99	1.3		
Water Temperature	Null (No covariates)	684.7	0		Lowest AIC
	Linear Temperature	667.7	-17	**	
	Quadratic Temperature	669.5	1.8		
	Fixed effects quadratic Temperature	677.0	7.4		
Cover and Turbidity	Null (where turbidity available)	640.1	0		Lowest AIC
	Cover	637.2	-2.9	**	
	Cover:Turbidity	638.06	-2.0		
	Fixed effects Cover:Turbidity	640.62	0.5		
Dissolved Oxygen	Null (sites with DO measured)	663.7	0	**	Linear and quadratic models are decreasing relationship with DO, which is not ecologically reasonable
	Linear DO	640.6	-23		
	Quadratic DO	639.8	-24		
	Fixed effects quadratic DO	641.8	-22		

Notes:

1 Displayed models are mixed/random effects models except where noted.

Table 5.6-23. AIC results for Arctic grayling fry multivariate models.

Intercept	Cover	Depth	Depth²	Temp	Velocity	Cover: Depth	Cover: Temperature	Cover: Velocity	Depth: Temperature	Depth: Velocity	Temperature: Velocity	Degrees of Freedom	AICc	deltaAIC¹	Notes³
x	x	x	x	x	x				x			8	635.2	0.0	S
x	x	x	x	x	x							7	639.2	4.1	BME
x	x	x	x	x	x		x					8	639.9	4.7	
x	x	x	x	x	x					x		8	640.3	5.1	
x	x	x	x	x	x						x	8	640.3	5.1	
x	x	x	x	x	x	x						8	641.2	6.1	
x	x	x	x	x	x			x				8	641.3	6.1	
x		x	x	x	x							6	643.0	7.9	
x	x	x	x	x								6	644.2	9.1	
x		x	x	x								5	648.9	13.8	
x	x	x	x		x							6	654.7	19.6	
x												2	684.7	49.6	NULL

Notes:

1 Models other than the null model with deltaAIC > 20 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-24. Arctic grayling juvenile utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns)

		All		Turbidity≤30		Turbidity>30	
Type of Cover		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	576	114	322	38	254	76
	Percent Utilization	11%	15%	9%	13%	13%	16%
Wood	Number of Observations	676	14	347	13	329	1
	Percent Utilization	12%	0%	10%	0%	13%	0%
Aquatic Vegetation	Number of Observations	669	21	347	13	322	8
	Percent Utilization	12%	5%	9.8%	0%	13%	13%
Overhead Vegetation	Number of Observations	681	9	351	9	330	0
	Percent Utilization	11%	33%	9%	33%	13%	na
Undercut Bank	Number of Observations	689	1	359	1	330	0
	Percent Utilization	11%	100%	9.2%	100%	13%	na
Any (Non-Turbidity)	Number of Observations	533	157	289	71	244	86
	Percent Utilization	11%	13%	9.3%	10%	12%	16%
Turbidity (>30 NTU)	Number of Observations	360	330				
	Percent Utilization	9.4%	13%				

Note:
na = not applicable

Table 5.6-25. Arctic grayling juvenile univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth[2]	Null (No covariates)	483.9	0		Lowest AIC with influential point removed
	Linear Depth	485.8	1.9		
	Quadratic Depth	475.6	-8.3	**	
	3rd order Depth	476.1	-7.8		
	Fixed effects: 3rd order Depth	477.6	-6.3		
Velocity	Null (No covariates)	488.9	0	**	Null model has lowest AIC
	Linear Velocity	490.8	1.9		
	Quadratic Velocity	491.3	2.4		
	3rd order Velocity	491.4	2.5		
	Fixed effects 3rd order Velocity	490.5	1.6		
Water Temperature	Null (No covariates)	488.9	0	**	Decreasing relationship with temperature is not ecologically reasonable
	Linear Temperature	483.0	-6		
	Quadratic Temperature	484.6	1.6		
	Fixed effects quadratic Temperature	482.6	-2.0		
Cover and Turbidity	Null	488.9	0		Lowest AIC
	Cover	487	-1.9	**	
	Turbidity	489	0.1		
	Cover + Turbidity	487.7	-1.2		
	Cover:Turbidity	489.47	0.6		
	Fixed effects Cover:Turbidity	490.06	1.2		
Dissolved Oxygen	Null (sites with DO measured)	477.8	0	**	Null model has lowest AIC
	Linear DO	479.8	2.0		
	Quadratic DO	481.5	3.7		
	Fixed effects quadratic DO	480.9	3.1		

Notes:

1 Displayed models are mixed/random effects models except where noted.

2 Displayed depth results are without influential observation with depth of 3.5 feet.

Table 5.6-26. AIC results for Arctic grayling juvenile multivariate models.

Intercept	Cover[1]	Depth	Depth[2]	Cover: Depth	Degrees of Freedom	AICc	deltaAIC	Notes[3]
x	x	x	x		5	474.1	0.0	BME,S
x		x	x		4	475.6	1.5	
x	x	x	x	x	6	476.1	2.0	
x	x				3	481.9	7.8	
x	x		x		4	482.7	8.6	
x	x	x			4	483.9	9.8	
x					2	483.9	9.9	NULL
x			x		3	484.0	10.0	
x		x			3	485.8	11.8	

Note:

1 Cover includes only boulder, overhead vegetation, and undercut bank.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-27. Whitefish fry utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns)

Type of Cover		All		Turbidity≤30		Turbidity>30	
		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	785	53	263	4	505	49
	Percent Utilization	13%	6%	11%	25%	14%	4%
Wood	Number of Observations	794	44	247	20	530	24
	Percent Utilization	12%	14%	11%	15%	13%	13%
Aquatic Vegetation	Number of Observations	744	94	216	51	519	35
	Percent Utilization	12%	19%	9%	18%	13%	20%
Overhead Vegetation	Number of Observations	816	22	250	17	550	4
	Percent Utilization	12%	36%	10%	29%	13%	75%
Undercut Bank	Number of Observations	838	0	267	0	554	0
	Percent Utilization	12%	na	11%	na	13%	na
Any (Non-Turbidity)	Number of Observations	636	202	182	85	447	107
	Percent Utilization	12%	14%	8%	16%	13%	12%
Turbidity (>30 NTU)	Number of Observations	267	541				
	Percent Utilization	11%	13%				

Note:
na = not applicable

Table 5.6-28. Whitefish fry univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	634.7	0		Lowest AIC
	Linear Depth	636.2	1.5		
	Quadratic Depth	634.5	-0.2	**	
	3rd order Depth	635.8	1.1		
	Mixed effects: 3rd order Depth	637.1	2.4		
Velocity[2]	Null (No covariates)	615.3	0		Lowest AIC
	Linear Velocity	612.8	-2.5		
	Quadratic Velocity	605.9	-9.4	**	
	3rd order Velocity	607.9	-7.4		
	Mixed effects 3rd order Velocity	609.3	-6.0		
Water Temperature	Null (No covariates)	634.7	19		Lowest AIC
	Linear Temperature	634.0	-1		
	Quadratic Temperature	629.0	-5.0	**	
	Mixed effects quadratic Temperature	630.8	1.8		
Cover and Turbidity	Null (where turbidity available)	618.2	0	**	Null model has lowest AIC
	Cover	619.6	1.4		
	Turbidity	619.3	1.1		
	Cover:Turbidity	619.4	1.2		
	Mixed effects Cover:Turbidity	620.4	2.1		
Dissolved Oxygen	Null (sites with DO measured)	634.7	0	**	Decreasing relationship with DO not ecologically reasonable
	Linear DO	631.0	-3.7		
	Quadratic DO	632.2	-2.6		
	Mixed effects quadratic DO	633.8	-1.0		

Notes:

1 Displayed Models are fixed effects models except where noted.

2 Velocity results shown are without two influential observations with velocity>2.4 fps.

Table 5.6-29. AIC results for whitefish fry multivariate models.

Intercept	Depth	Depth^2	Temp	Temp^2	Velocity	Velocity^2	Depth: Temperature	Depth: Velocity	Depth^2: Velocity	Velocity: Temperature	Degrees of Freedom	AICc	deltaAIC[1]	Notes[3]
x	x	x	x	x	x	x			x		8	596.3	0.0	S
x	x	x	x	x	x	x		x			8	596.8	0.5	
x	x	x	x	x	x	x		x	x		9	598.4	2.1	
x	x	x	x	x	x	x					7	601.1	4.8	BME
x	x	x			x	x					5	602.4	6.1	
x	x	x	x	x	x	x				x	8	602.6	6.3	
x	x	x	x	x	x	x	x				8	602.8	6.5	
x	x	x	x		x	x					6	603.7	7.4	
x			x	x	x	x					5	603.9	7.6	
x	x		x	x	x	x					6	605.4	9.1	
x					x	x					3	605.9	9.6	
x	x				x	x					4	606.9	10.6	
x			x		x	x					4	607.4	11.1	
x	x	x	x	x	x						6	608.5	12.2	
x	x		x		x	x					5	608.5	12.2	
x			x	x	x						4	609.6	13.3	
x											1	615.3	19	NULL

Notes:

1 Models other than the null model with deltaAIC > 10 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-30. Whitefish juvenile utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns).

		All		Turbidity ≤ 30		Turbidity > 30	
Type of Cover		**Cover Absent**	**Cover Present**	**Cover Absent**	**Cover Present**	**Cover Absent**	**Cover Present**
Boulder	Number of Observations	699	92	331	10	368	82
	Percent Utilization	12%	15%	10%	0%	15%	17%
Wood	Number of Observations	727	34	318	23	409	11
	Percent Utilization	13%	12%	9%	13%	16%	9%
Aquatic Vegetation	Number of Observations	696	65	296	45	400	20
	Percent Utilization	13%	9%	9%	11%	17%	5%
Overhanging Vegetation	Number of Observations	752	9	334	7	418	2
	Percent Utilization	13%	11%	9%	14%	16%	0%
Undercut Bank	Number of Observations	761	0	341	0	420	0
	Percent Utilization	13%	na	9%	na	16%	na
Any (Non-Turbidity)	Number of Observations	603	190	264	77	339	113
	Percent Utilization	13%	13%	9%	10%	16%	14%
Turbidity (30NTU)	Number of Observations	341	452				
	Percent Utilization	9%	15%				

Note:
na = not applicable

Table 5.6-31. Whitefish juvenile univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	594.4	0	**	Null model has lowest AIC
	Linear Depth	595.5	1.1		
	Quadratic Depth	595.7	1.3		
	3rd order Depth	597.6	3.2		
	Fixed effects: 3rd order Depth	608.7	14		
Velocity[2]	Null (No covariates)	588.1	0		Lowest AIC
	Linear Velocity	587.8	-0.3	**	
	Quadratic Velocity	589.3	1.2		
	3rd order Velocity	591.4	3.3		
	Fixed effects 3rd order Velocity	602.4	14		
Water Temperature	Null (No covariates)	594.4	6.3		Lowest AIC
	Linear Temperature	590.3	-4	**	
	Quadratic Temperature	592.1	1.8		
	Fixed effects quadratic Temperature	596.1	4.0		
Cover and Turbidity	Null (where turbidity available)	594.4	0		Turbidity is similar to null model - retain
	Cover	596.5	2.1		
	Turbidity	594.8	0.4	**	
	Cover:Turbidity	598.7	4.3		
	Fixed effects Cover:Turbidity	606.4	12		
Dissolved Oxygen	Null (sites with DO measured)	594.4	0	**	Null model has lowest AIC
	Linear DO	595.9	1.5		
	Quadratic DO	597.6	3.2		
	Fixed effects quadratic DO	610.0	16		

Notes:

1 Displayed models are mixed/random effects models except where noted.

2 Displayed results for velocity are with influential observation at 2.94 fps removed.

Table 5.6-32. AIC results for whitefish juvenile multivariate models.

Intercept	Turbidity	Temperature	Velocity	Turbidity: Temperature	Turbidity: Velocity	Temperature: Velocity	Degrees of Freedom	AICc	deltaAIC	Notes[1]
x	x	x	x	x			6	580.5	0.0	S
x		x	x				4	583.0	2.5	BME
x	x	x	x				5	583.4	2.9	
x		x					3	584.0	3.5	
x		x	x			x	5	584.9	4.4	
x	x	x					4	585.1	4.6	
x	x	x	x		x		6	585.3	4.8	
x	x	x	x			x	6	585.4	4.9	
x	x		x				4	587.6	7.1	
x			x				3	587.8	7.3	
x							2	588.1	7.6	NULL
x	x						3	588.5	8.0	

Notes:

1 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-33. Longnose sucker juvenile utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns)

		All		Turbidity≤30		Turbidity>30	
Type of Cover		Cover Absent	Cover Present	Cover Absent	Cover Present	Cover Absent	Cover Present
Boulder	Number of Observations	949	73	463	11	486	62
	Percent Utilization	10%	10%	10%	0%	9%	11%
Wood	Number of Observations	963	59	453	21	510	38
	Percent Utilization	10%	7%	9%	14%	10%	3%
Aquatic Vegetation	Number of Observations	891	131	360	114	531	17
	Percent Utilization	9%	12%	9%	11%	9%	18%
Overhead Vegetation	Number of Observations	995	27	452	22	543	5
	Percent Utilization	10%	7%	10%	9%	10%	0%
Undercut Bank	Number of Observations	1022	0	474	0	548	0
	Percent Utilization	10%	na	10%	na	9%	na
Any (Non-Turbidity)	Number of Observations	751	271	323	151	428	120
	Percent Utilization	9%	11%	9%	11%	9%	11%
Turbidity (>30 NTU)	Number of Observations	474	548				
	Percent Utilization	10%	10%				

Note:
na = not applicable

Table 5.6-34. Longnose sucker juvenile univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth[2]	Null (No covariates)	621	0		Lowest AIC
	Linear Depth	623.1	2.1		
	Quadratic Depth	620.2	-0.8	**	
	3rd order Depth	622.2	1.2		
	Mixed effects: 3rd order Depth	622.4	1.4		
Velocity	Null (No covariates)	643.3	0		Lowest AIC
	Linear Velocity	639.5	-3.8	**	
	Quadratic Velocity	641	-2.3		
	3rd order Velocity	642.9	-0.4		
	Mixed effects 3rd order Velocity	644.9	1.6		
Water Temperature	Null (No covariates)	643.3	0	**	Null model has lowest AIC
	Linear Temperature	644.8	1.5		
	Quadratic Temperature	644.8	1.5		
	Mixed effects quadratic Temperature	647.4	4.1		
Cover and Turbidity[3]	Null (where turbidity available)	643.3	0	**	Null model has lowest AIC
	Cover	645.1	1.8		
	Turbidity	645.3	2.0		
	Cover:Turbidity	649	5.7		
	Mixed effects Cover:Turbidity	650.2	6.9		
Dissolved Oxygen	Null (sites with DO measured)	643.3	0	**	Decreasing relationship with DO is not ecologically reasonable
	Linear DO	639.1	-4.2		
	Quadratic DO	630.8	-13		
	Mixed effects quadratic DO	632.8	-11		

Notes:

1 Displayed models are fixed effects models except where noted.

2 Displayed models are for depth <3 feet only. Four observations in deeper water have been removed.

3 Cover does not include overhanging vegetation.

Table 5.6-35. AIC results for longnose sucker juvenile multivariate models.

Intercept	Depth	Depth[2]	Velocity	Depth: Velocity	Degrees of Freedom	AICc[1]	deltaAIC[3]	Notes[4]
x	x	x	x	x	5	615.0	0.0	
x	x	x	x		4	615.4	0.4	BME,S
x			x		2	618.2	3.2	
x	x	x			3	620.2	5.2	
x	x		x		3	620.2	5.2	
x					1	621.0	6.0	NULL
x	x				2	623.1	8.1	

Notes:
1 These models fit to data with depths <3 feet.
2 Quadratic term.
3 Models other than the null model with deltaAIC > 10 are not displayed for brevity.
4 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

Table 5.6-36. Longnose sucker adult utilization of habitats with and without each cover type, including turbidity (>30 NTU) as a cover type (last two rows), or as an interacting factor (last four columns).

		All		Turbidity≤30		Turbidity>30	
Type of Cover		**Cover Absent**	**Cover Present**	**Cover Absent**	**Cover Present**	**Cover Absent**	**Cover Present**
Boulder	Number of Observations	796	63	286	11	494	52
	Percent Utilization	8%	10%	6%	0%	10%	12%
Wood	Number of Observations	837	22	293	4	528	18
	Percent Utilization	8%	9%	5%	0%	10%	11%
Aquatic Vegetation	Number of Observations	797	62	266	31	522	24
	Percent Utilization	8%	8%	6%	3%	10%	13%
Overhead Vegetation	Number of Observations	850	9	294	3	541	5
	Percent Utilization	8%	0%	5%	0%	10%	0%
Undercut Bank	Number of Observations	858	1	297	0	545	1
	Percent Utilization	8%	100%	5%	na	10%	100%
Any (Non-Turbidity)	Number of Observations	699	160	246	51	446	100
	Percent Utilization	8%	9%	6%	2%	9%	12%
Turbidity (>30 NTU)	Number of Observations	297	511				
	Percent Utilization	5%	10%				

Note:
na = not applicable

Table 5.6-37. Adult longnose sucker univariate model AIC comparisons used to select relationships for multivariate analysis.

Predictor	Model[1]	AICc	Difference From Null Model	Selected Model	Reason for Model Selection
Depth	Null (No covariates)	487	0		Lowest AIC
	Linear Depth	484.3	-2.7		
	Quadratic Depth	471	-16.0	**	
	3rd order Depth	473.0	-14.0		
	Mixed effects: 3rd order Depth	475.1	-11.9		
Velocity	Null (No covariates)	492	0		Lowest AIC
	Linear Velocity	487.4	-4.6	**	
	Quadratic Velocity	487.8	-4.2		
	3rd order Velocity	489.7	-2.3		
	Mixed effects 3rd order Velocity	491.8	-0.2		
Water Temperature	Null (no covariates)	492	0	**	Null Model has lowest AIC
	Linear Temperature	494.0	2.0		
	Quadratic Temperature	495.6	3.6		
	Mixed effects quadratic Temperature	497.6	5.6		
Cover and Turbidity	Null (where turbidity available)	484.4	0		Lowest AIC
	Cover	486.4	2.0		
	Turbidity	481	-3.4	**	
	Cover:Turbidity	482.6	-1.8		
	Mixed effects Cover:Turbidity	484.7	0.3		
Dissolved Oxygen	Null (sites with DO measured)	480.1	0	**	Decreasing relationship with DO is not ecologically reasonable
	Linear DO	478.2	-1.9		
	Quadratic DO	480.1	-0.1		
	Mixed effects quadratic DO	482.1	2.0		

Note:

1 Displayed Models are fixed effects models except where noted.

Table 5.6-38. AIC results for longnose sucker adult multivariate models.

Intercept	Turbidity	Depth	Depth[2]	Velocity	Depth: Velocity	Turbidity: Depth	Turbidity: Velocity	Degrees of Freedom	AICc	deltaAIC[1]	Notes[3]
x	x	x	x	x				5	450.0	0.0	BME, S
x	x	x	x	x		x		6	450.8	0.8	
x	x	x	x	x	x			6	451.5	1.5	
x	x	x	x	x			x	6	452.0	2.0	
x		x	x	x				4	455.8	5.8	
x	x	x	x					4	459.0	9.0	
x		x	x					3	464.1	14	
x	x	x		x				4	469.4	19	
x	x			x				3	471.5	22	
x		x		x				3	472.9	23	
x	x	x						3	473	23	
x				x				2	474.7	25	
x								1	479.4	29	NULL

Notes:

1 Models other than the null model with deltaAIC > 25 are not displayed for brevity.

2 Quadratic term.

3 S = Selected Model; BME = Best main-effects model (i.e., no interactions); NULL = model with no predictors.

10. FIGURES

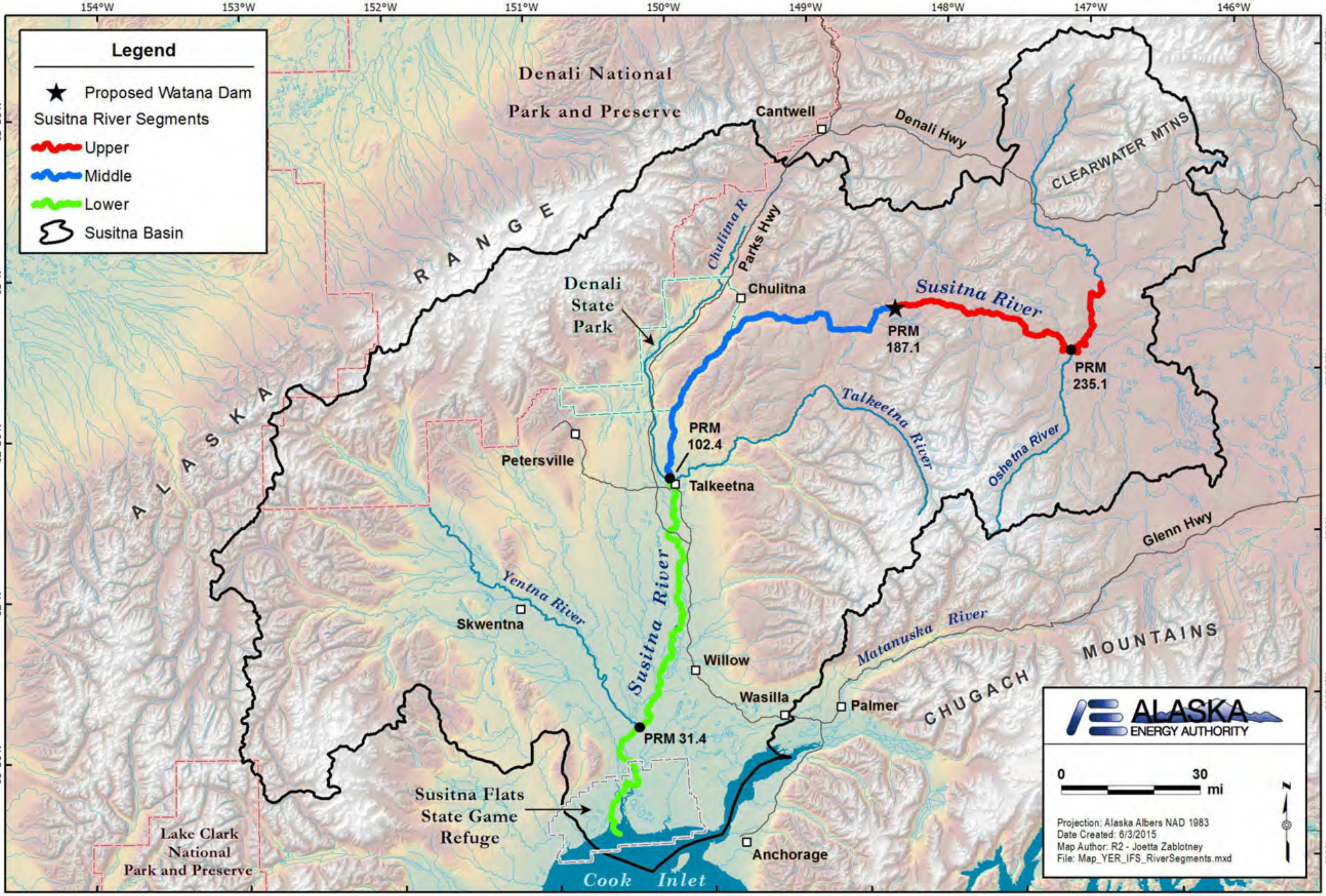

Figure 3-1. Map depicting the Upper, Middle and Lower segments of the Susitna River potentially influenced by the Susitna-Watana Hydroelectric Project.

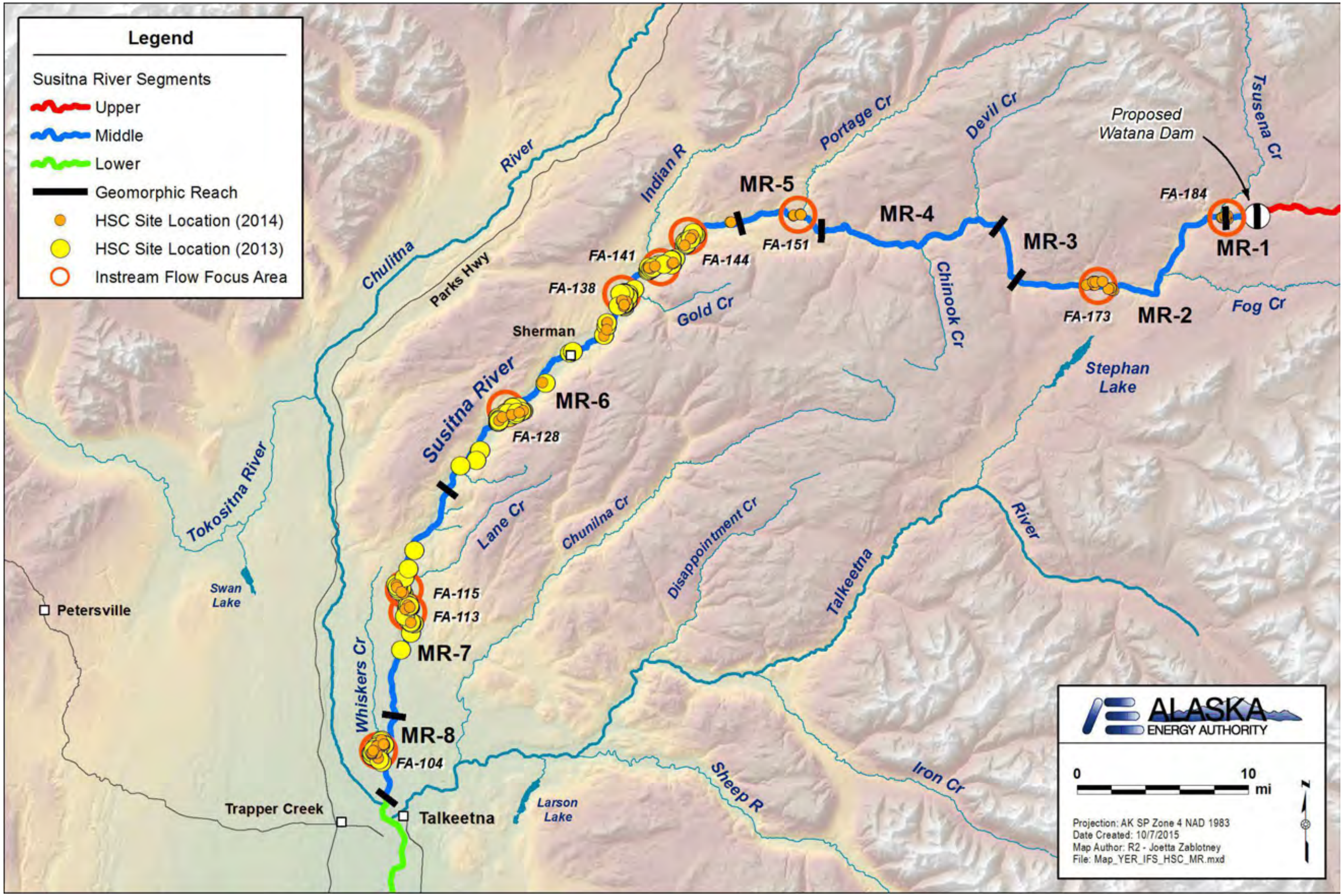

Figure 4.2-1. Map showing 2013 (yellow dots) and 2014 (orange dots) HSC sampling locations in relationship to geomorphic reaches and Focus Areas (red circles) in the Middle River Segment of the Susitna River, Alaska.

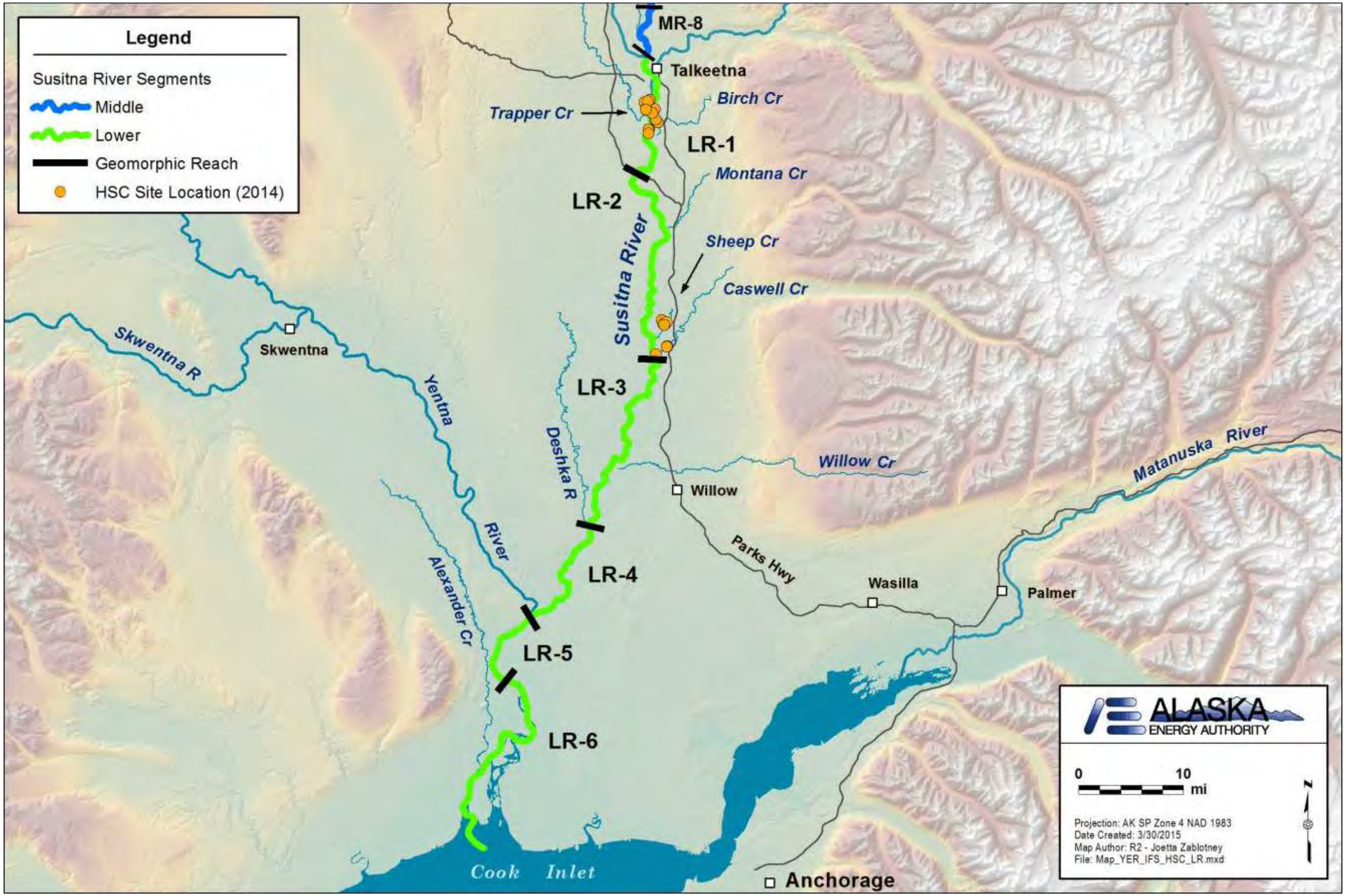

Figure 4.2-2. Map showing 2014 HSC sampling locations (orange dots) in relationship to geomorphic reaches and tributary complexes in the Lower River Segment of the Susitna River, Alaska.

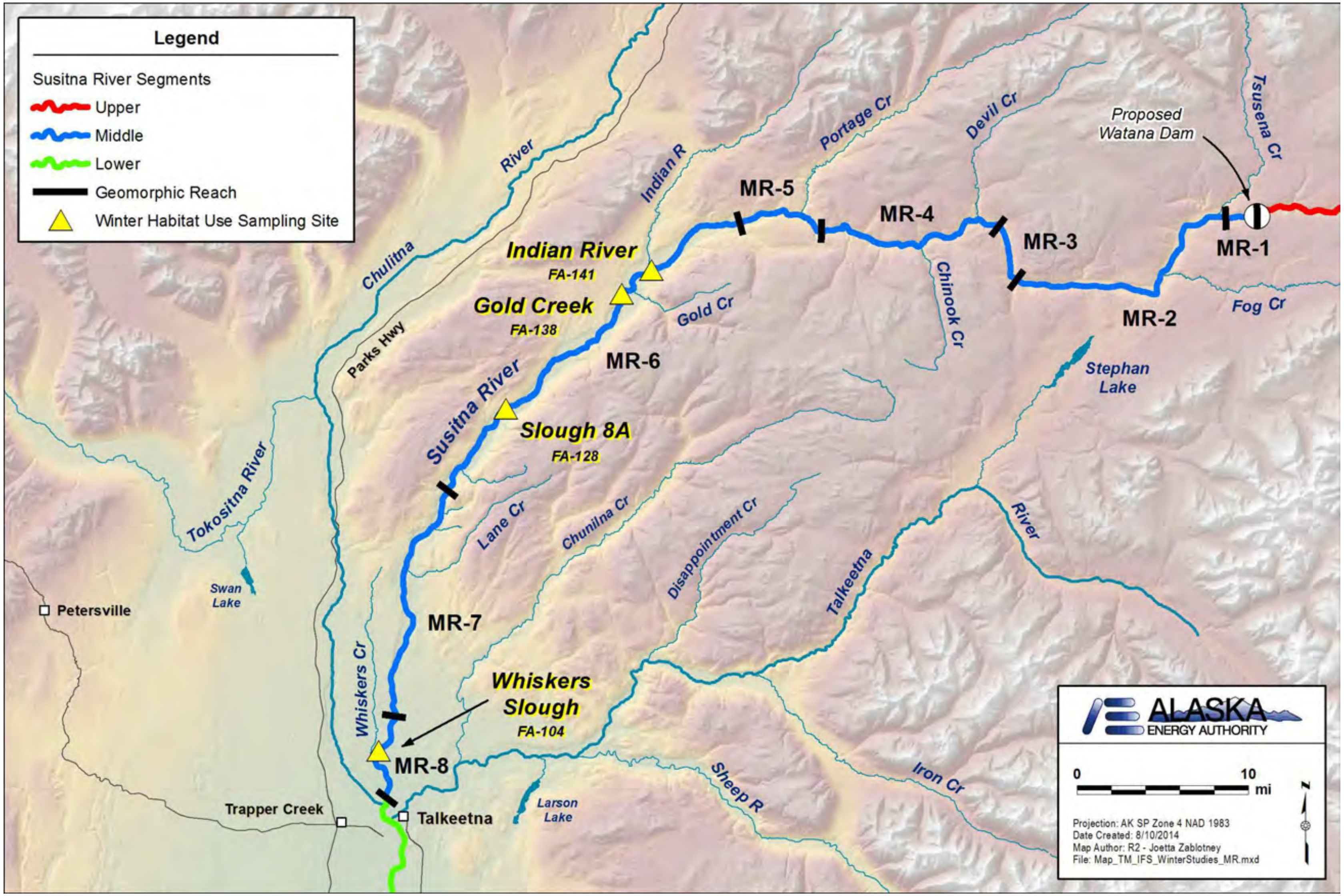

Figure 4.2-3. Location of Focus Areas sampled during winter HSC surveys.

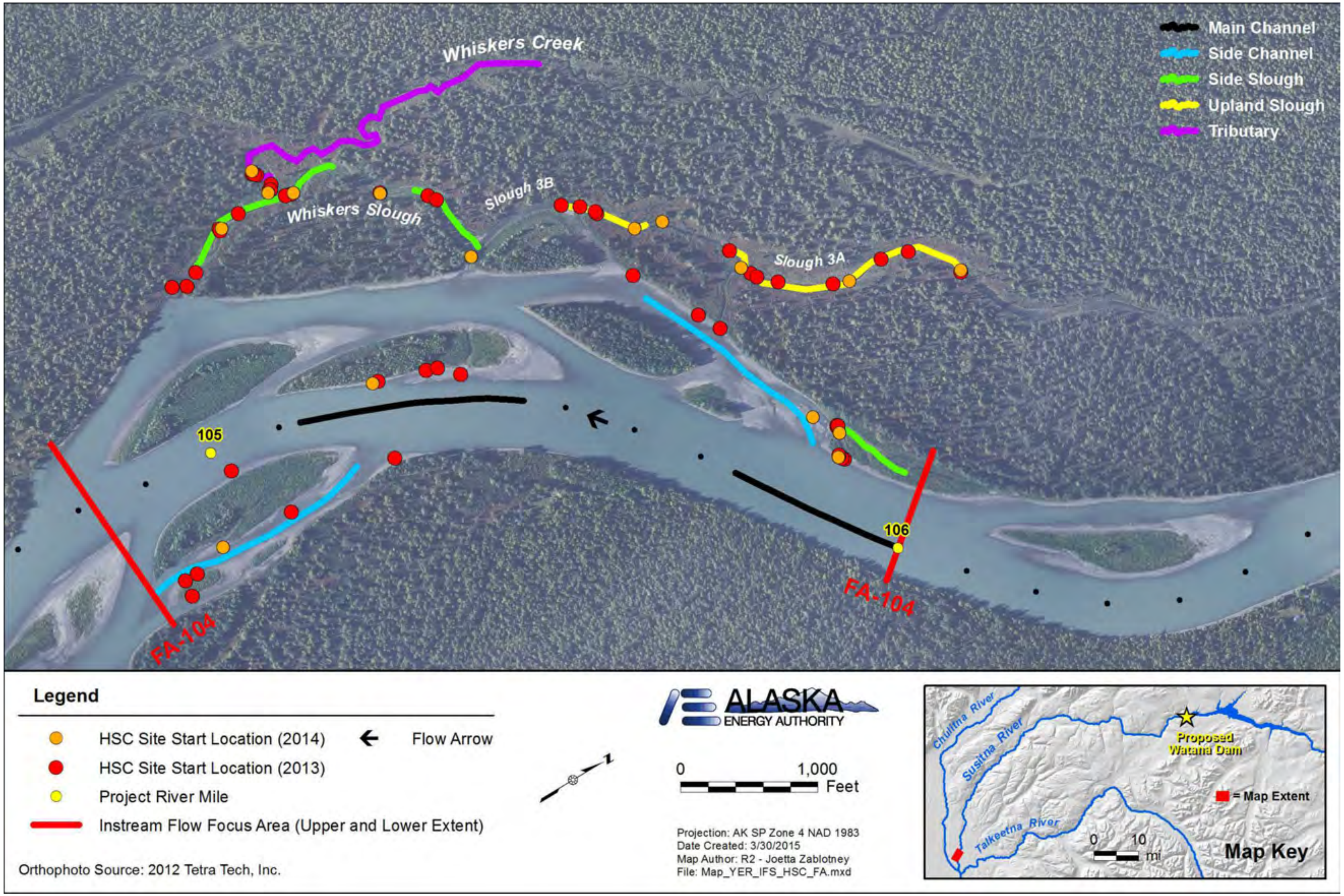

Figure 5.2-1. Map displaying FA-104 (Whiskers Slough) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

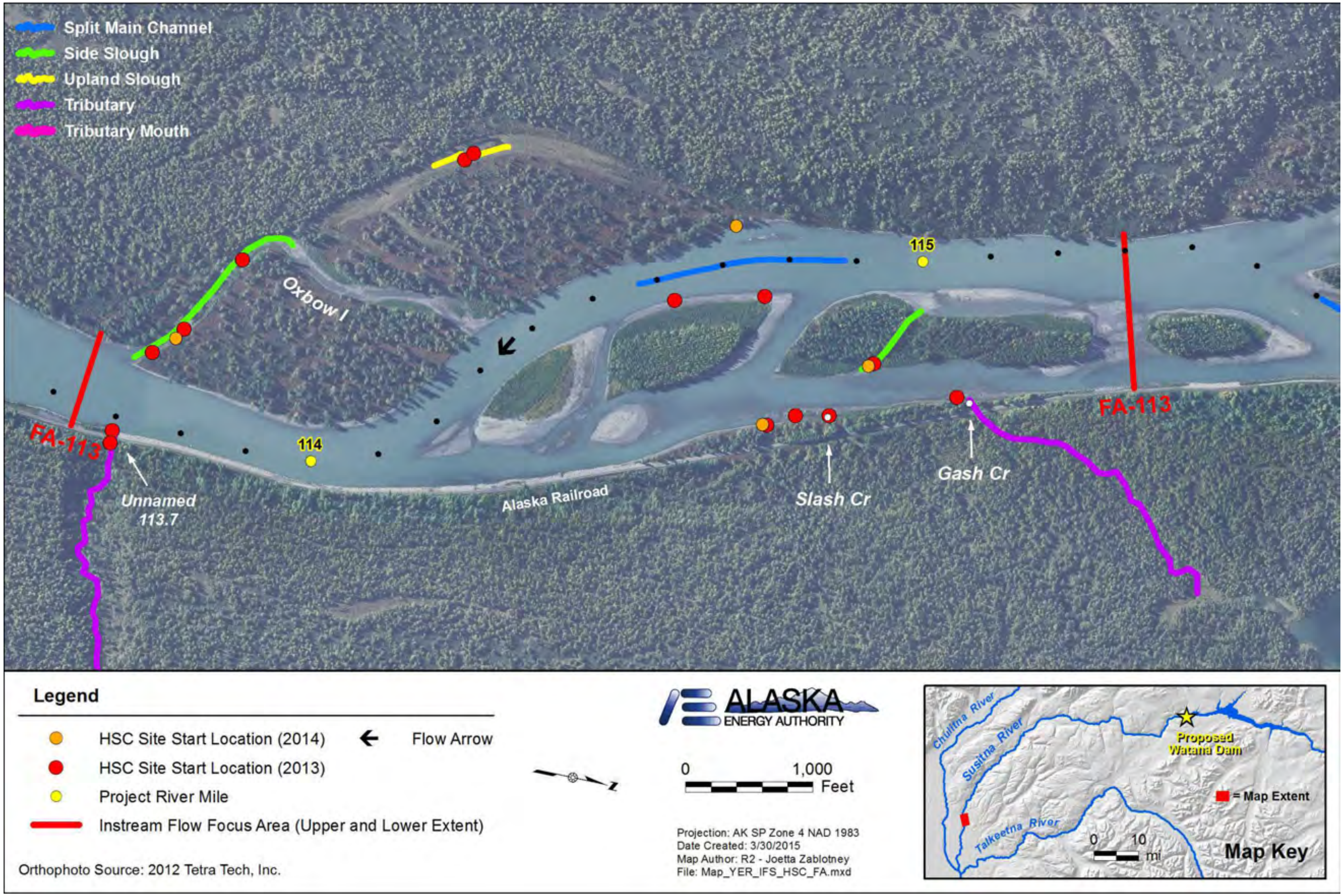

Figure 5.2-2. Map displaying FA-113 (Oxbow I) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

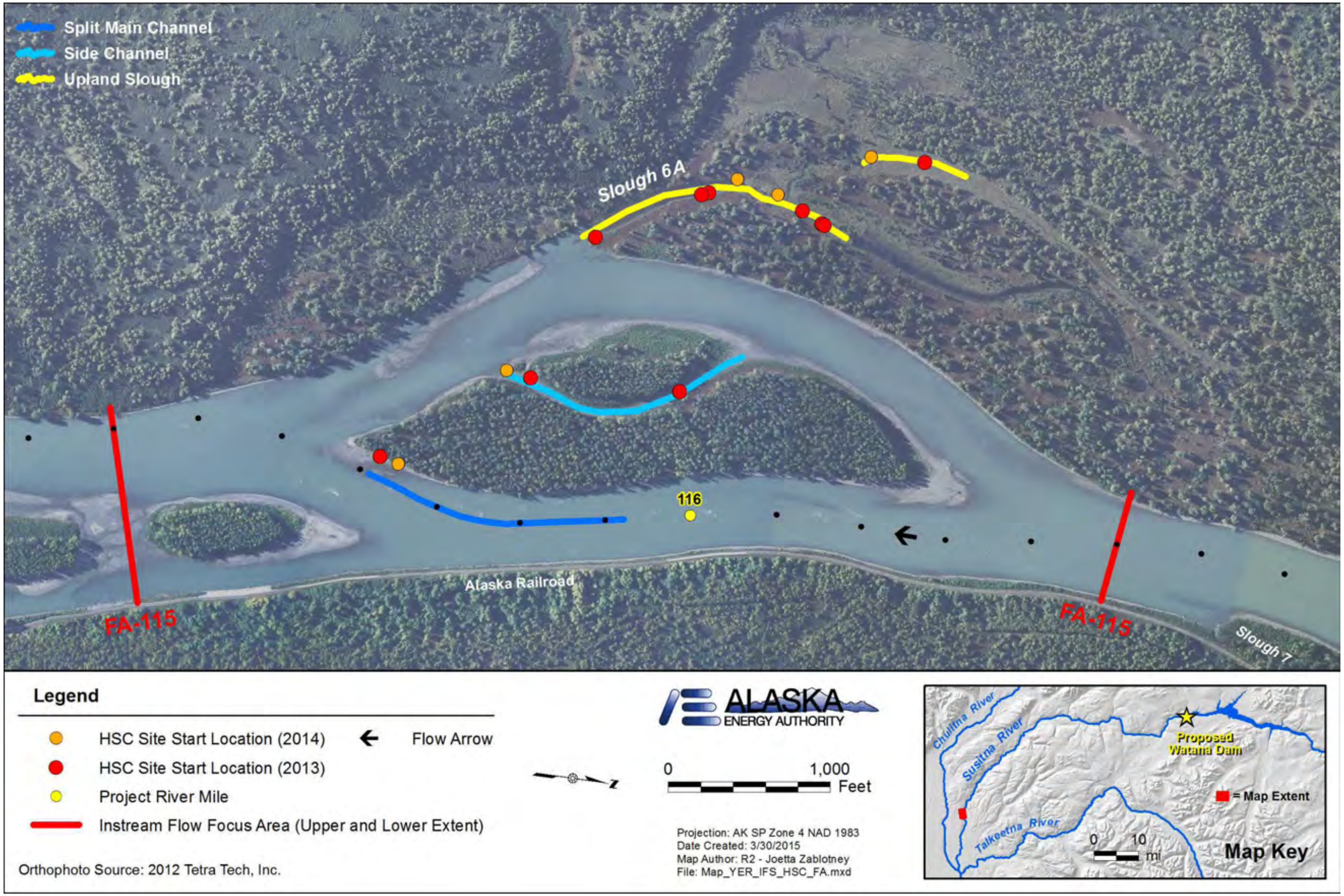

Figure 5.2-3. Map displaying g FA-115 (Lane Creek) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

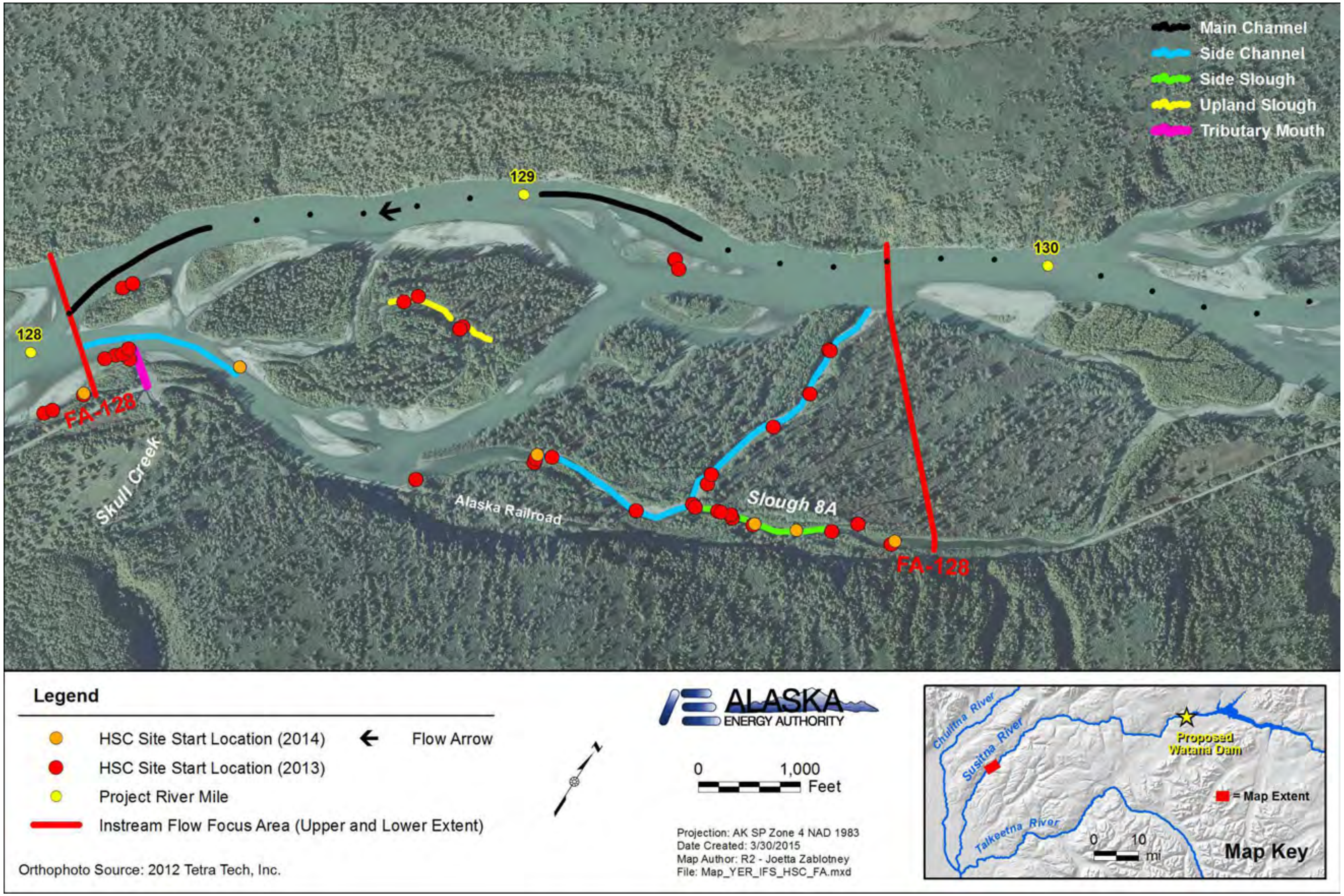

Figure 5.2-4. Map displaying g FA-128 (Skull Creek) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

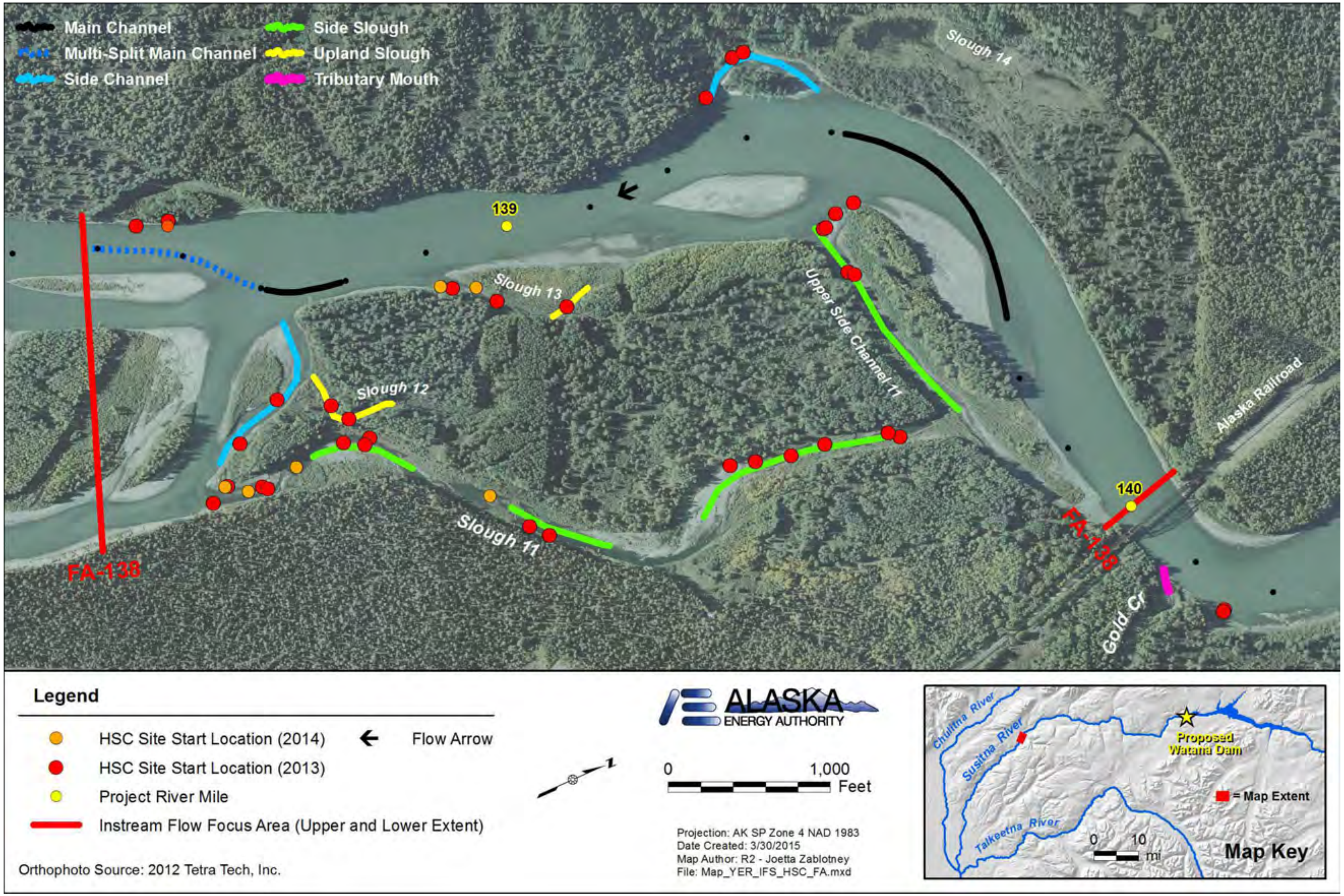

Figure 5.2-5. Map displaying g FA-138 (Gold Creek) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

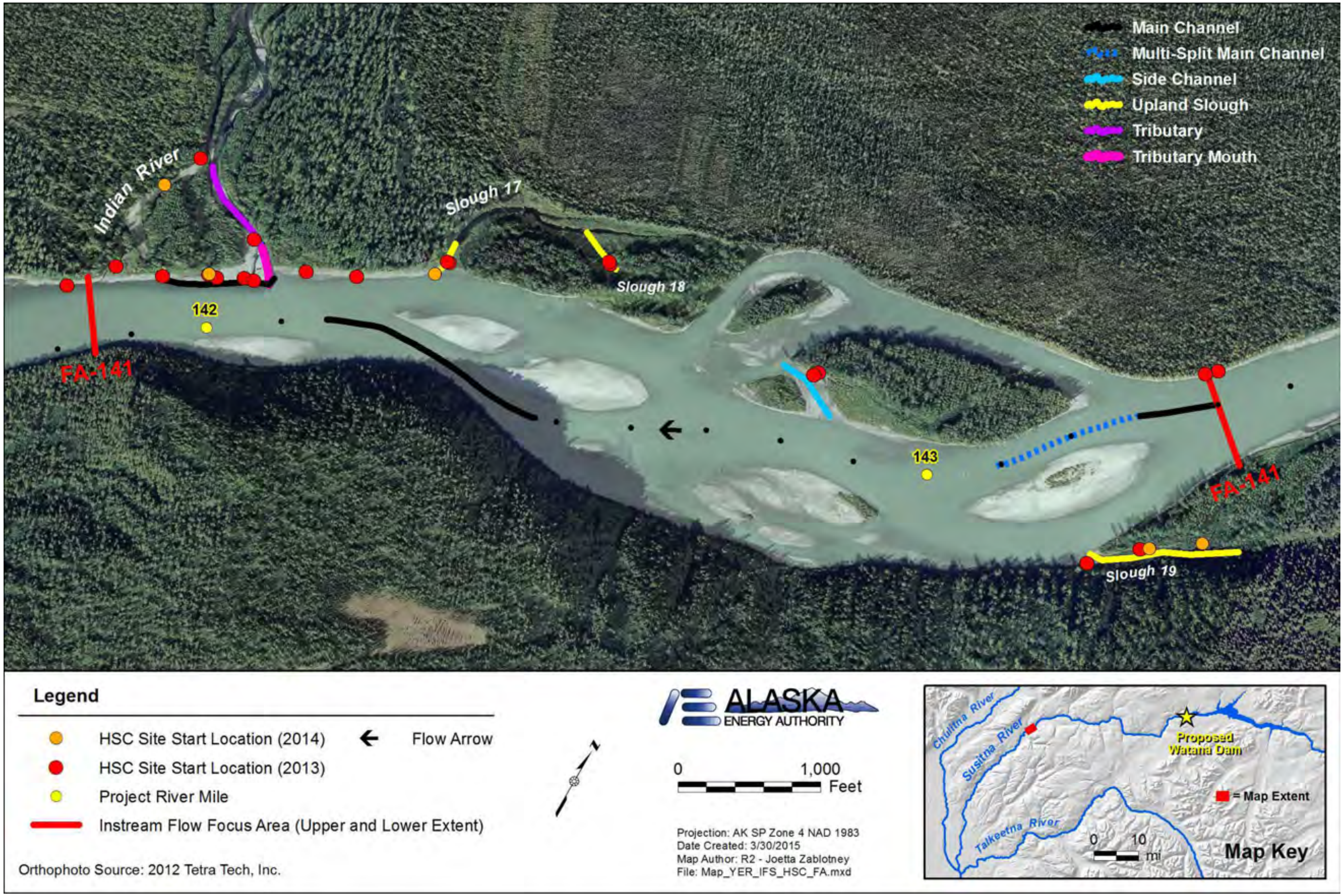

Figure 5.2-6. Map displaying g FA-141 (Indian River) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

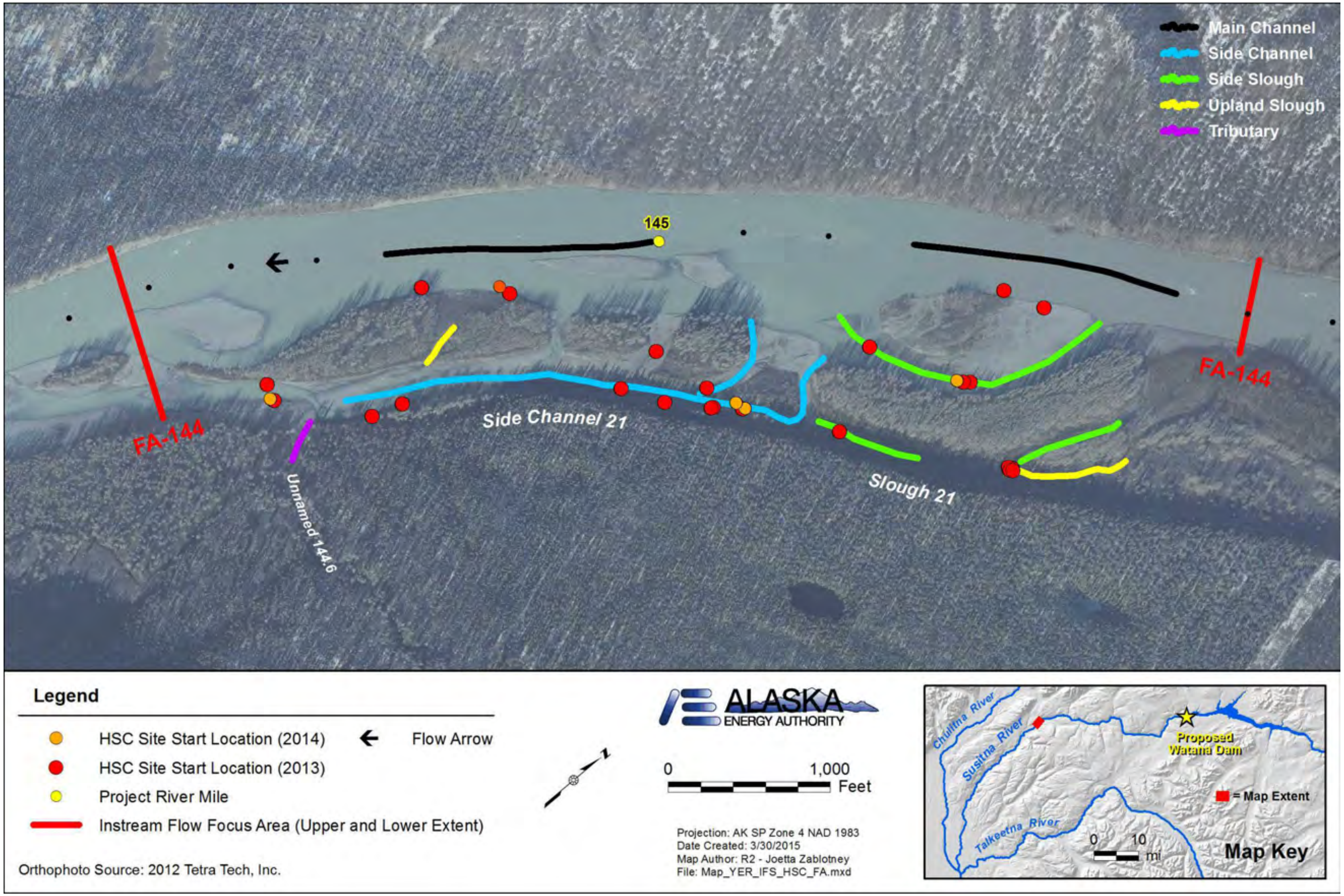

Figure 5.2-7. Map displaying g FA-144 (Side Channel 21) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

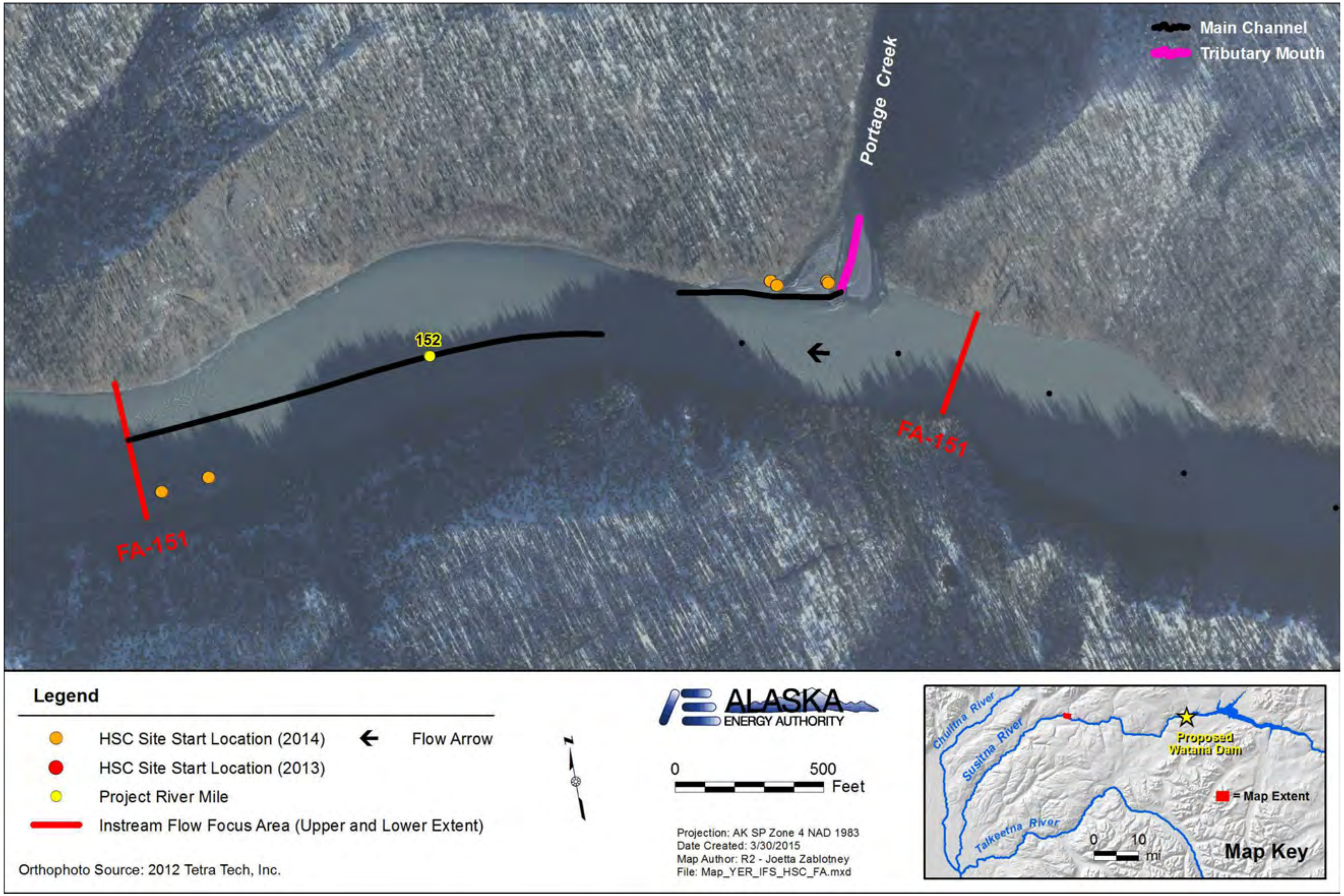

Figure 5.2-8. Map displaying FA-151 (Portage Creek) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

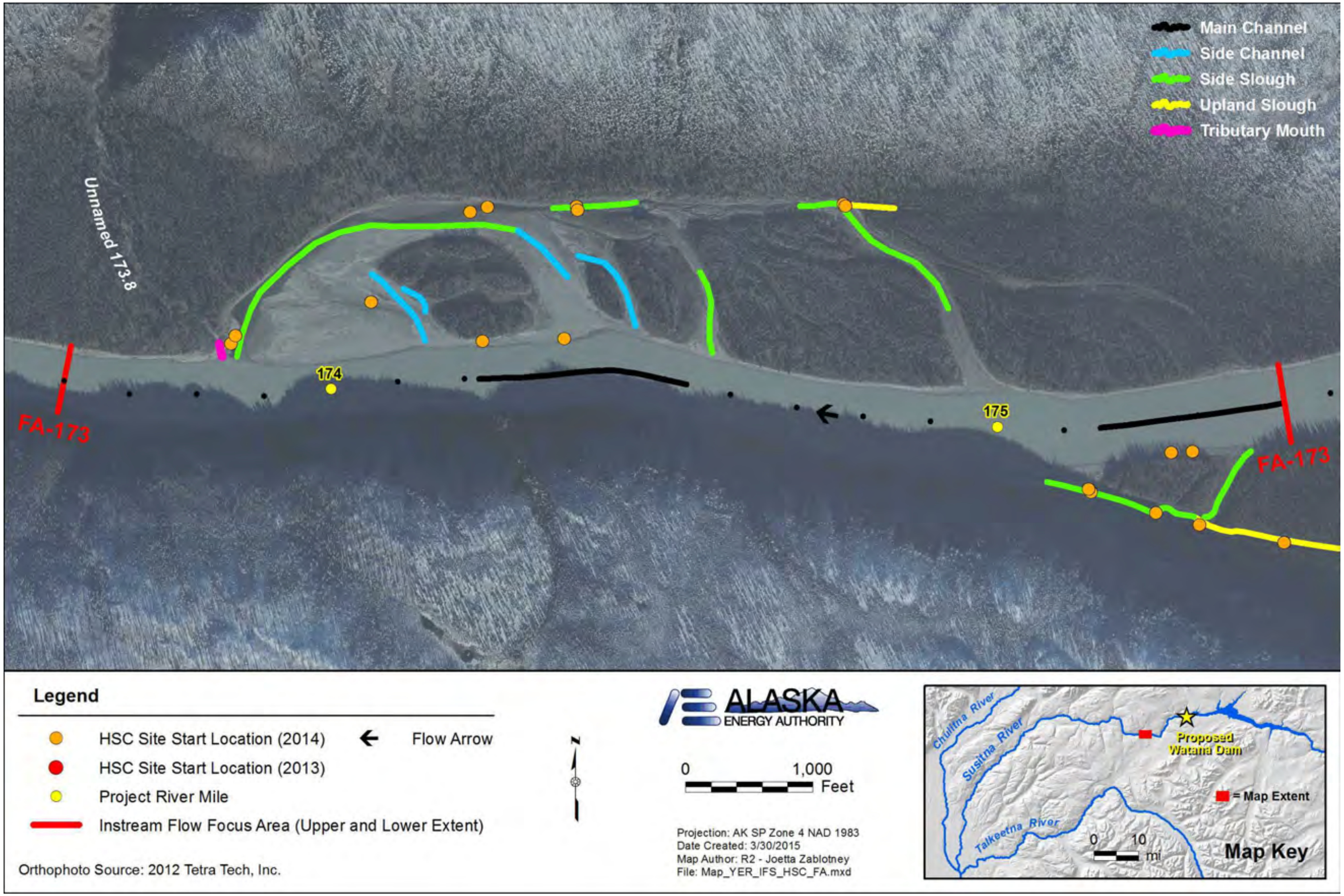

Figure 5.2-9. Map displaying FA-173 (Stephan Lake) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

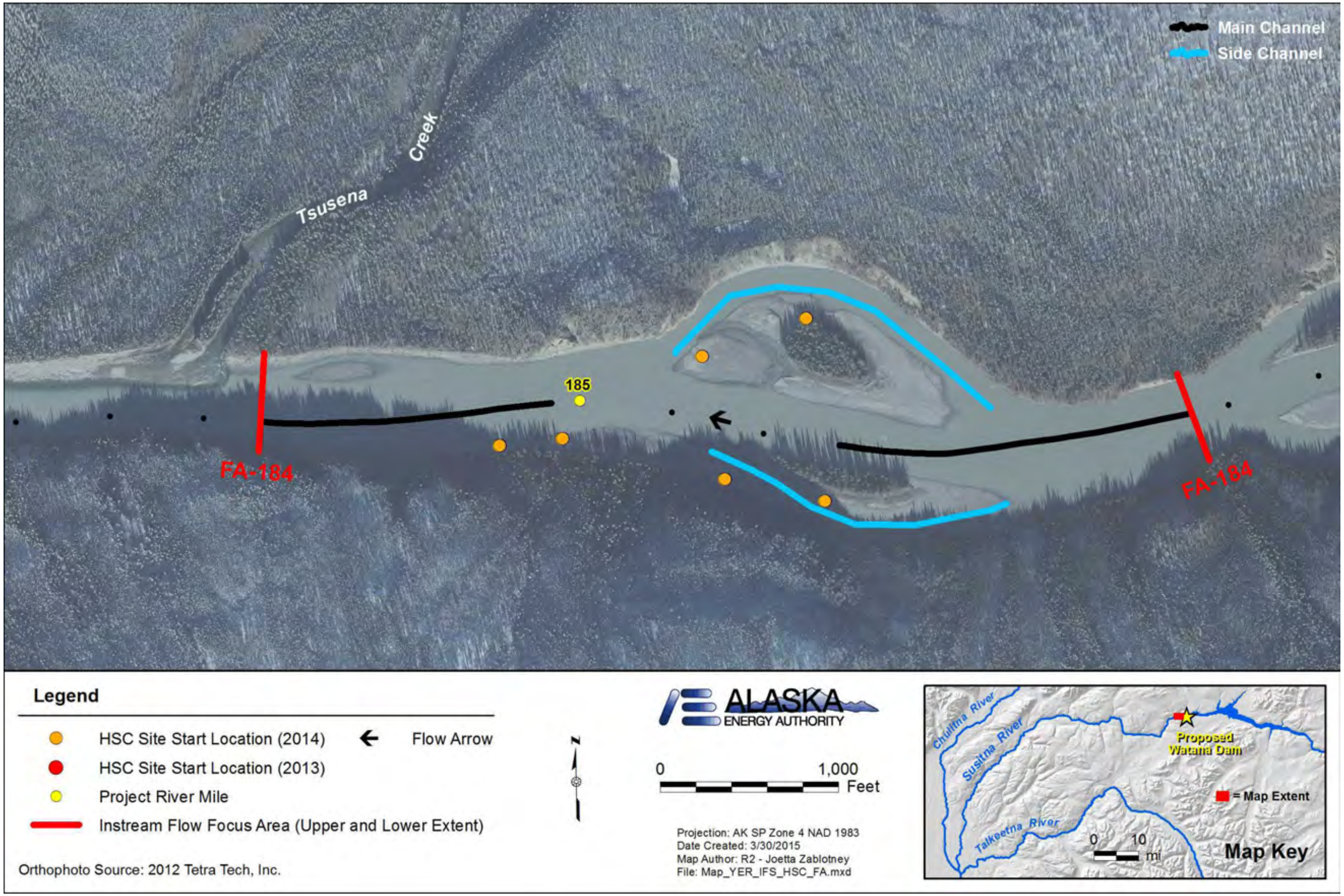

Figure 5.2-10. Map displaying FA-184 (Watana Dam) with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Middle River Segment of the Susitna River, Alaska.

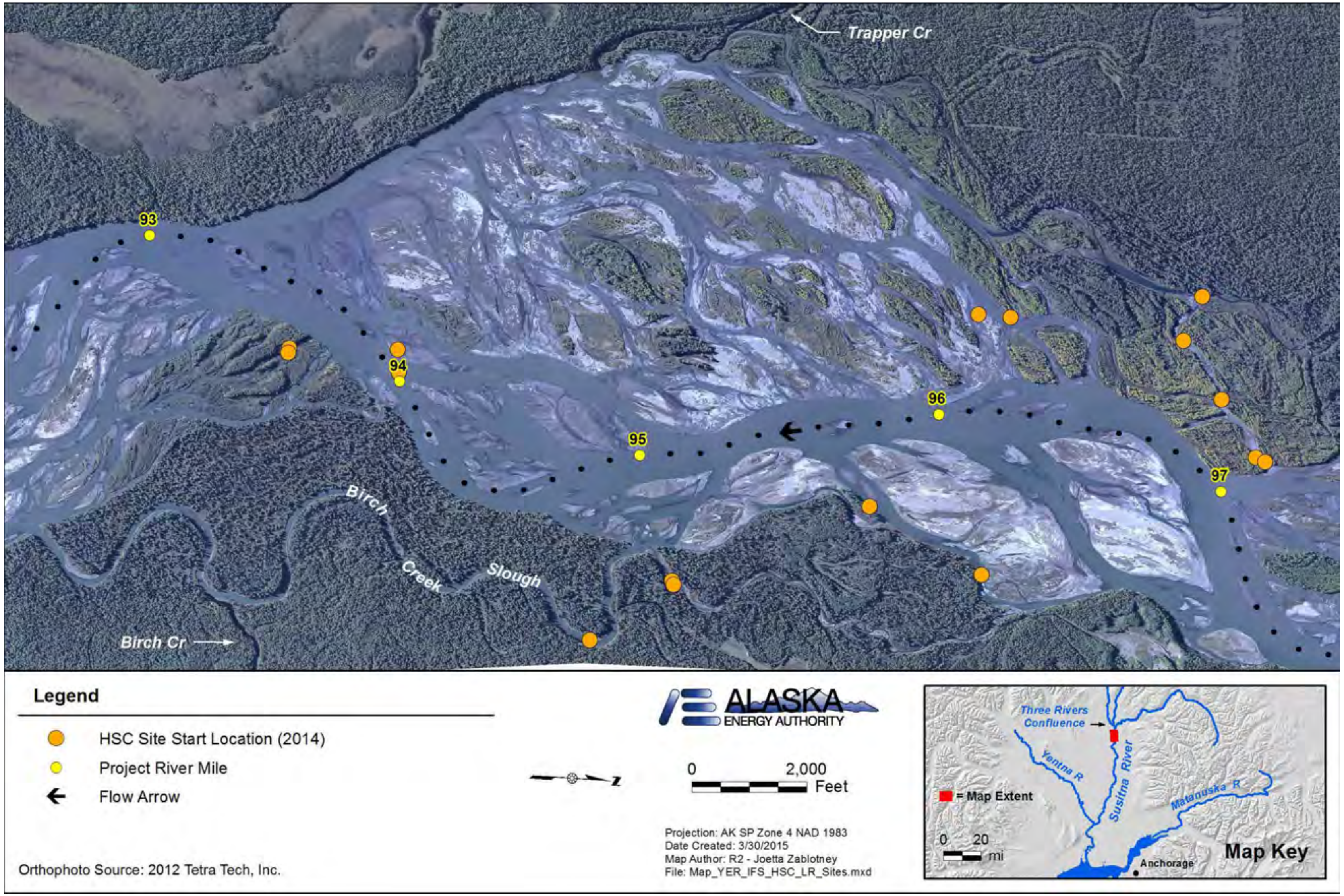

Figure 5.2-11. Map displaying location of Trapper/Birch Creek complex with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Lower River Segment of the Susitna River, Alaska.

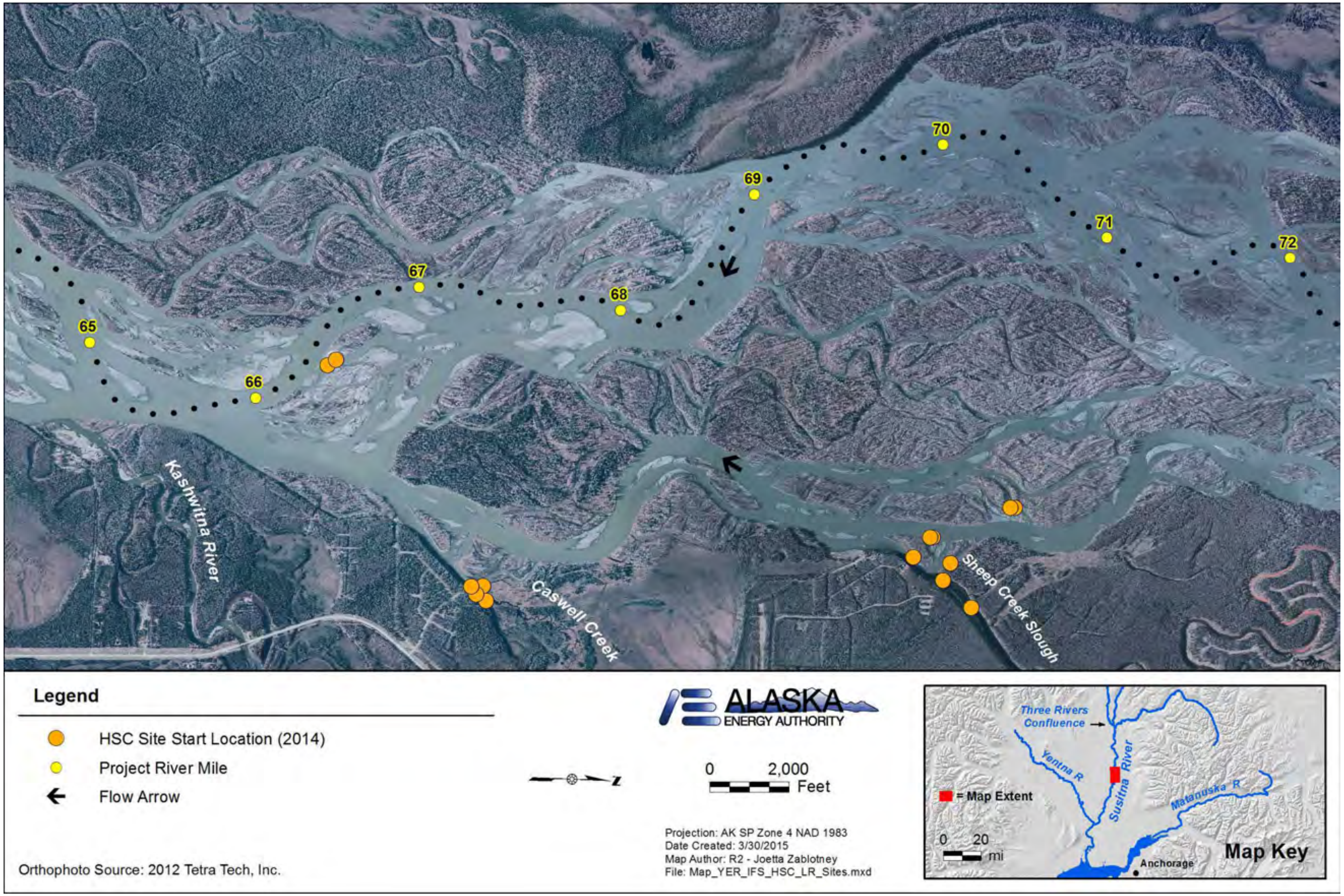

Figure 5.2-12. Map displaying location of Sheep/Caswell Creek complex with randomly selected habitat segments and the location of each 2014 HSC sampling event (orange dots) within the Lower River Segment of the Susitna River, Alaska.

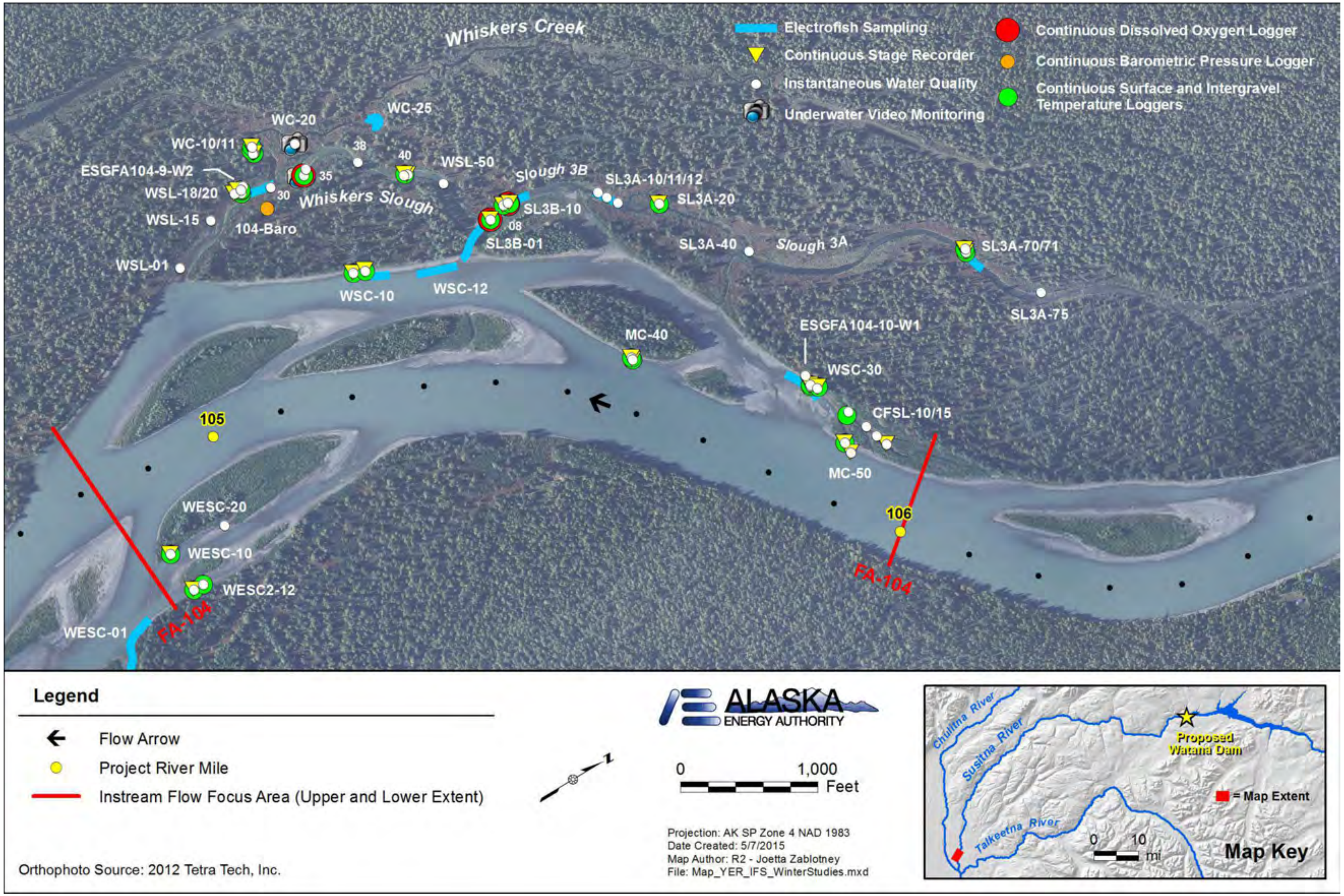

Figure 5.2-13. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-104 (Whiskers Slough) during the winter seasons of 2012-2013, 2013-2014 and 2014-2015.

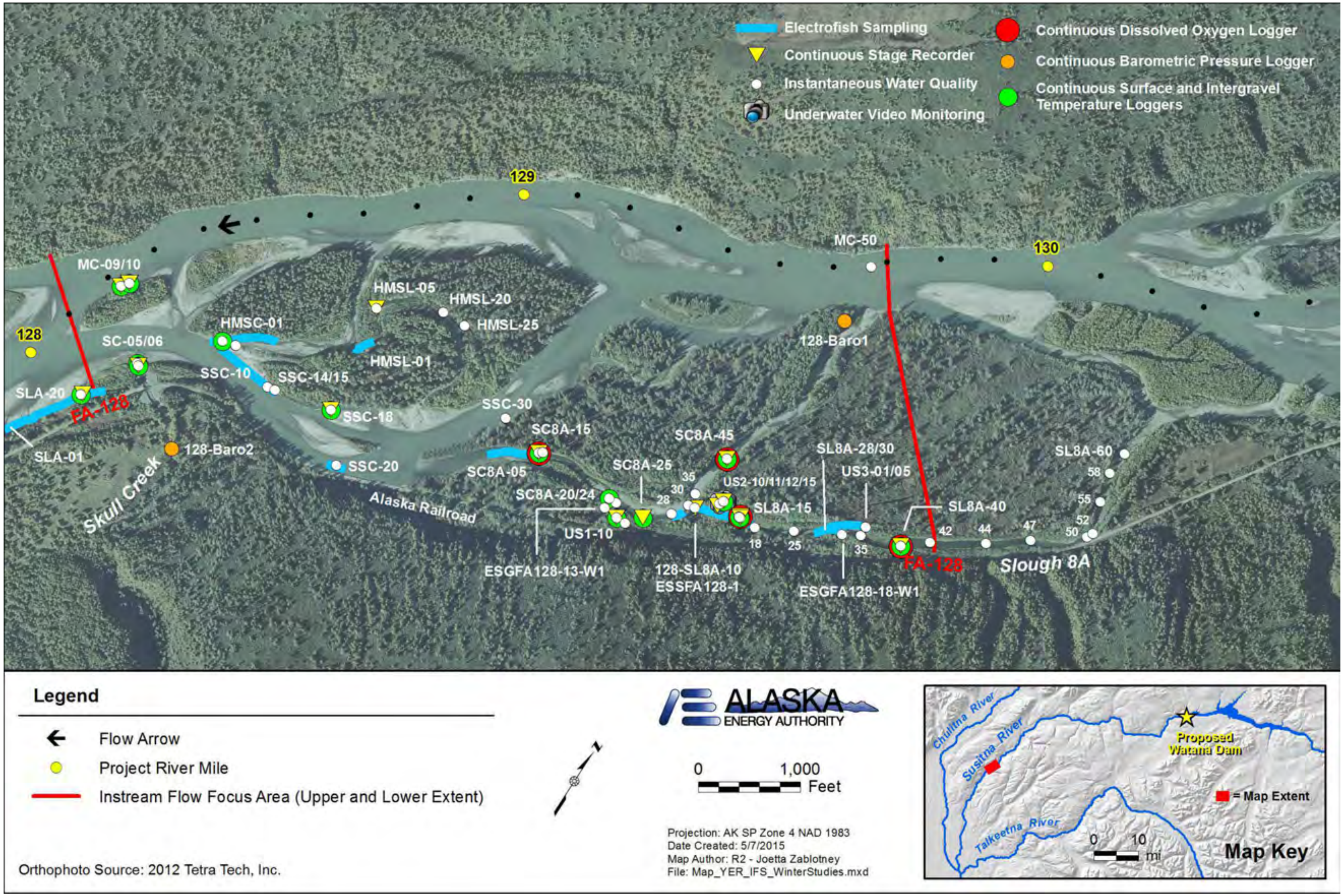

Figure 5.2-14. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-128 (Slough 8A) during the winter seasons of 2012-2013, 2013-2014 and 2014-2015.

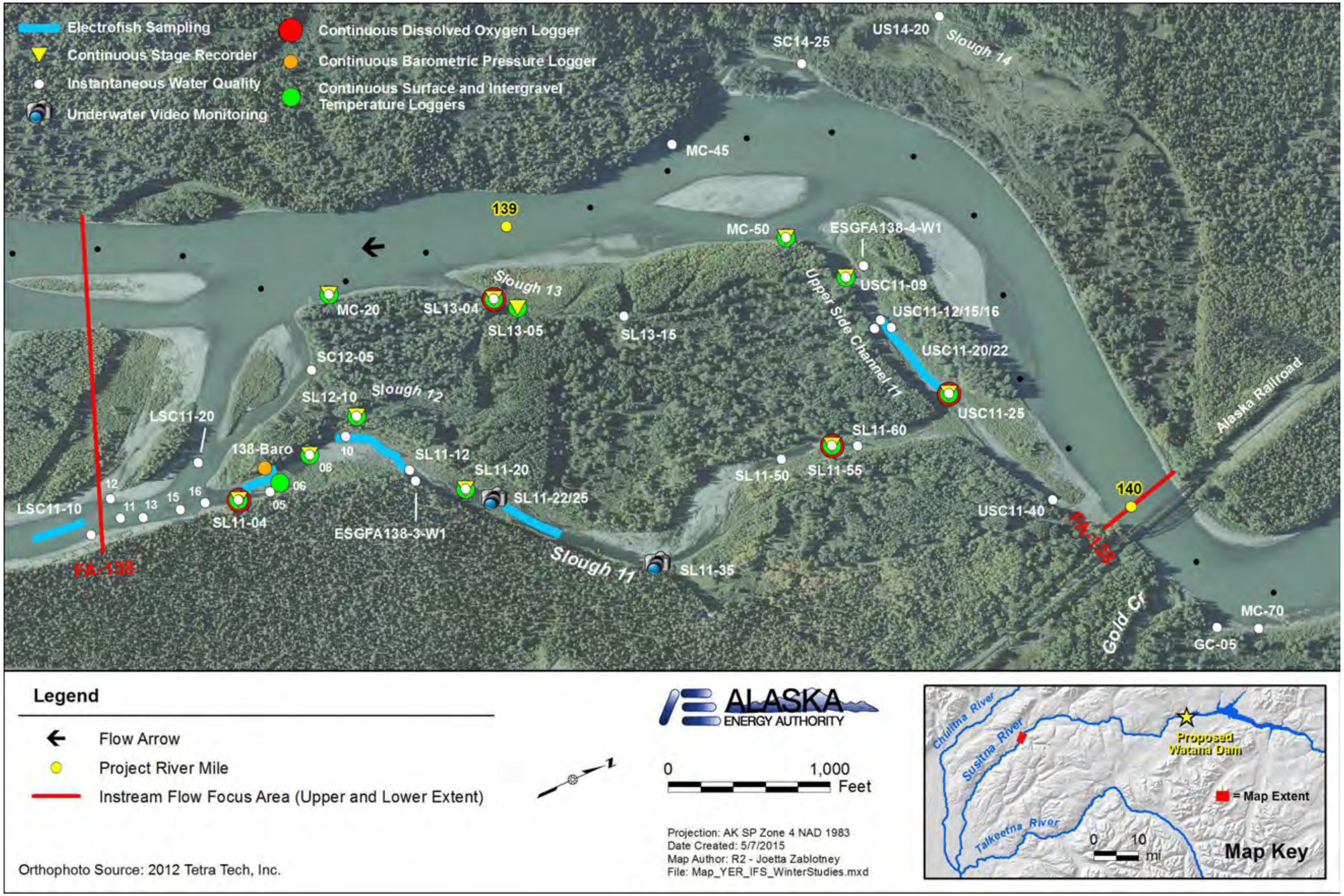

Figure 5.2-15. Locations of IFS winter studies sites used for continuous and instantaneous water quality monitoring, water level monitoring, and fish sampling in FA-138 (Gold Creek) during the winter seasons of 2013-2014 and 2014-2015.

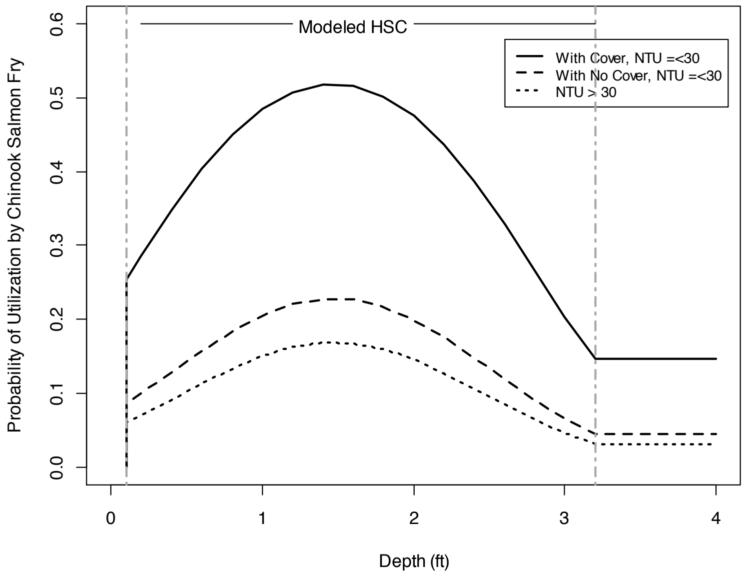

Figure 5.6-1. HSC model for Chinook salmon fry as a function of depth for fixed velocity of 0.2 fps for three different substrate/turbidity groups.

Note: Estimated preference for depth < 0.05 feet is zero, and estimated preference for depths > 3.3 feet (last observed fish) is non-limiting (i.e., fixed at the highest modeled value).

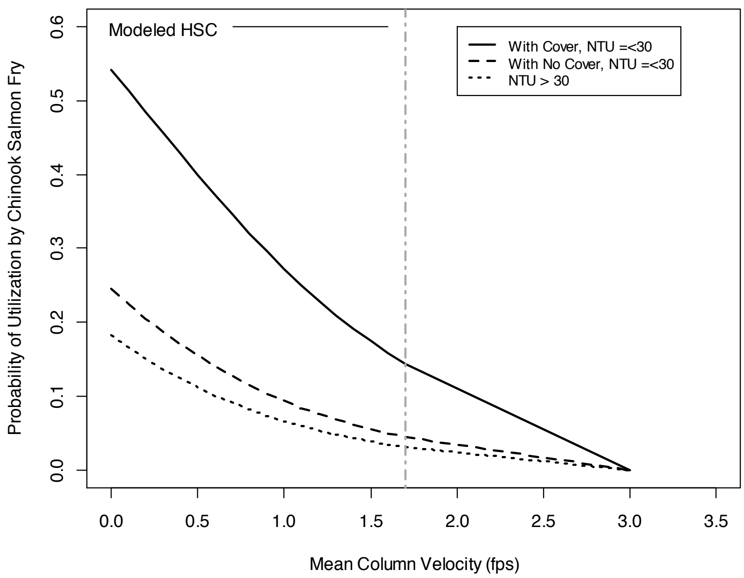

Figure 5.6-2. HSC model for Chinook Salmon Fry as a function of velocity for fixed depth of 1 foot for three different substrate/turbidity groups.

Note: Estimated preference for velocity > 1.7 fps (last observed fish) is based on linear decline to 0 probability at threshold value of 3 fps.

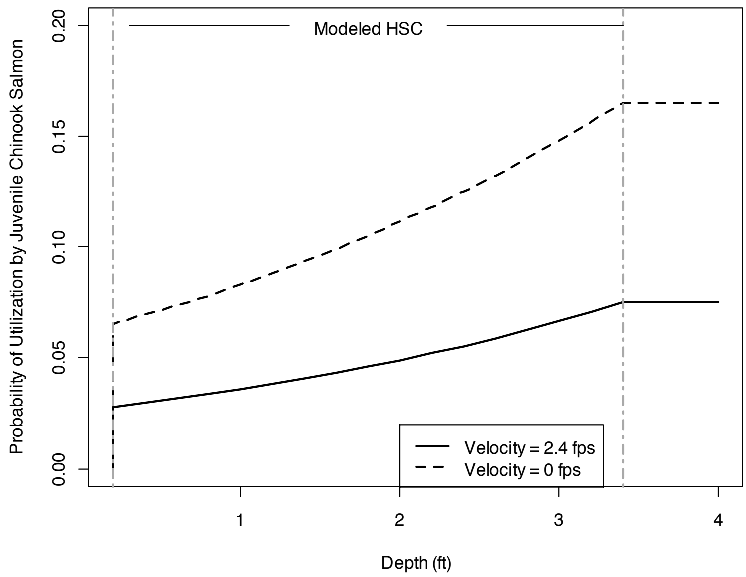

Figure 5.6-3. HSC model for juvenile Chinook salmon as a function of depth for two mean column velocities.

Note: Estimated preference for depth < 0.2 feet is zero, and estimated preference for depths > 3.4 feet (last observed fish utilized in the model) is non-limiting (i.e., fixed at the highest modeled value).

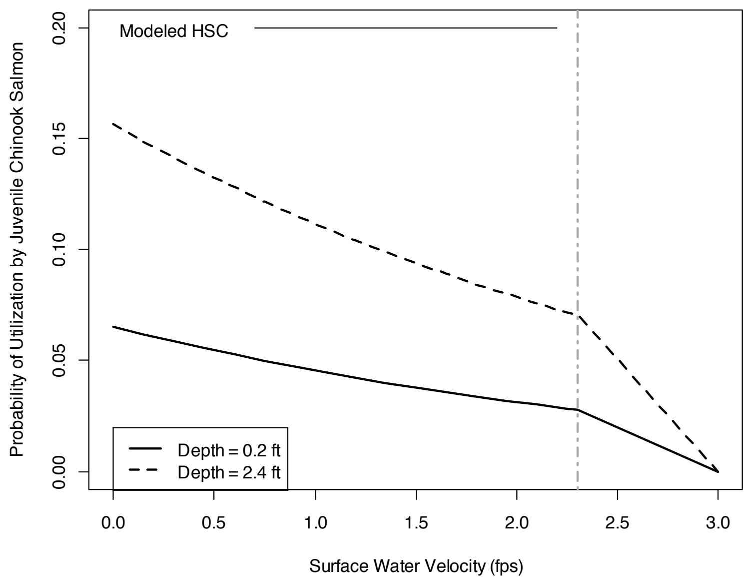

Figure 5.6-4. HSC model for juvenile Chinook salmon as a function of velocity for two depths.

Note: Estimated preference for velocity > 2.3 fps (last observed fish) is based on linear decline to 0 probability at threshold value of 3 fps.

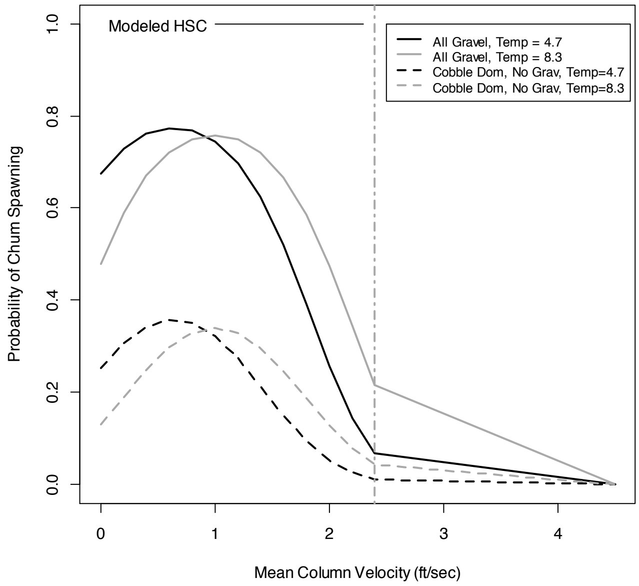

Figure 5.6-5. Chum spawning HSC as a function of velocity for two substrate types and surface water temperatures, with depth fixed at 1.2 feet.

Note: Estimated preference for velocity > 2.4 fps is based on linear decline to 0 probability at threshold value of 4.5 fps.

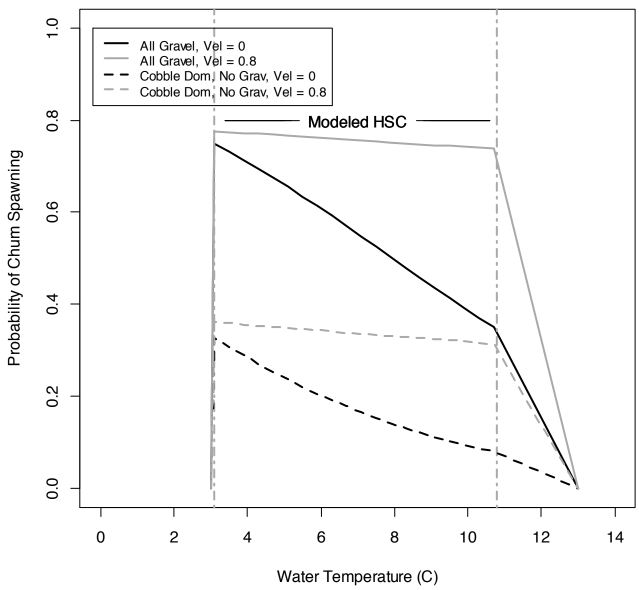

Figure 5.6-6. Chum spawning HSC as a function of surface water temperature for two substrate types and velocities, with depth fixed at 1.2 feet.

Note: Estimated preference for temperatures less than 3.1 and greater than 9.3 are based on linear decline to 0 probability at threshold values of 3 and 13 degrees C, respectively.

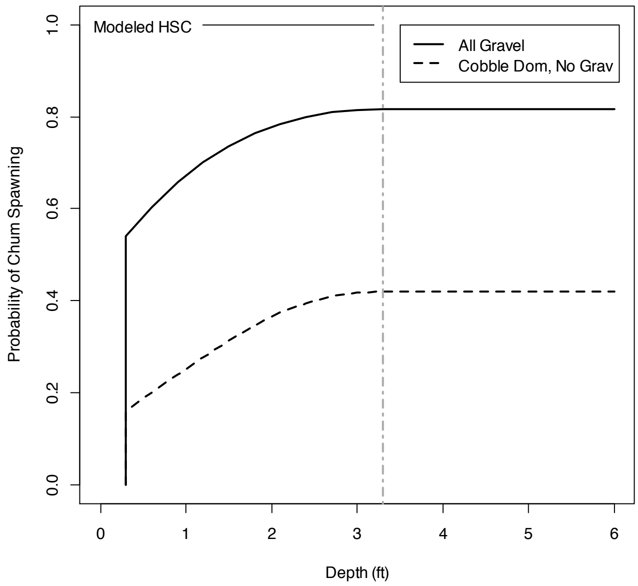

Figure 5.6-7. Chum spawning HSC as a function of depth for two substrate types, with velocity fixed at 0.2 fps, and water temperature fixed at 5.5 degrees C.

Note: Estimated preference for depth < 0.3 feet is zero, and estimated preference for depth > 3.3 feet is non-limiting (i.e., fixed at the highest modeled value).

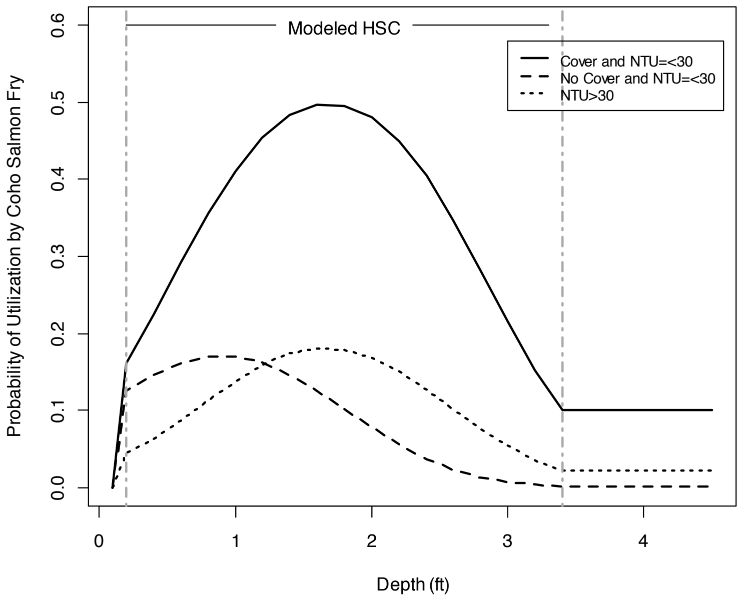

Figure 5.6-8. HSC model for coho salmon fry as a function of depth for fixed velocity of 0.4 fps for three different substrate/turbidity groups.

Note: Estimated preference for depth < 0.2 feet (first observed fish) is linear decreasing to the threshold of 0.05 feet, and estimated preference for depths > 3.4 feet (last observed fish) is non-limiting (i.e., fixed at the highest modeled value).

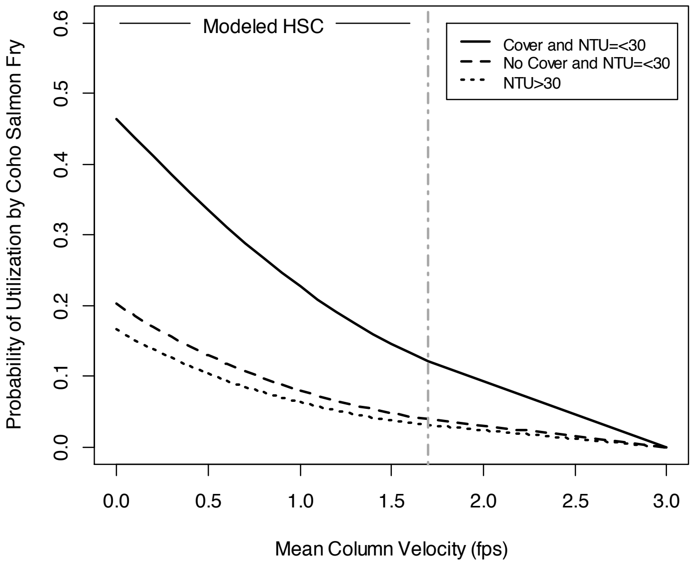

Figure 5.6-9. HSC model for coho salmon fry as a function of velocity for fixed depth of 1 foot for three different substrate/turbidity groups.

Note: Estimated preference for velocity > 1.7 fps (last observed fish) is based on linear decline to 0 probability at threshold value of 3 fps.

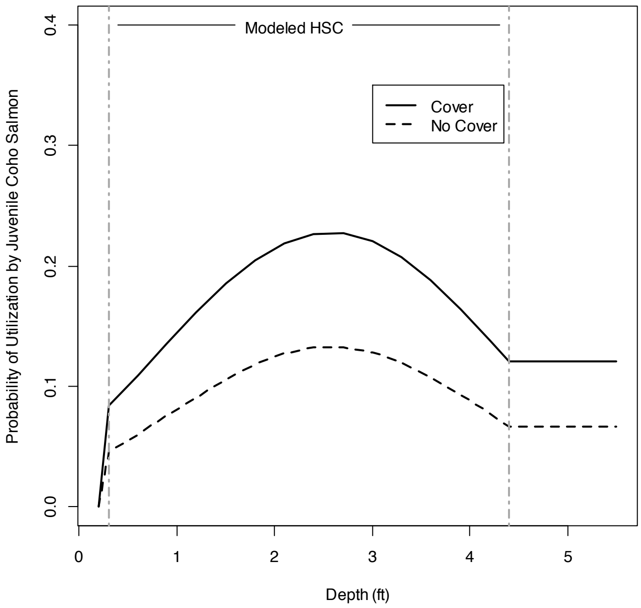

Figure 5.6-10. Coho salmon juvenile HSC as a function of depth with and without non-boulder cover.

Note: Estimated preference for depths outside observed range of utilization is set based on theoretical thresholds (depth < 0.3 feet: linear decrease to 0 suitability at 0.2 ft; depth > 4.4 feet: non-limiting - fixed at the highest modeled value).

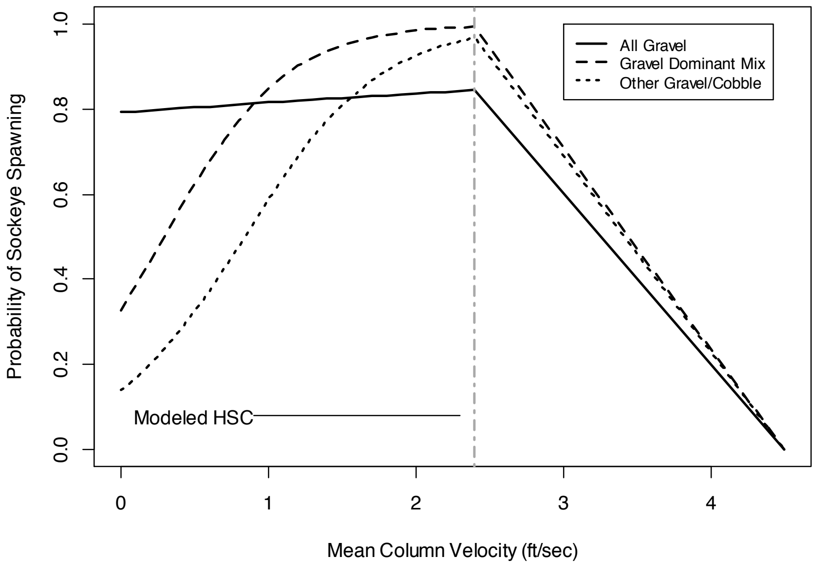

Figure 5.6-11. Sockeye salmon spawning preference as a function of velocity at a constant water temperature of 6.1 degrees C for three substrate categories.

Note: Estimated preference for velocity > 2.4 fps is based on linear decline to 0 probability at threshold value of 4.5 fps.

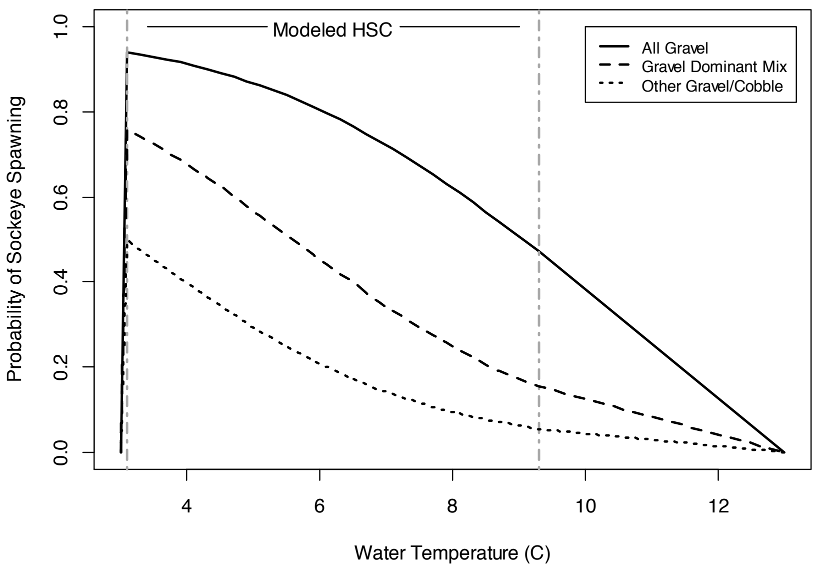

Figure 5.6-12. Sockeye salmon spawning preference as a function of surface water temperature at a constant mean column velocity of 0.2 fps for three substrate categories.

Note: Estimated preference for temperatures less than 3.1 degrees C and greater than 9.3 degrees C are based on linear decline to 0 probability at threshold values of 3 and 13 degrees C, respectively.

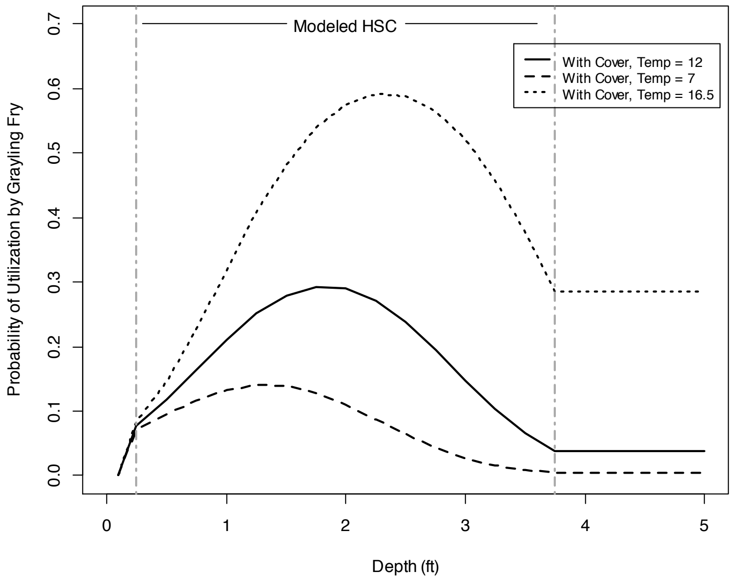

Figure 5.6-13. HSC model for Arctic grayling fry as a function of depth in the presence of cover, for fixed velocity of 0.2 fps for three water temperatures.

Note: Estimated preference for depth < 0.25 feet (first observed fish) is linear decreasing to the threshold of 0.05 feet, and estimated preference for depth > 3.75 feet (last observed fish) is non-limiting (i.e., fixed at the highest modeled value).

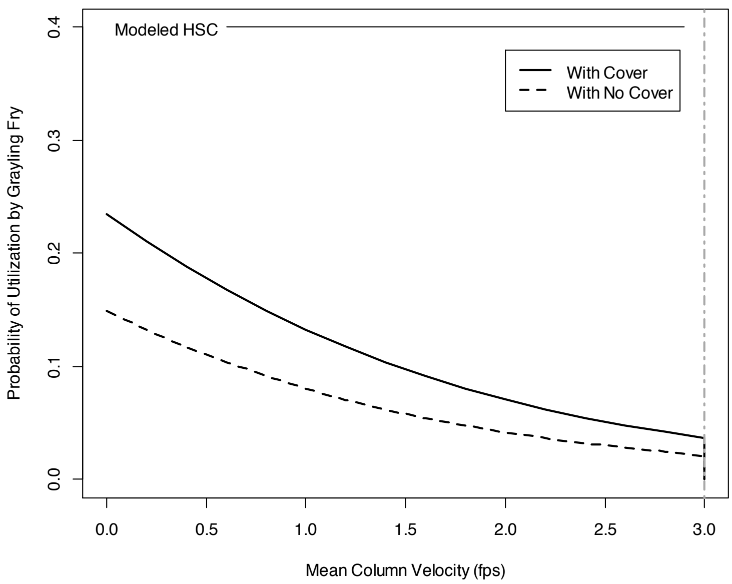

Figure 5.6-14. HSC model for Arctic grayling fry as a function of velocity for fixed depth of 1 foot, and fixed temperature of 12 degrees C, with and without cover.

Note: Estimated preference for velocity > 3 fps (last observed fish) is 0.

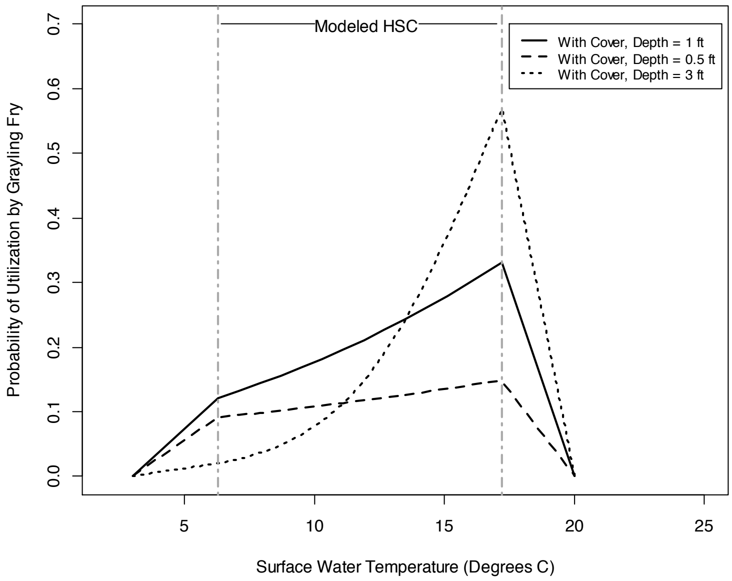

Figure 5.6-15. HSC model for Arctic grayling fry as a function of temperature in the presence of cover, for fixed velocity of 0.2 fps for three depths.

Note: Estimated preference for temperature < 6.3 degrees C (first observed fish) is linear decreasing to 0 at the threshold of 3 degrees C, and estimated preference for temperatures > 17.2 degrees C (last observed fish) is linear decreasing to 0 at the threshold of 20 degrees C.

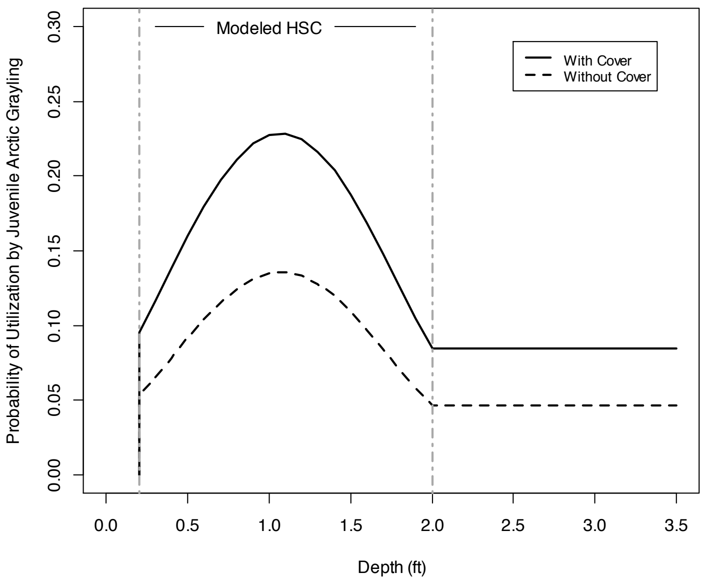

Figure 5.6-16. HSC model for Arctic grayling juvenile as a function of depth in the presence of boulder, overhanging vegetation, or undercut bank cover, for fixed velocity of 0.2 fps for three water temperatures.

Note: Estimated preference for depth < 0.25 feet (first observed fish) is linear decreasing to the threshold of 0.2 feet, and estimated preference for depth > 3.75 feet (last observed fish) is non-limiting (i.e., fixed at the highest modeled value).

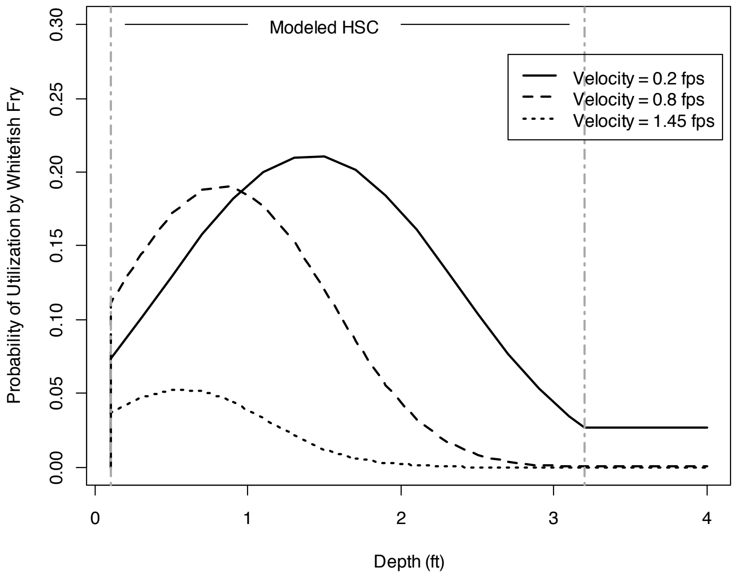

Figure 5.6-17. HSC model for whitefish fry as a function of depth, for fixed temperature of 10 degrees C, for three mean column velocities.

Note: Estimated preference for depth < 0.05 feet is 0, and estimated preference for depth > 3.2 feet (last observed fish) is non-limiting (i.e., fixed at the highest modeled value).

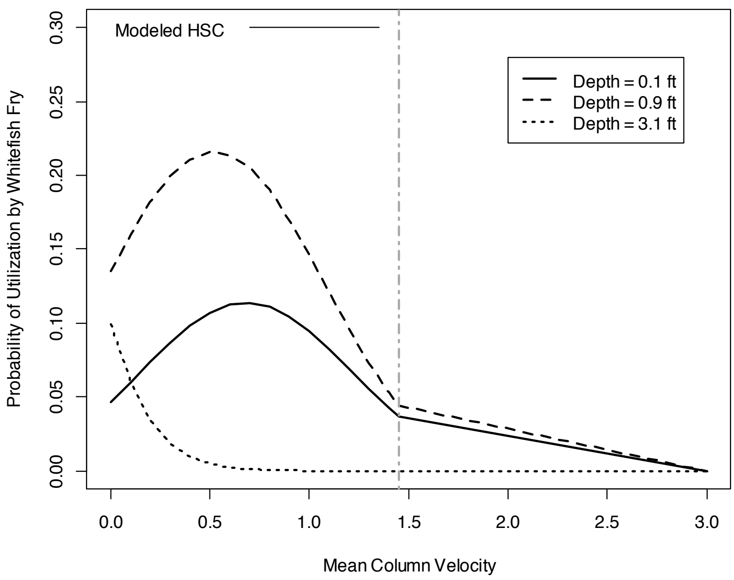

Figure 5.6-18. HSC model for whitefish fry as a function of velocity for fixed temperature of 10 degrees C, for three depths.

Notes: Estimated preference for velocity > 1.45 fps is a linear decrease to 0 at the threshold of 3 fps. Note that two utilization observations between 2.4 and 3 fps were not included in the model.

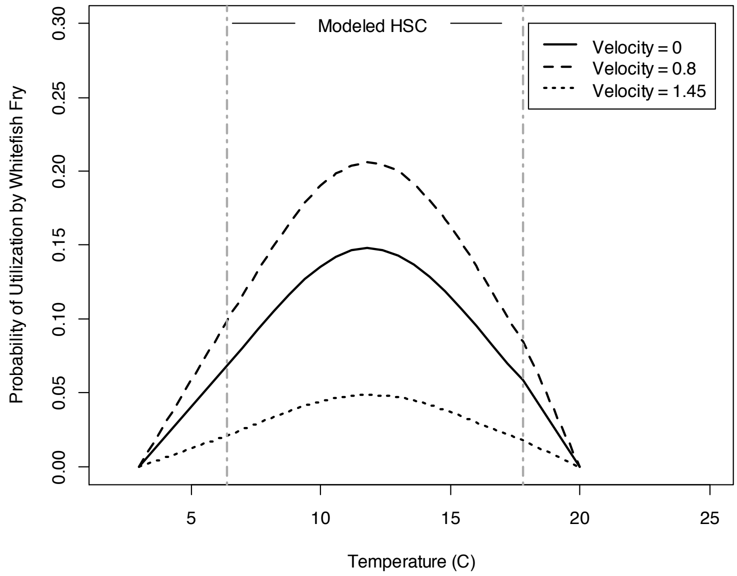

Figure 5.6-19. HSC model for whitefish fry as a function of temperature for fixed depth of 0.9 feet for three velocities.

Note: Estimated preference for temperature < 6.4 degrees C (first observed fish) is linear decreasing to 0 at the threshold of 3 degrees C, and estimated preference for temperatures > 17.8 degrees C (last observed fish) is linear decreasing to 0 at the threshold of 20 degrees C.

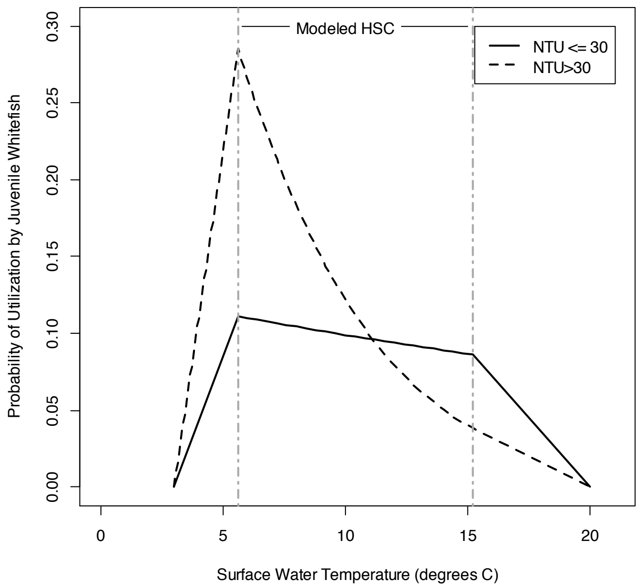

Figure 5.6-20. HSC model for juvenile whitefish as a function of temperature, for fixed velocity of 0.2 fps, for turbid and non-turbid sites.

Note: Estimated preference for temperature < 5.6 degrees C (first observed fish), and for temperatures > 15.2 degrees C (last observed fish) are assumed linear decreasing to 0 suitability at the temperature thresholds of 3 and 20 degrees C, respectively.

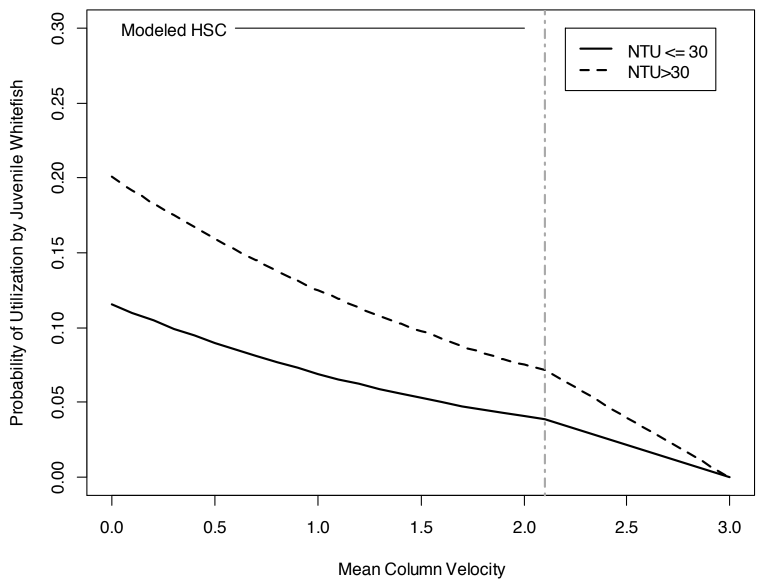

Figure 5.6-21. HSC model for juvenile whitefish as a function of velocity for fixed temperature of 8 degrees C, for turbid and non-turbid sites.

Note: Estimated preference for velocity > 2.1 fps is a linear decrease to 0 at the threshold of 3 fps. Note that one utilization observations at velocity of 2.9 fps was not used for the model estimation.

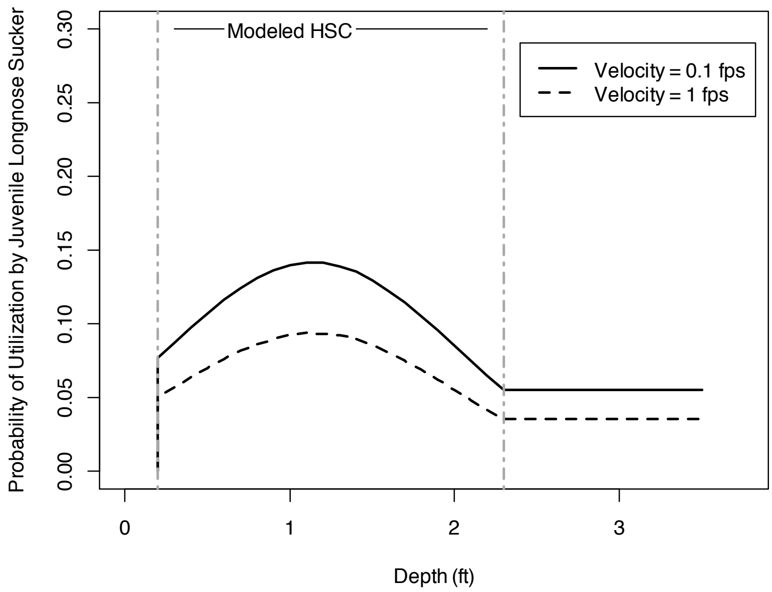

Figure 5.6-22. HSC model for juvenile longnose sucker as a function of depth, for two mean column velocities.

Note: Estimated preference for depth < 0.2 feet is 0, and estimated preference for depth > 2.3 feet is non-limiting (i.e., fixed at the highest modeled value). Note that three utilization observations at depths >= 3 feet are not included in this model.

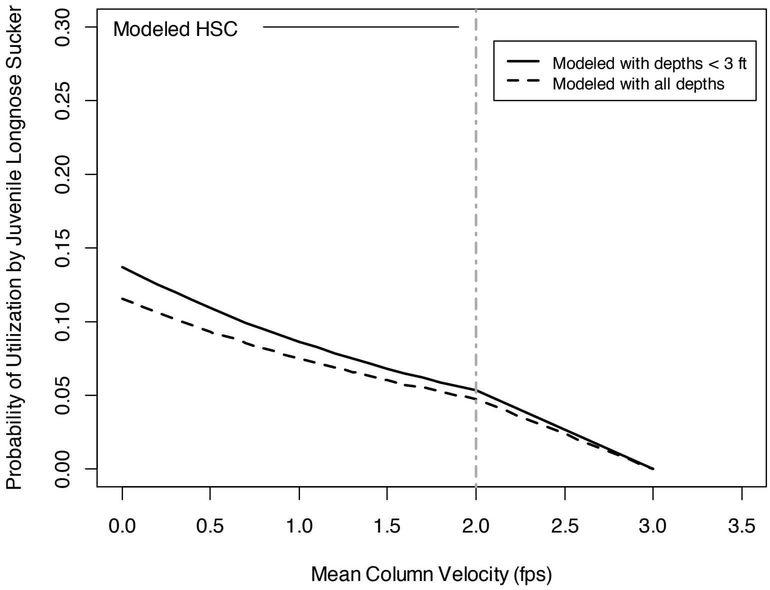

Figure 5.6-23. HSC model for juvenile longnose sucker as a function of velocity.

Note: The solid line is for the model fit on observations at depth < 3 feet, which includes depth as a covariate. The dashed line is fit for all data, with velocity as the only included variable. Estimated preference for velocity > 2 fps is a linear decrease to 0 at the threshold of 3 fps.

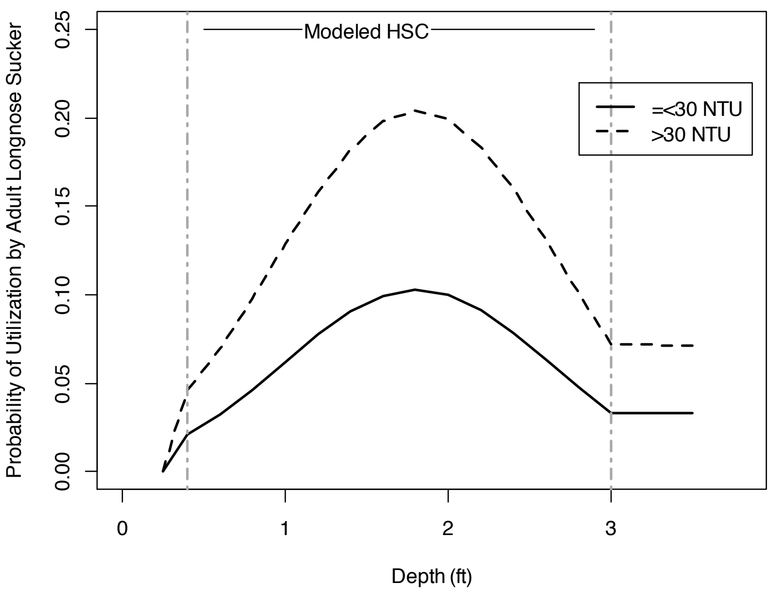

Figure 5.6-24. HSC model for adult longnose sucker as a function of depth, for fixed velocity of 0.4 fps, in turbid and non-turbid water.

Note: Estimated preference for depth < 0.4 feet (last observed fish) is linear decreasing to the threshold of 0.25, and estimated preference for depth > 3 feet is non-limiting (i.e., fixed at the highest modeled value).

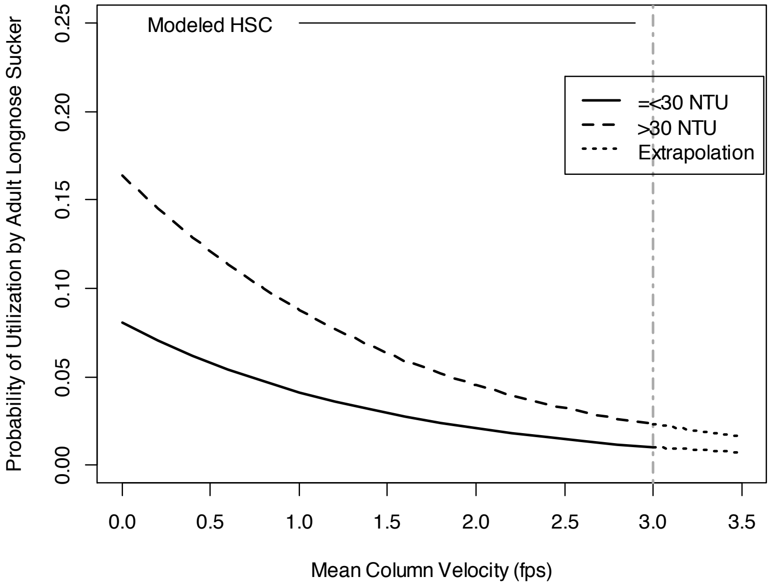

Figure 5.6-25. HSC model for adult longnose sucker as a function of velocity for fixed depth of 1 foot for turbid and non-turbid water.

Note: Estimated preference for velocity > 3 fps (last observed fish) is extrapolated based on the model.

ATTACHMENT 1: HSC HISTOGRAMS – RIVER SEGMENT COMPARISON

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D Attachment 1

HSC Histograms (River Segment)

Prepared for

Alaska Energy Authority

Prepared by

R2 Resource Consultants, Inc.

November 2015

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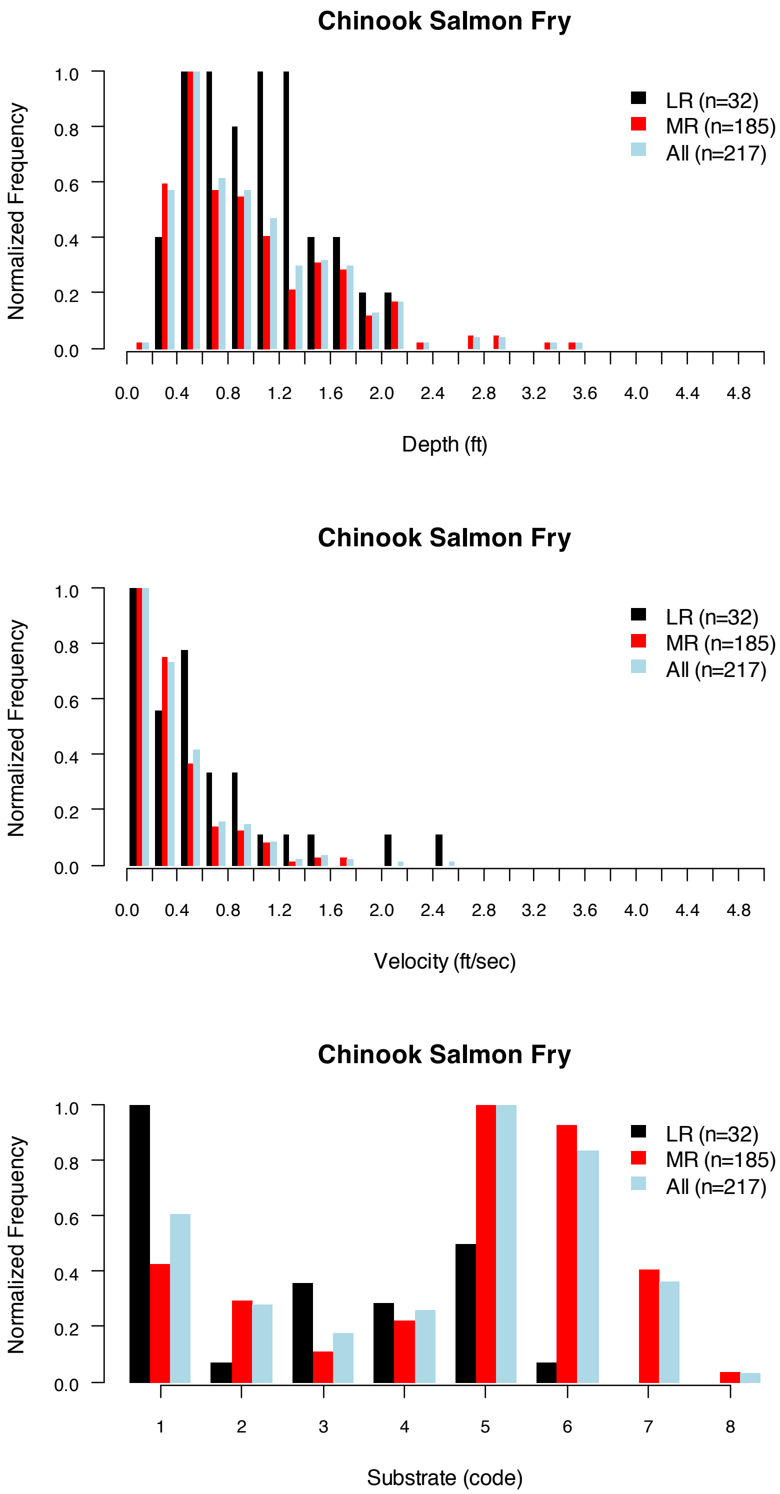


Figure D1-1. Chinook salmon fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: 2014-2013 HSC database.

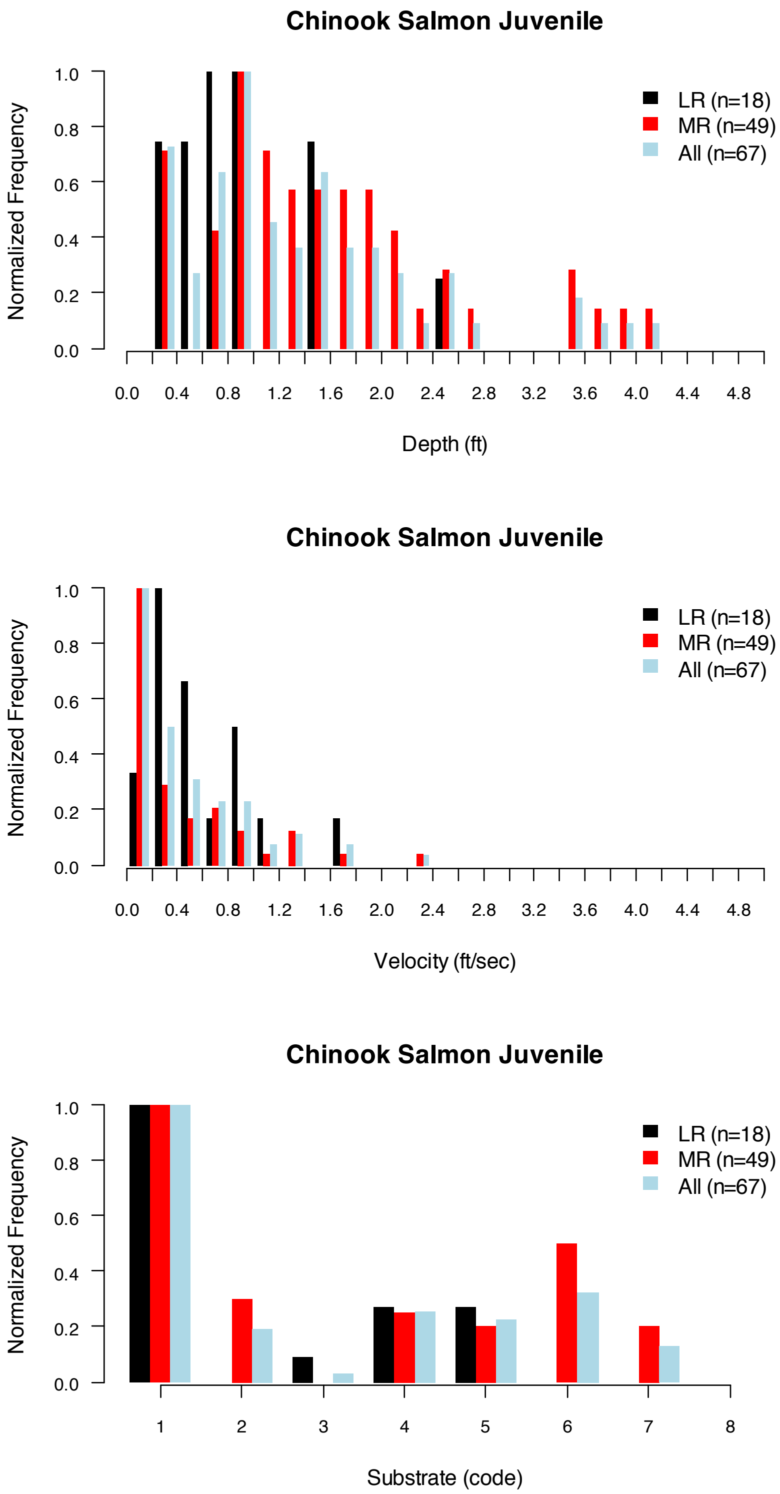


Figure D1-2. Chinook salmon juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam site), and all segments combined for the Susitna River, Alaska. Data source: 2014-2013 HSC database.

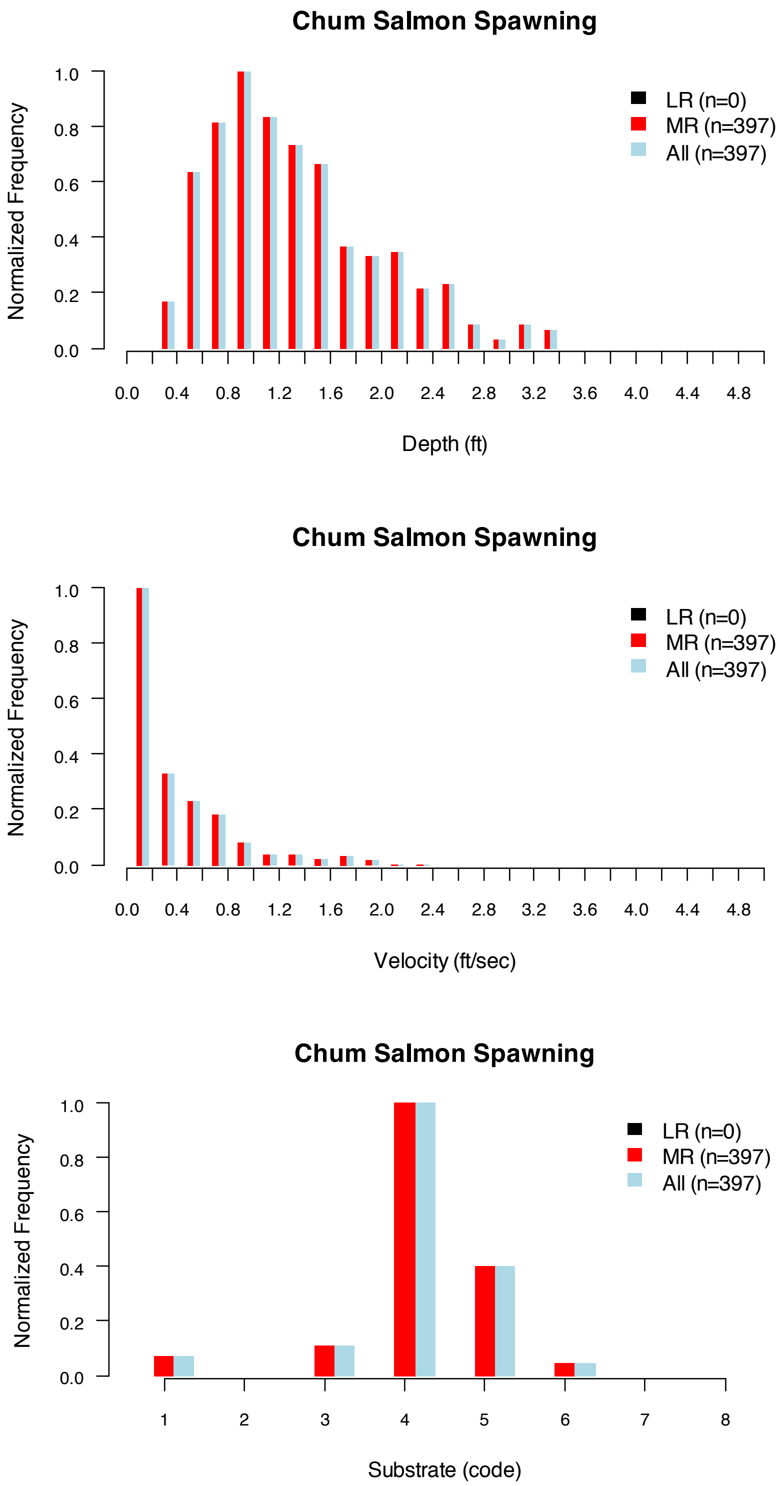


Figure D1-3. Chum salmon spawner frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

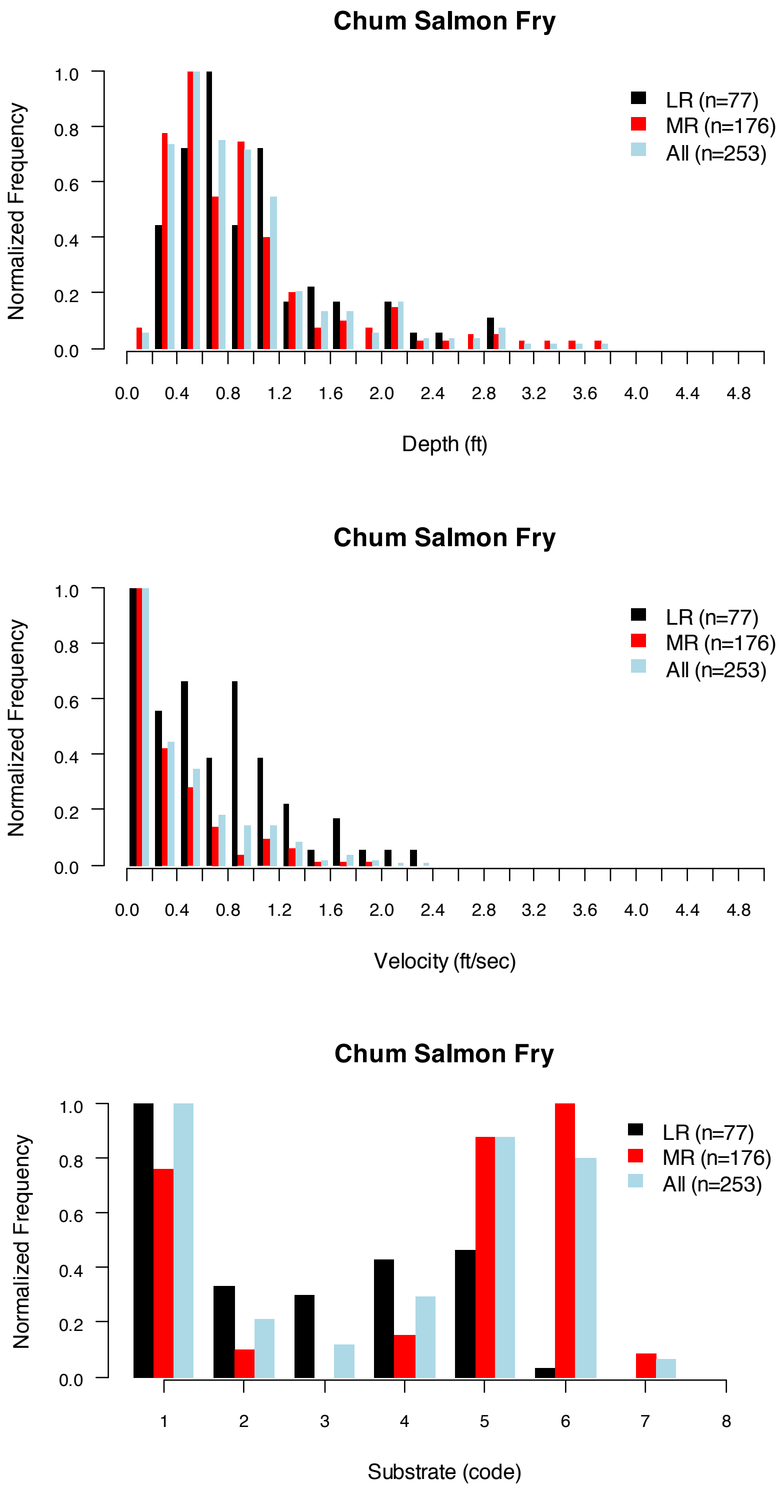


Figure D1-4. Chum salmon fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

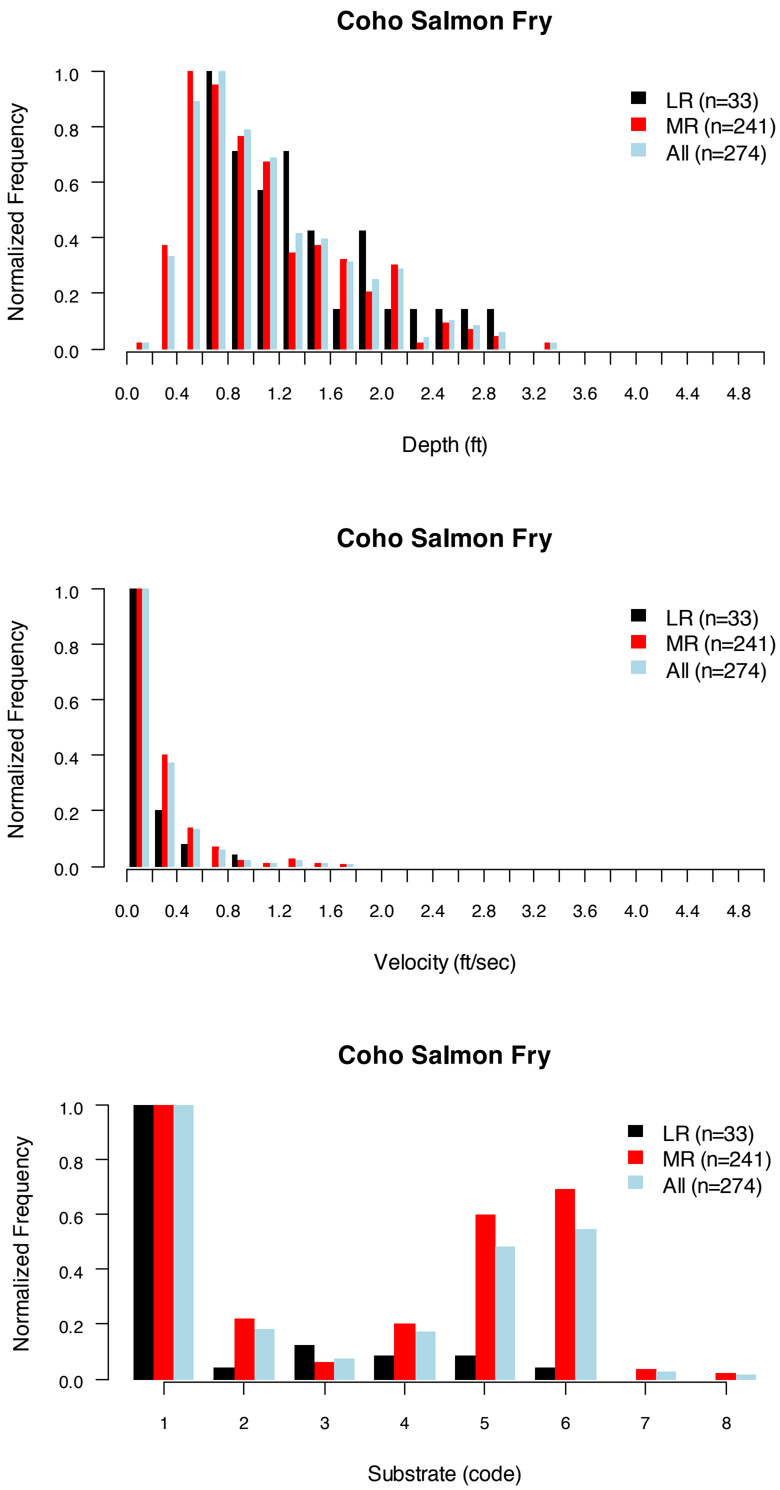
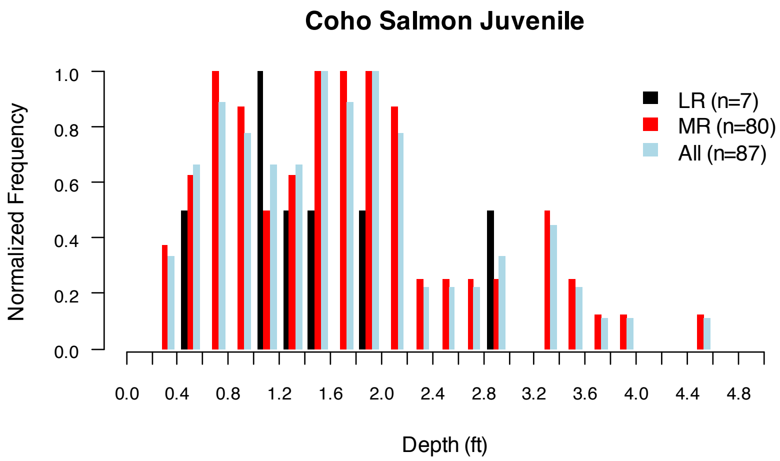
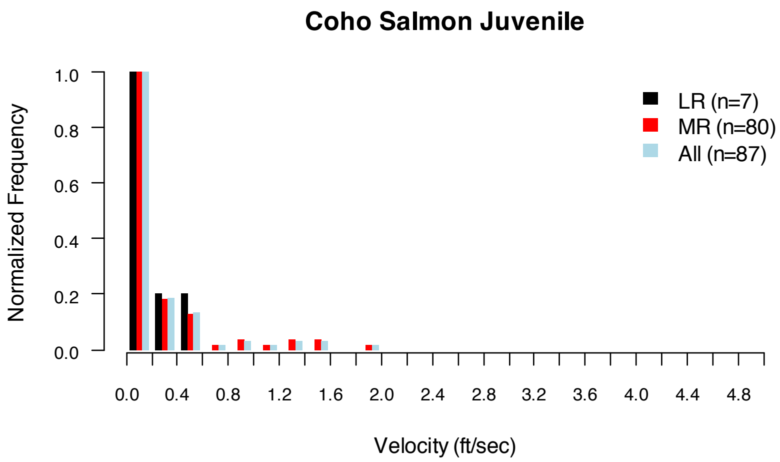


Figure D1-5. Coho salmon fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.





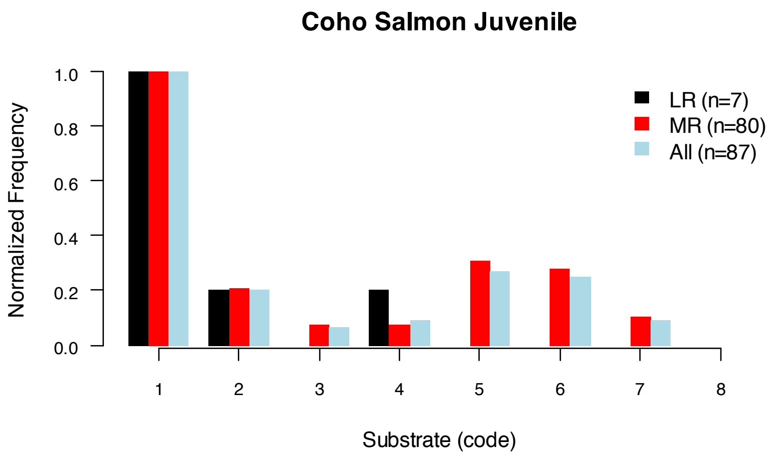


Figure D1-6. Coho salmon juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

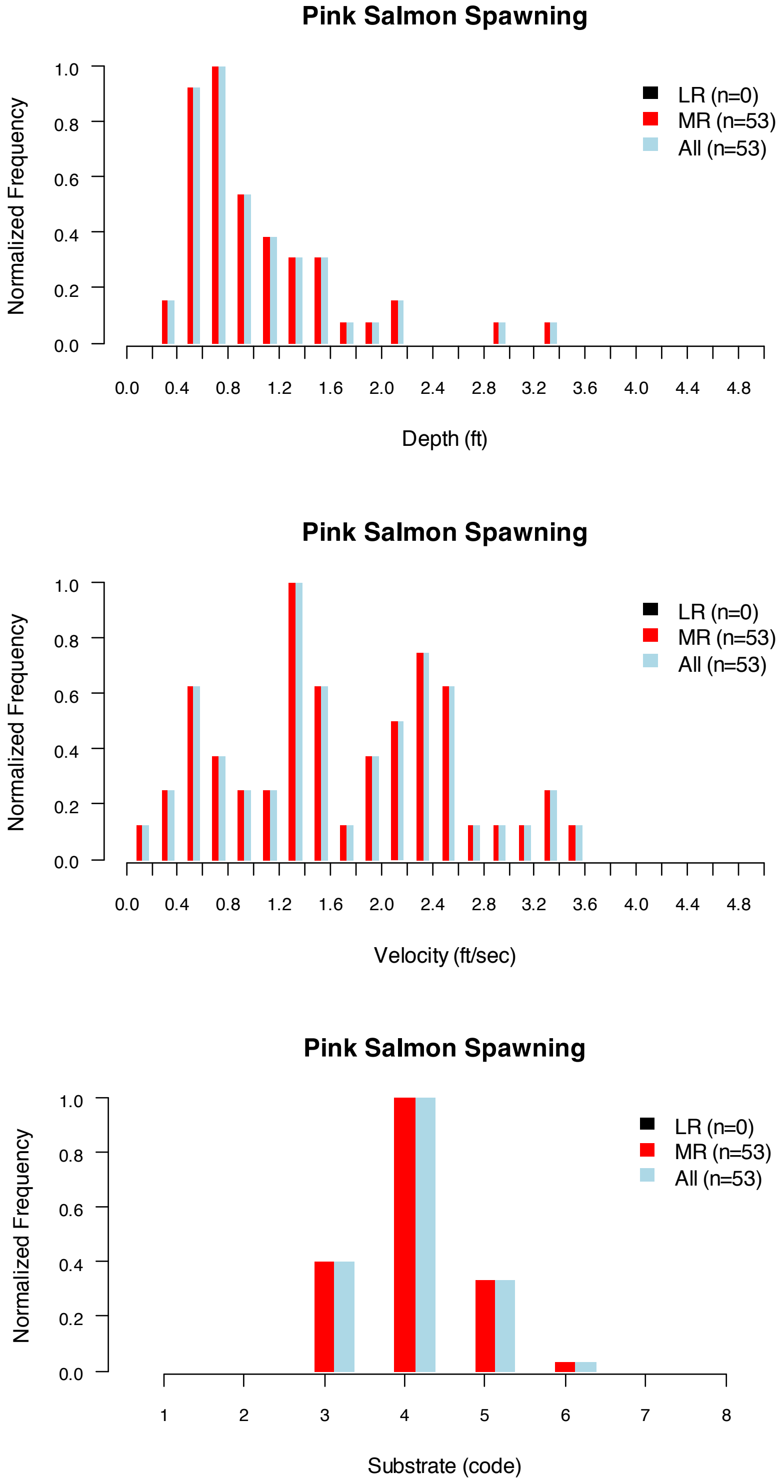
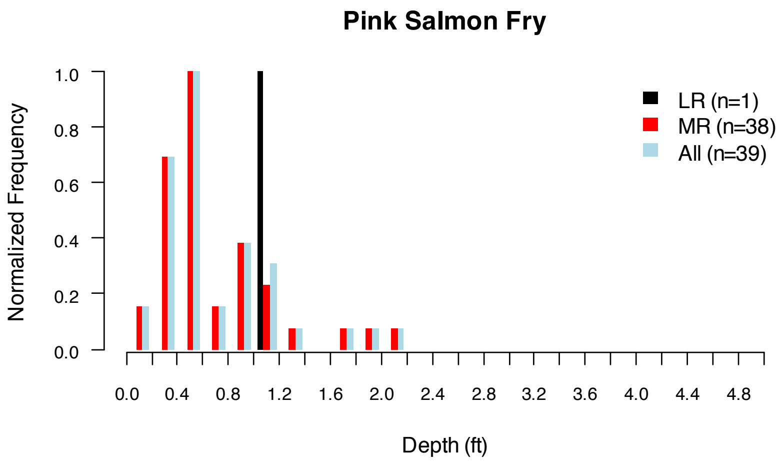
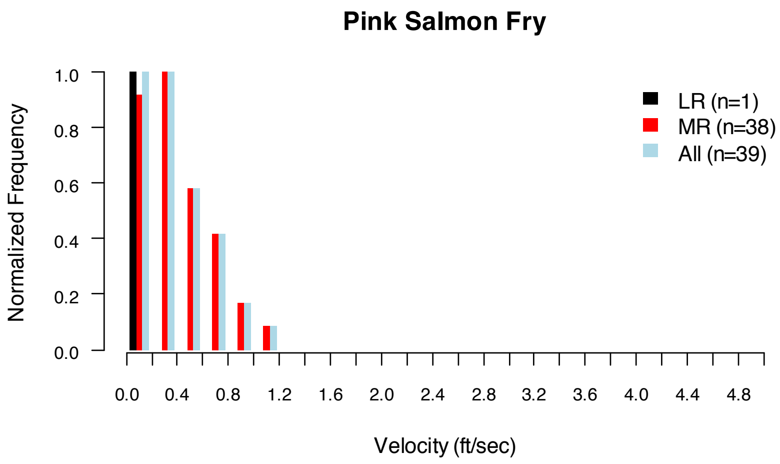


Figure D1-7. Pink salmon spawner frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.





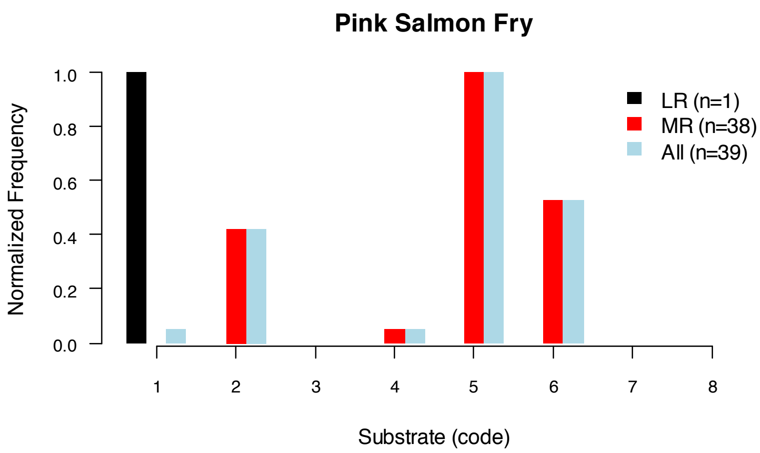


Figure D1-8. Pink salmon fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

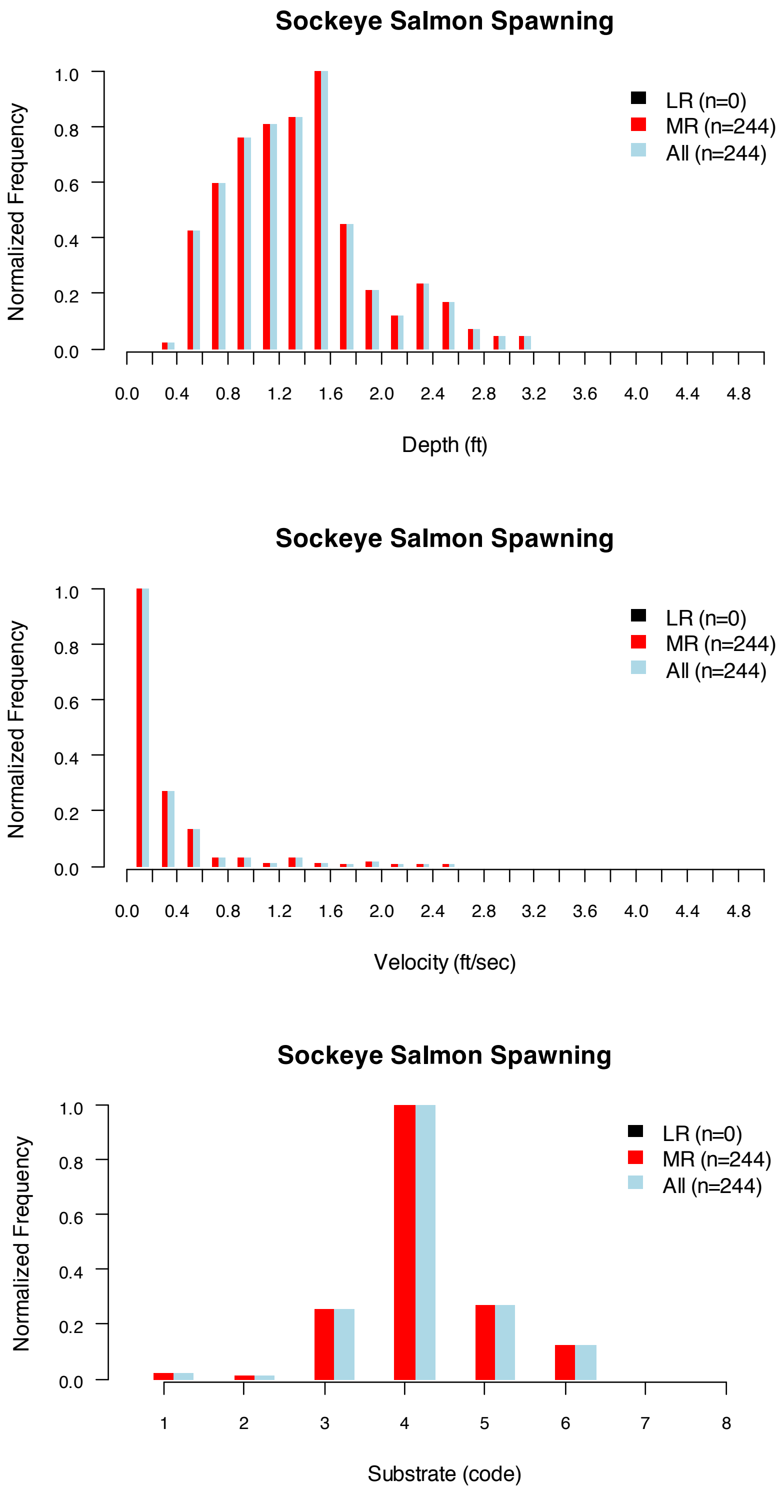


Figure D1-9. Sockeye salmon spawner frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database e.

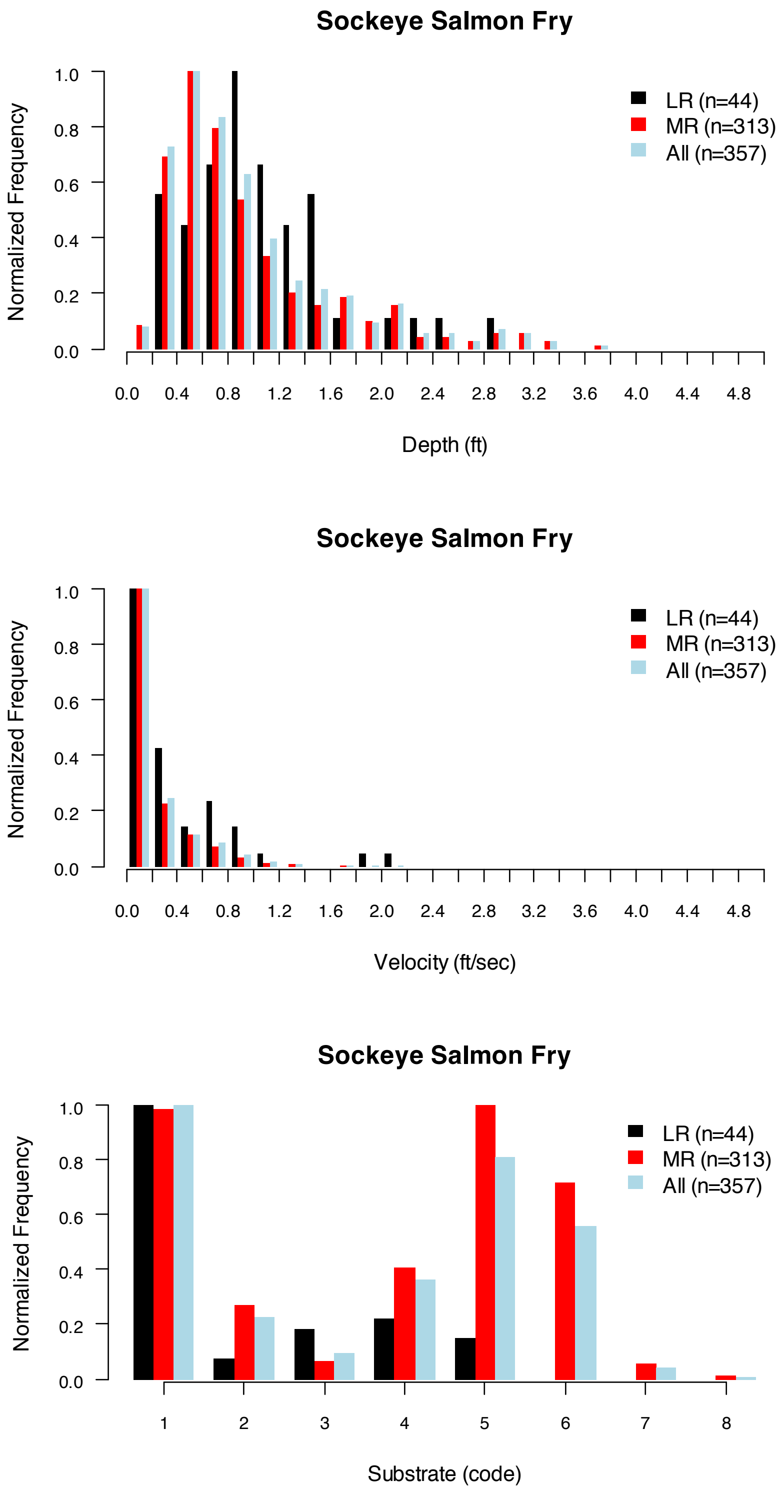


Figure D1-10. Sockeye salmon fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

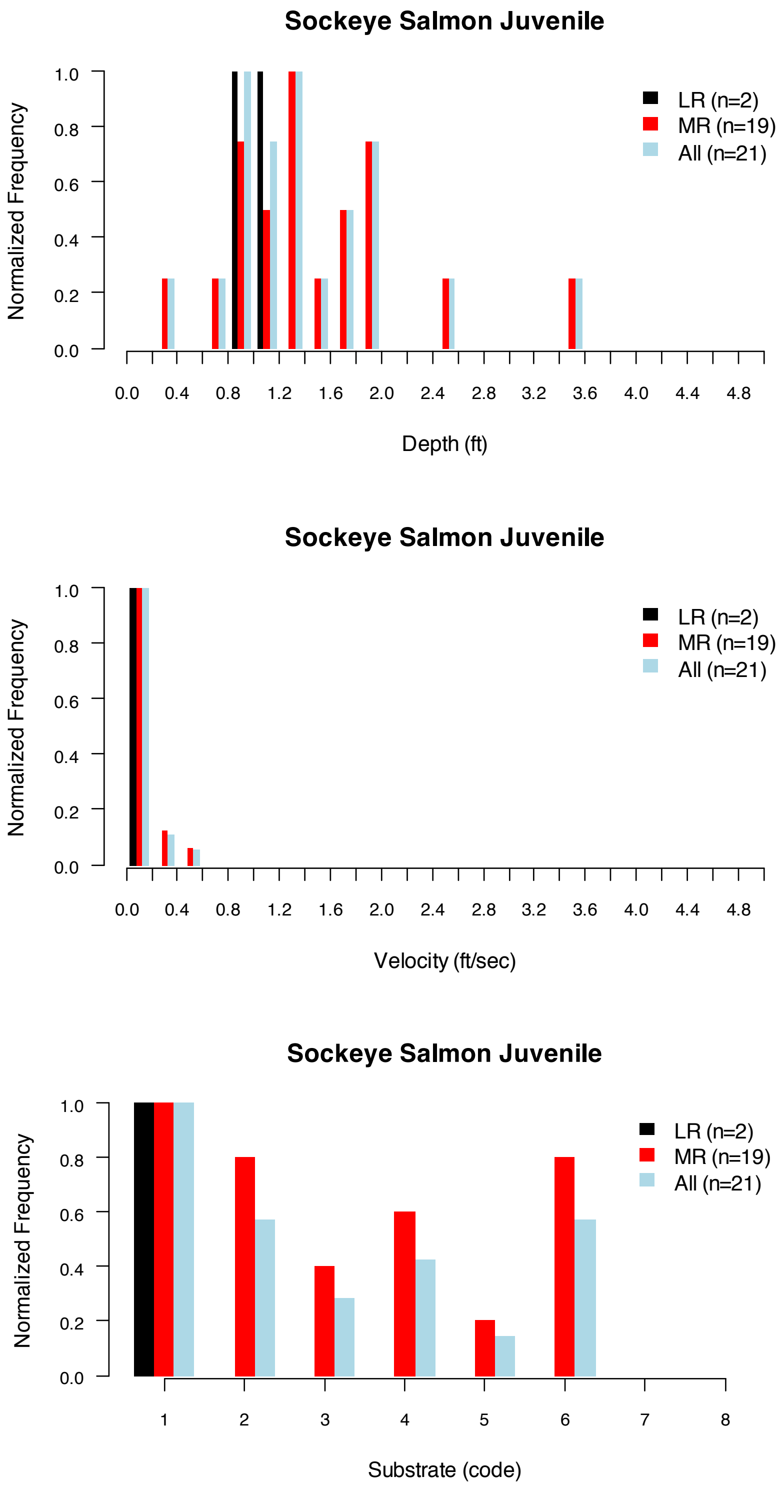


Figure D1-11. Sockeye salmon juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

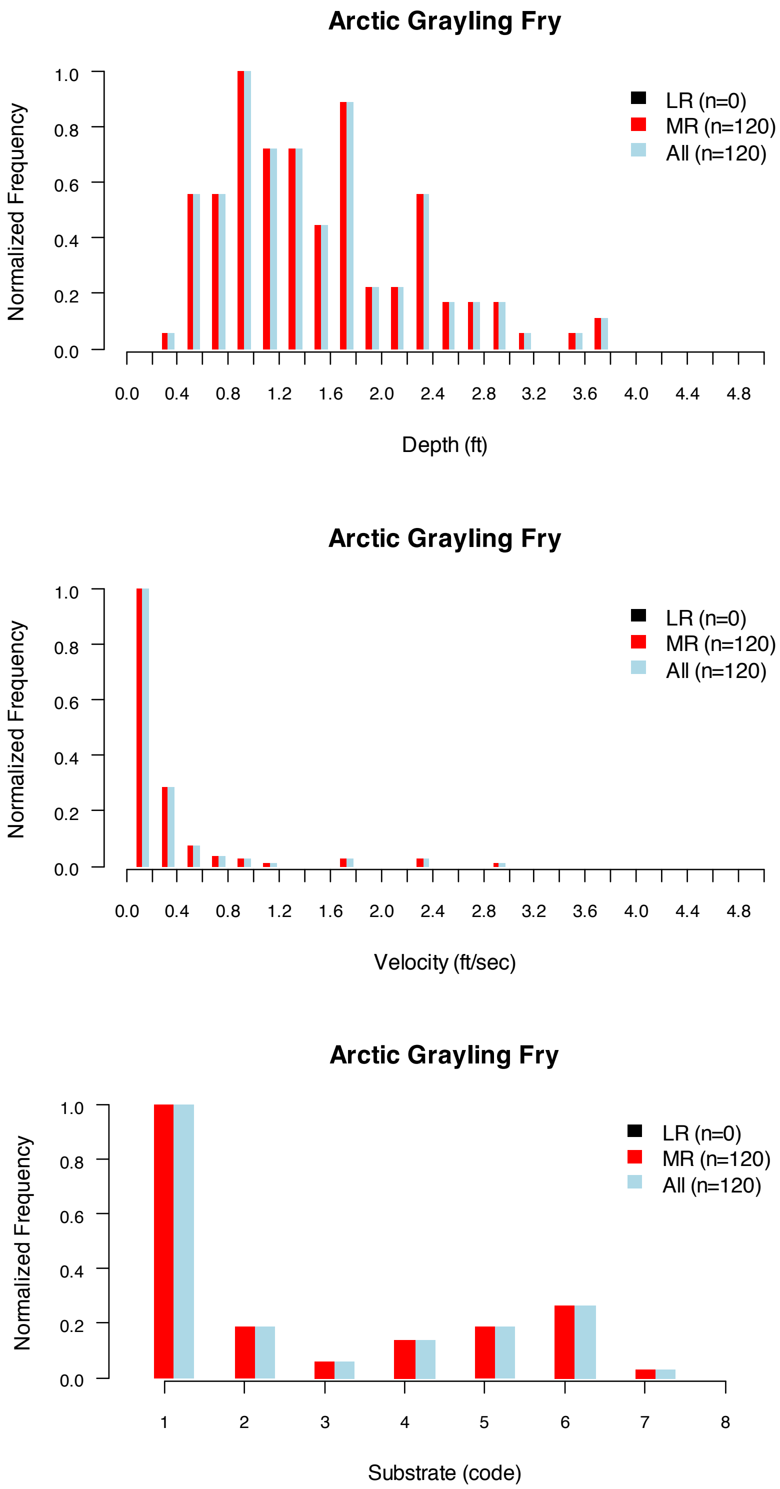


Figure D1-12. Arctic grayling fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

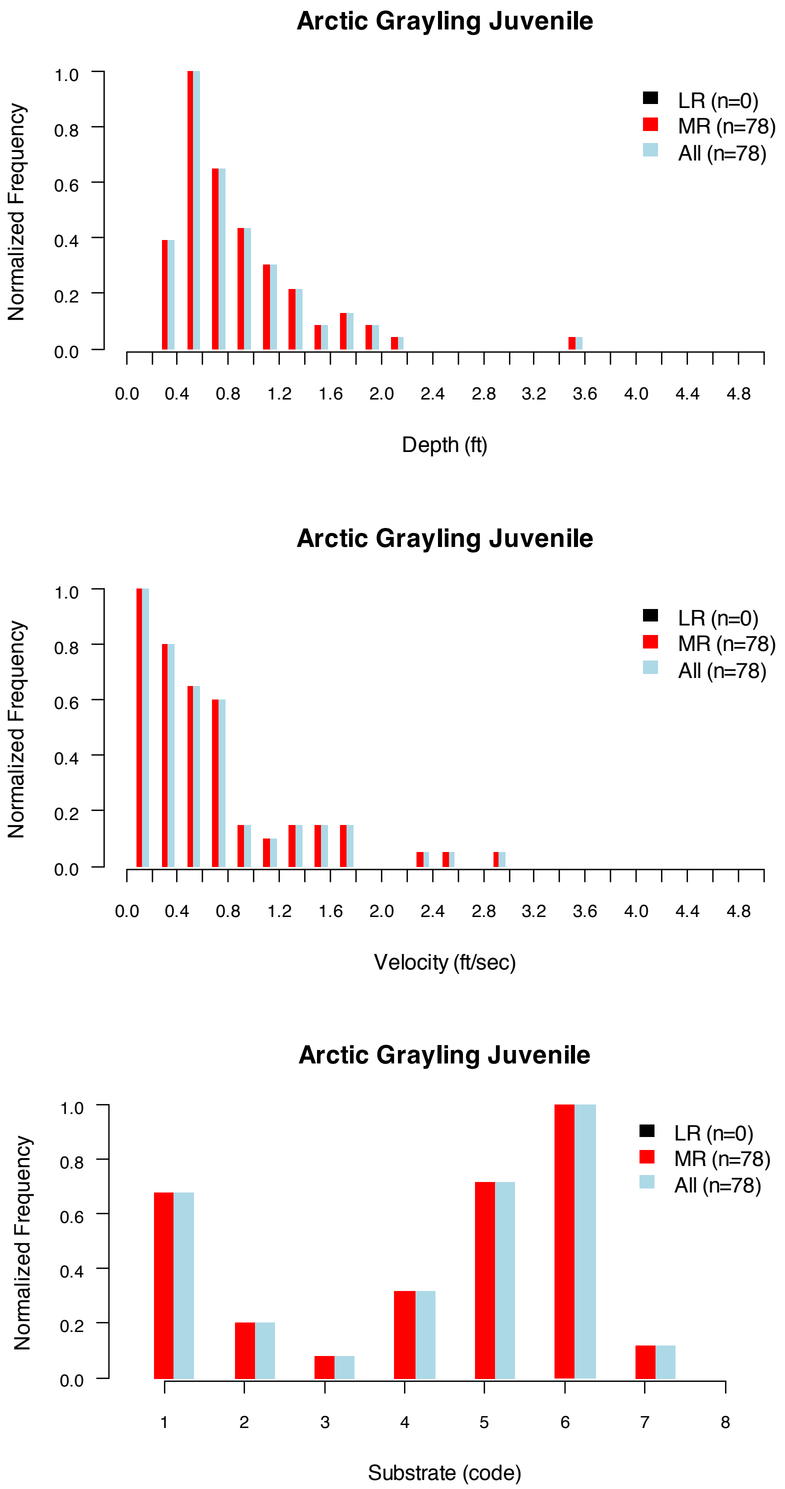


Figure D1-13. Arctic grayling juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

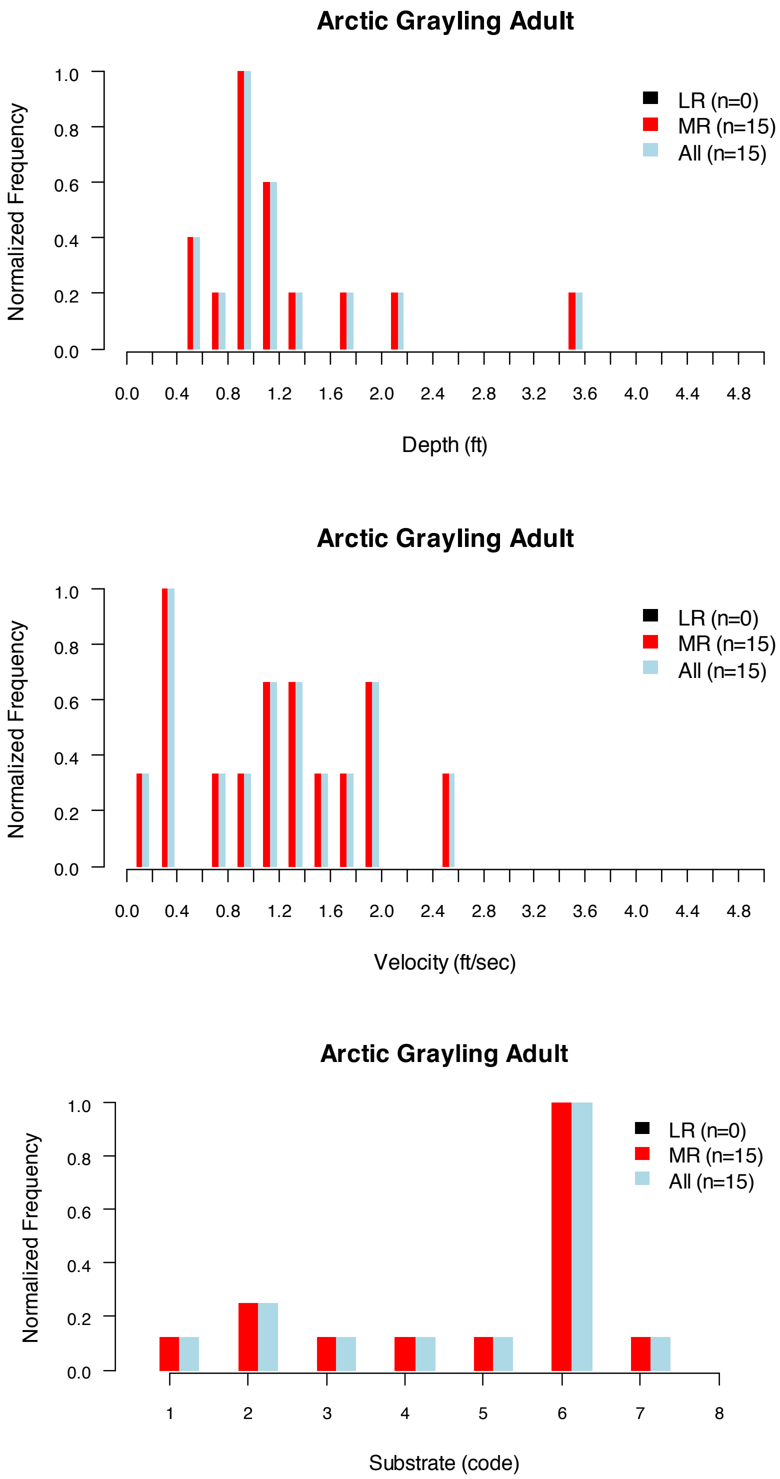


Figure D1-14. Arctic grayling adult frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

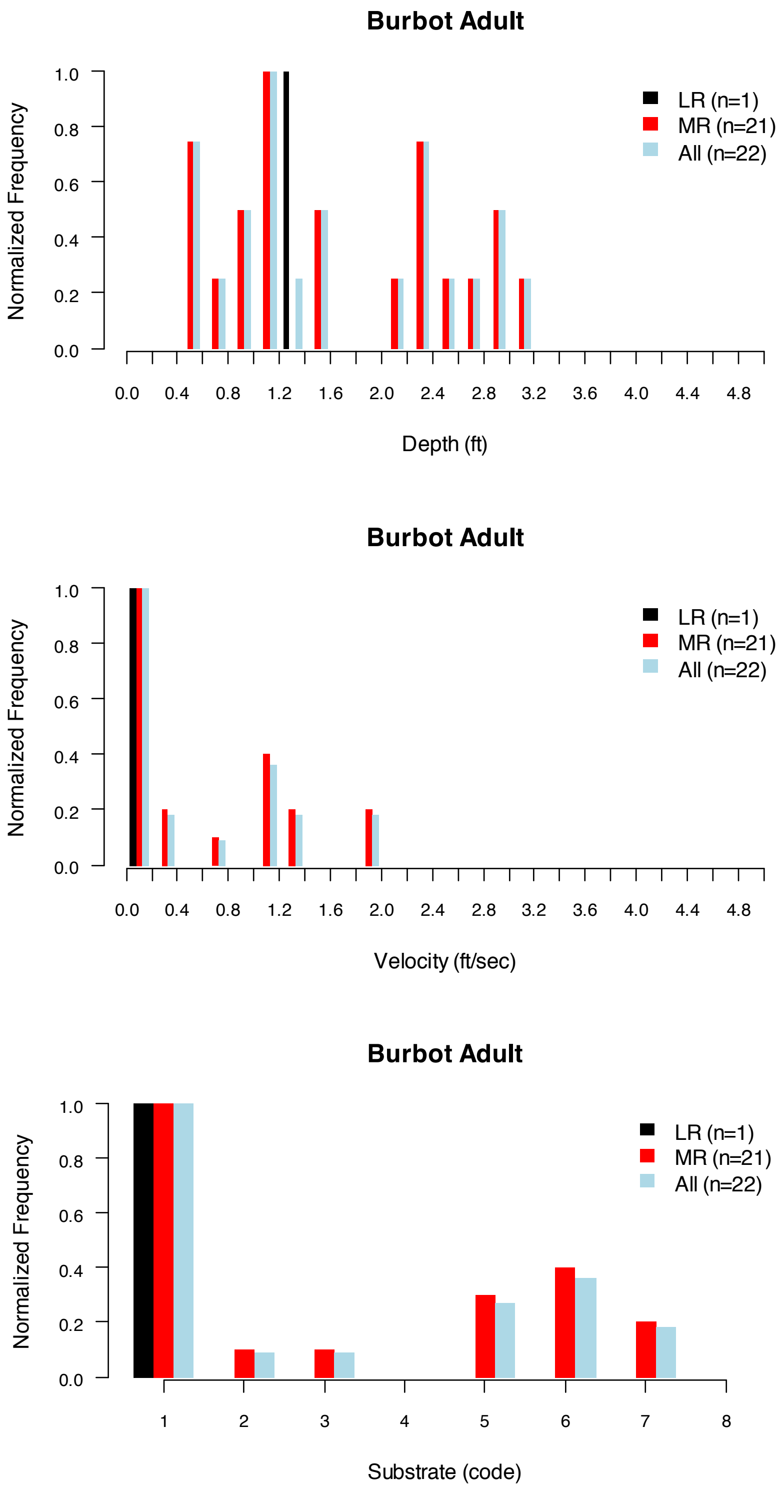


Figure D1-15. Burbot adult frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

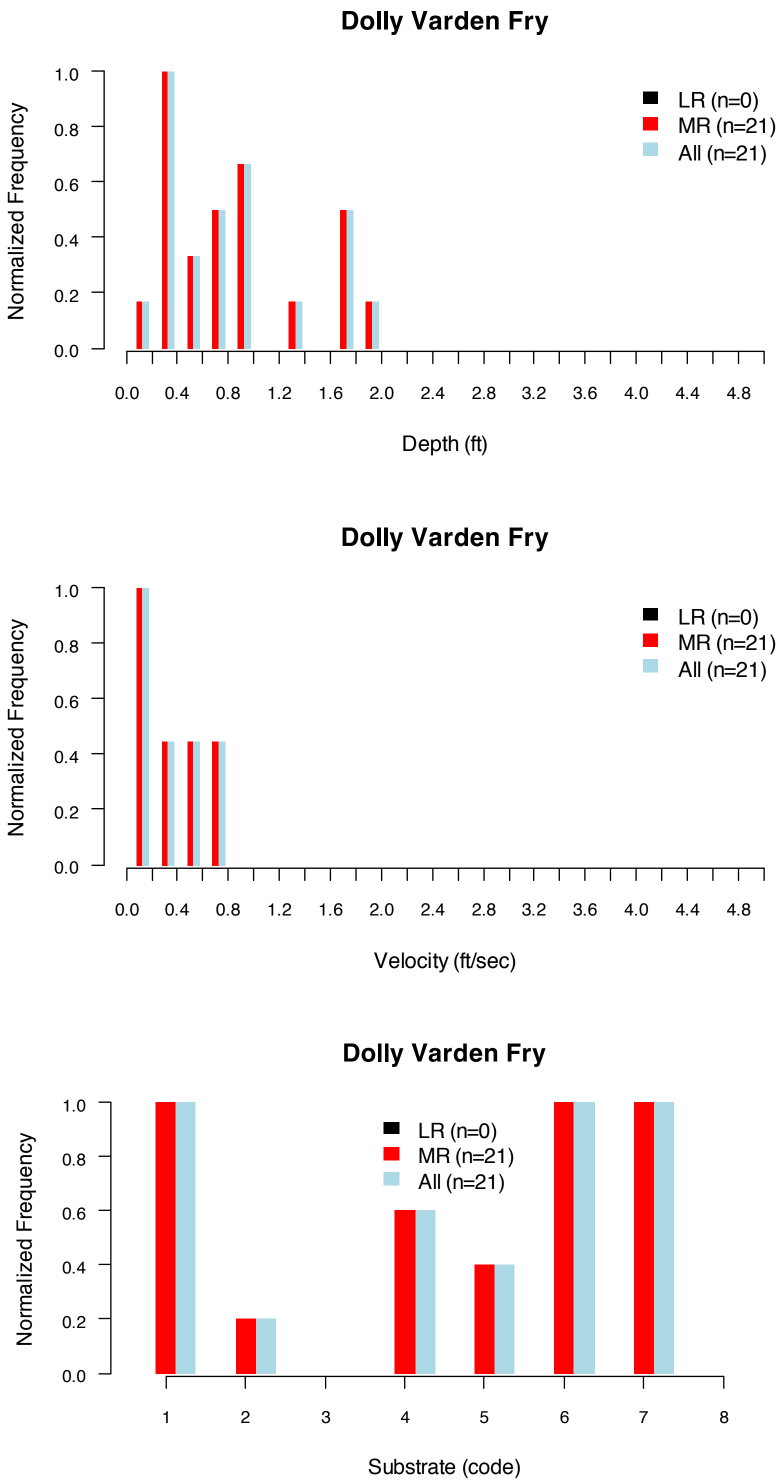
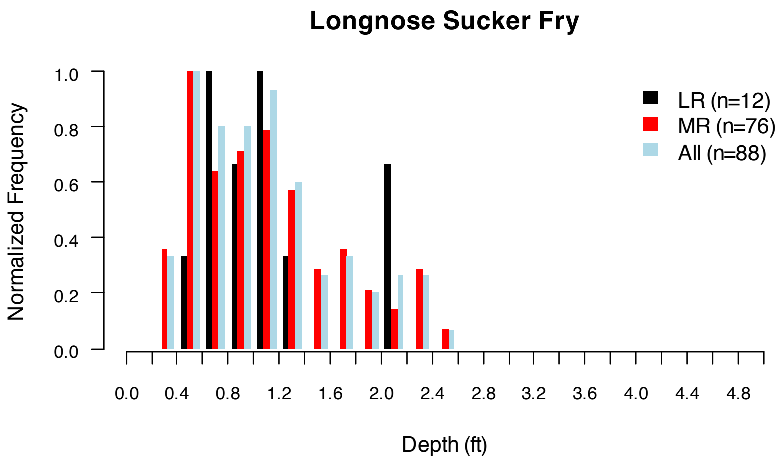
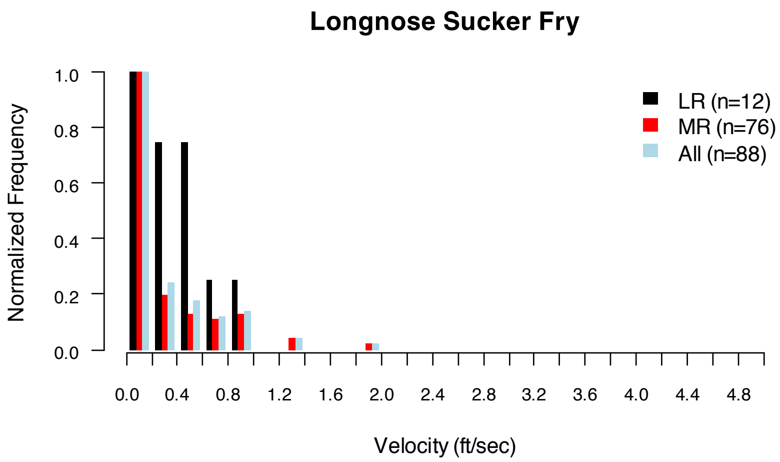


Figure D1-16. Dolly Varden fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.





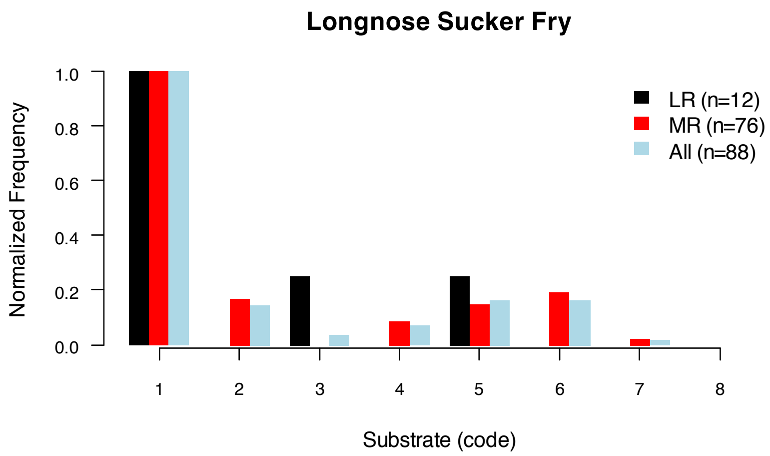


Figure D1-17. Longnose sucker fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

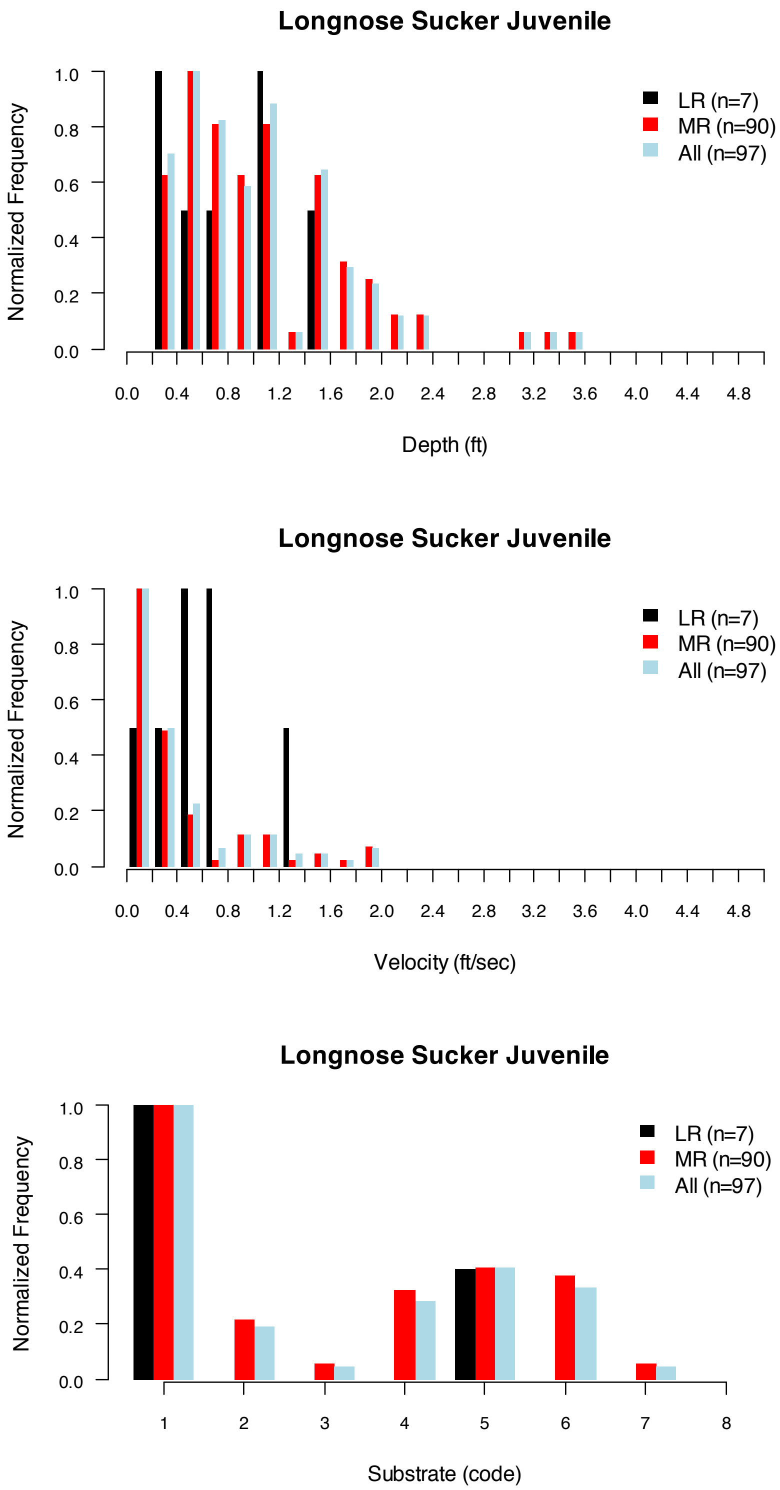


Figure D1-18. Longnose sucker juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

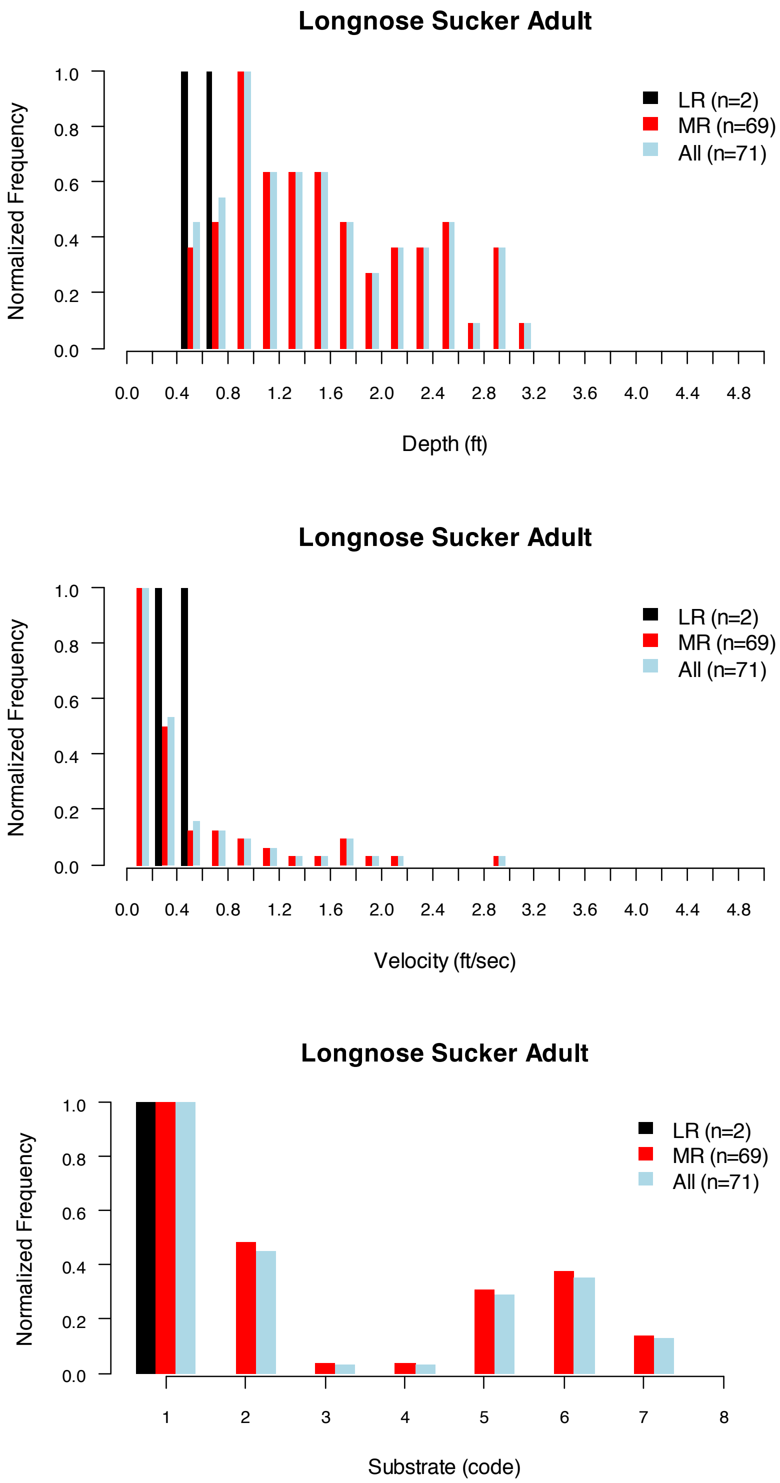


Figure D1-19. Longnose sucker adult frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

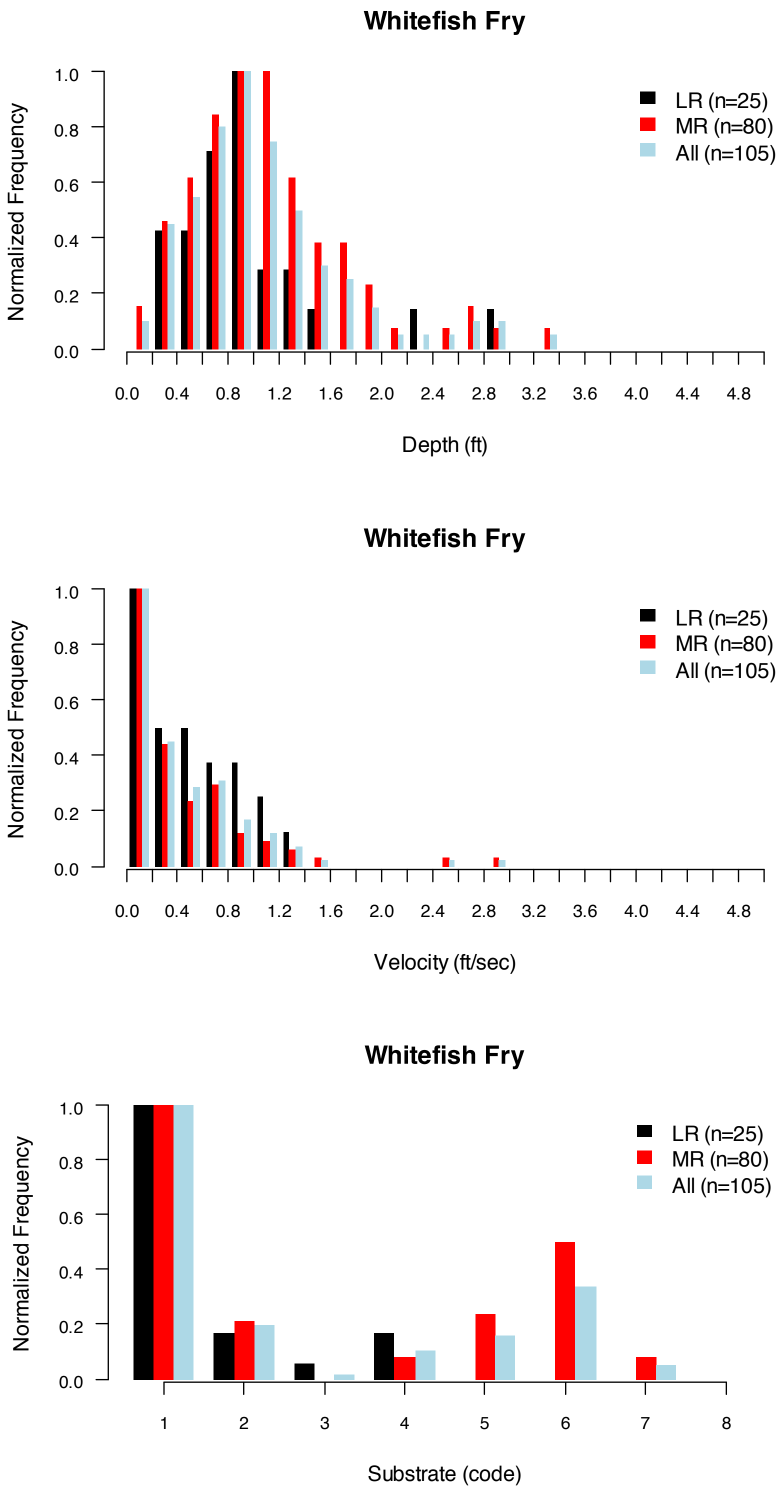


Figure D1-20. Whitefish spp. fry frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

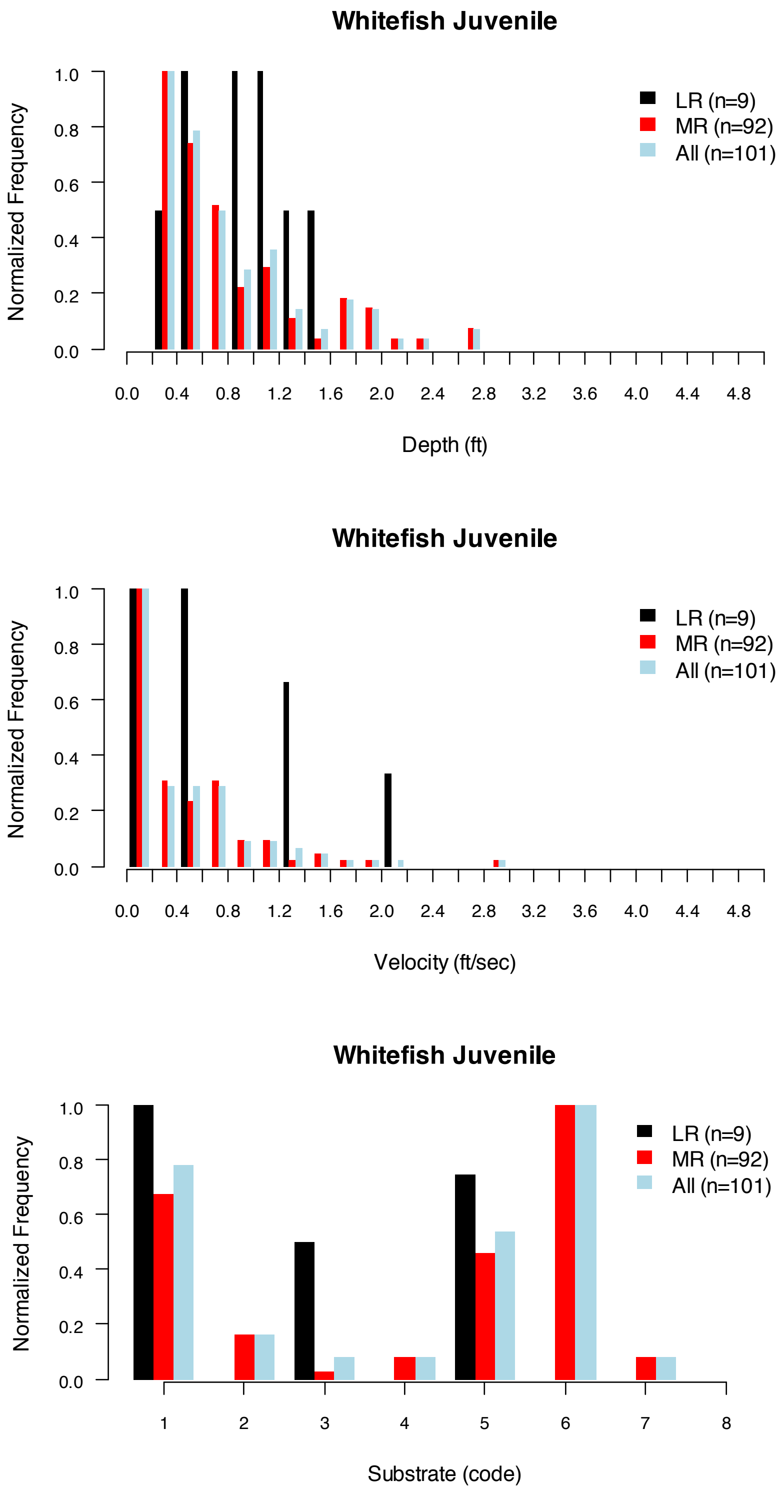


Figure D1-21. Whitefish spp. juvenile frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

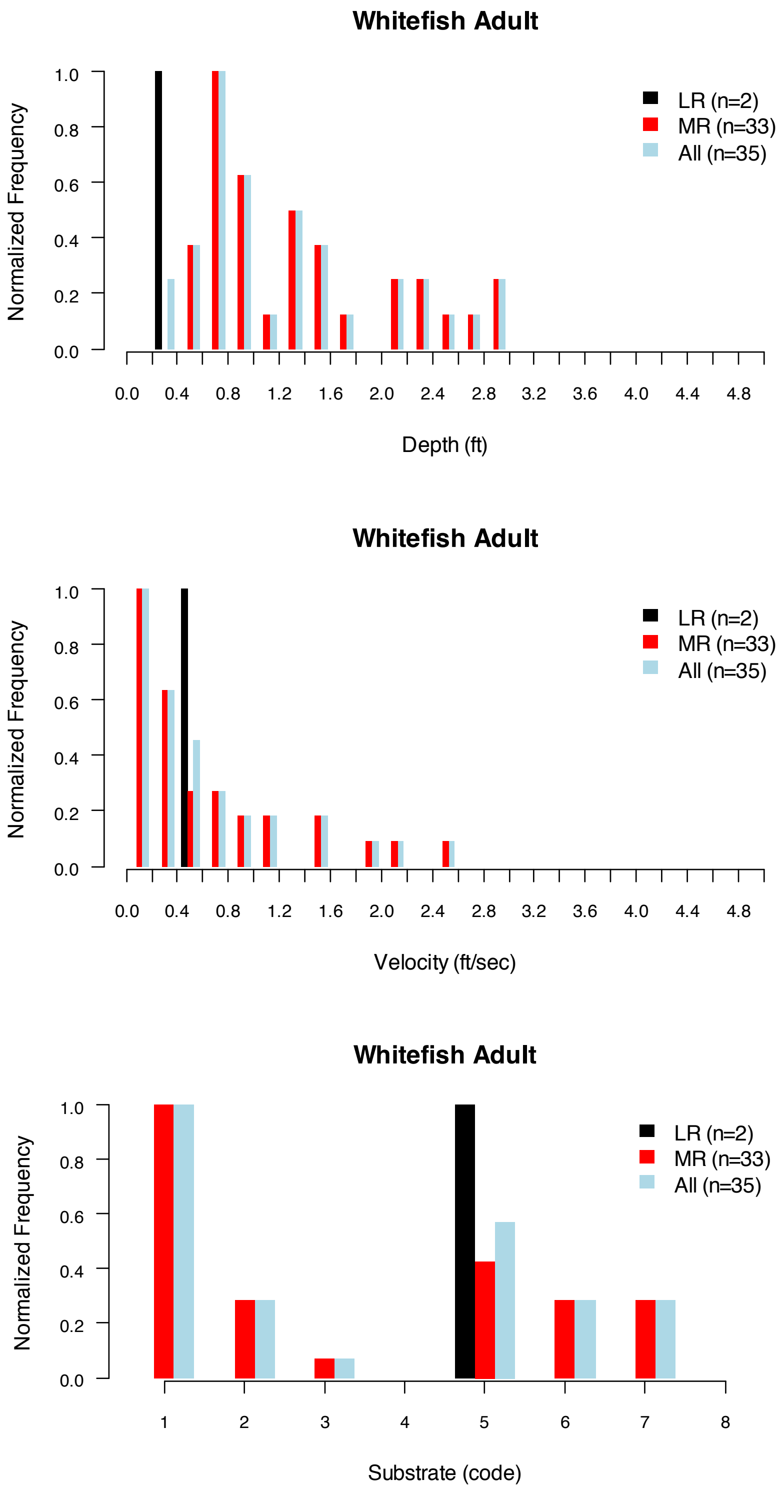


Figure D1-22. Whitefish spp. adult frequency distribution of microhabitat use by river segment: Lower (downstream of Three Rivers Confluence), Middle (Three Rivers Confluence to proposed Watana Dam Site), and all segments combined for the Susitna River, Alaska. Data source: Data source: 2014-2013 HSC database.

ATTACHMENT 2: HSC HISTOGRAMS – SEASONAL COMPARISON

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D Attachment 2

HSC Histograms (Seasonal)

Prepared for

Alaska Energy Authority

Prepared by

R2 Resource Consultants, Inc.

November 2015

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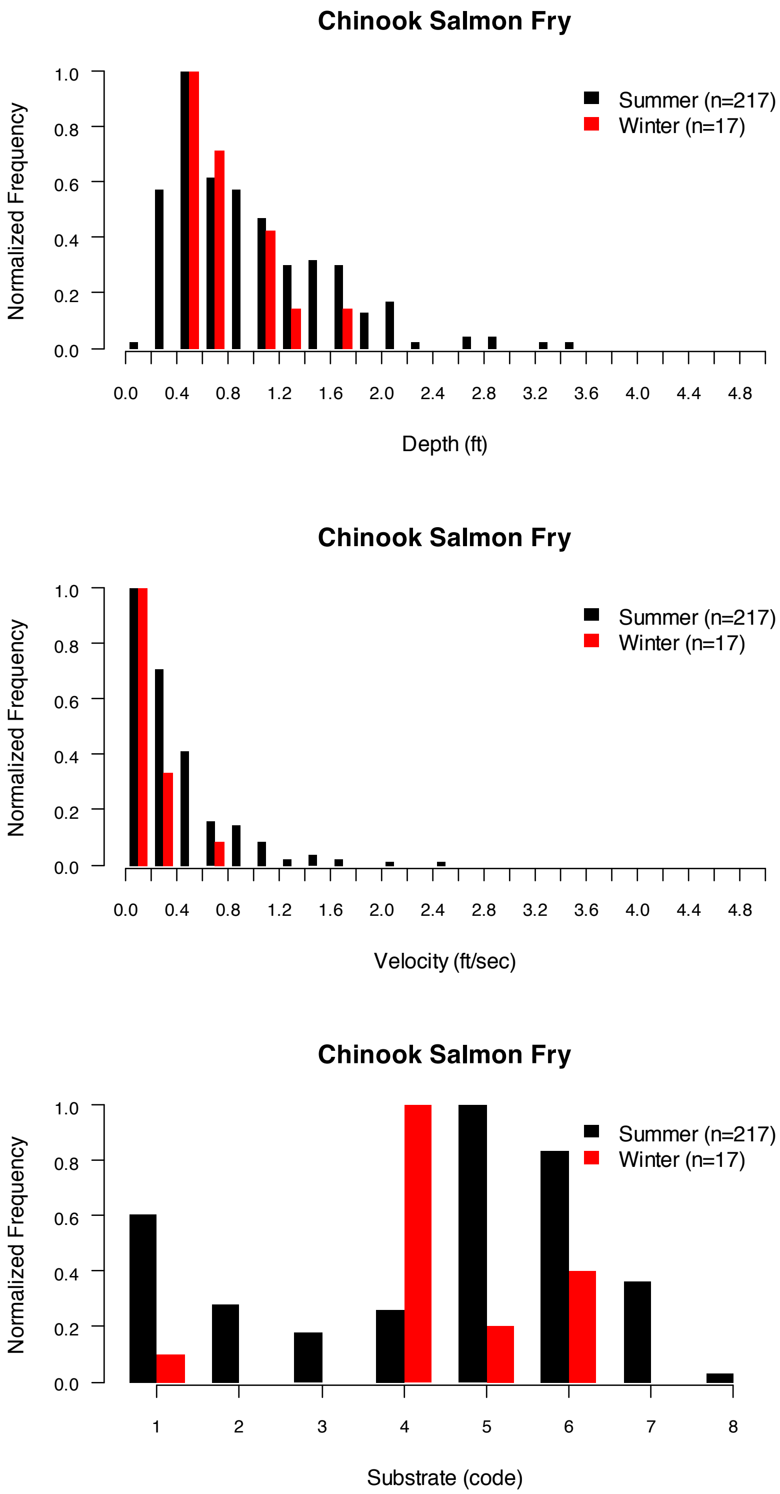

Figure D2-1. Chinook salmon fry frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

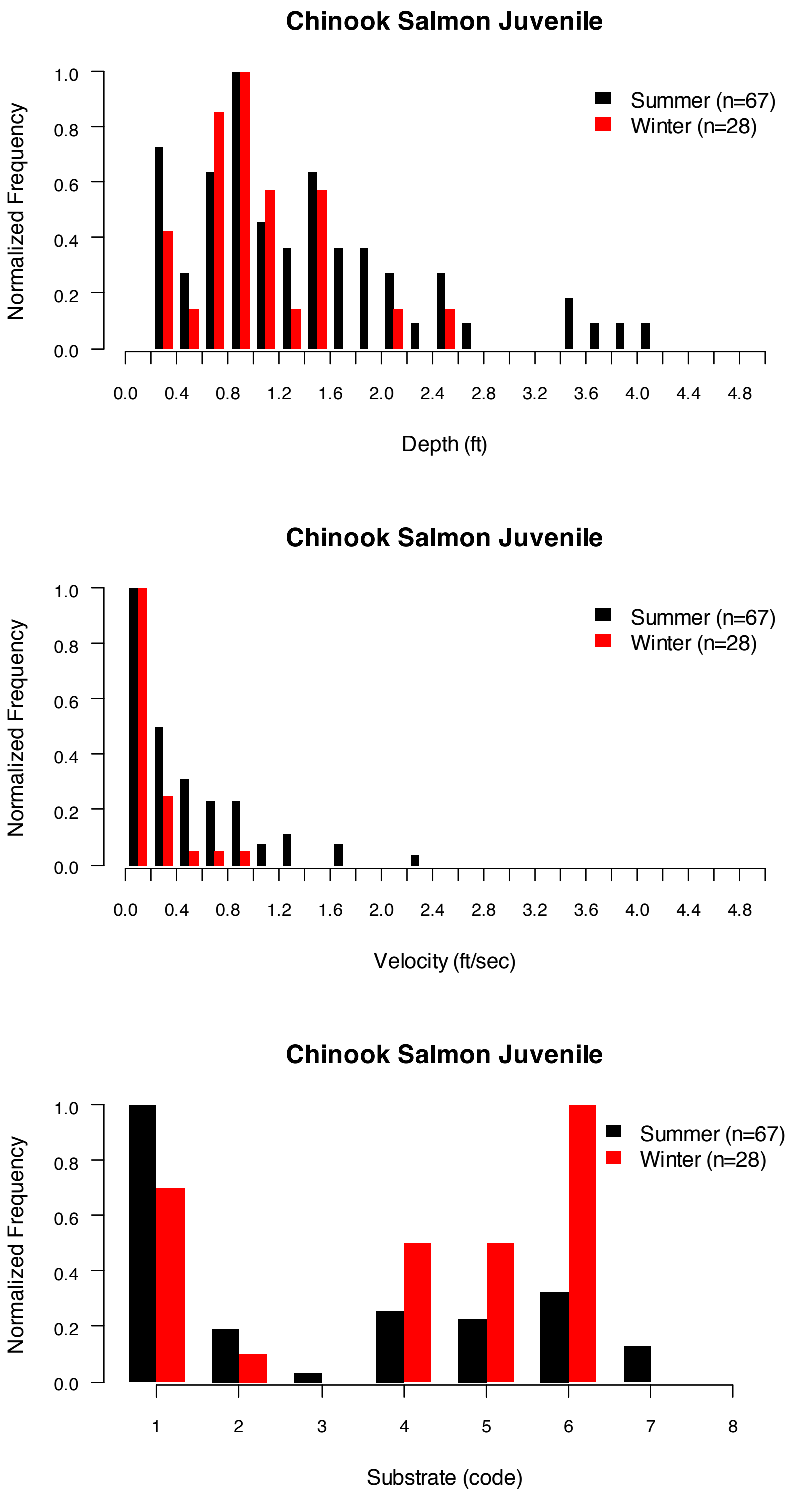

Figure D2-2. Chinook salmon juvenile frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

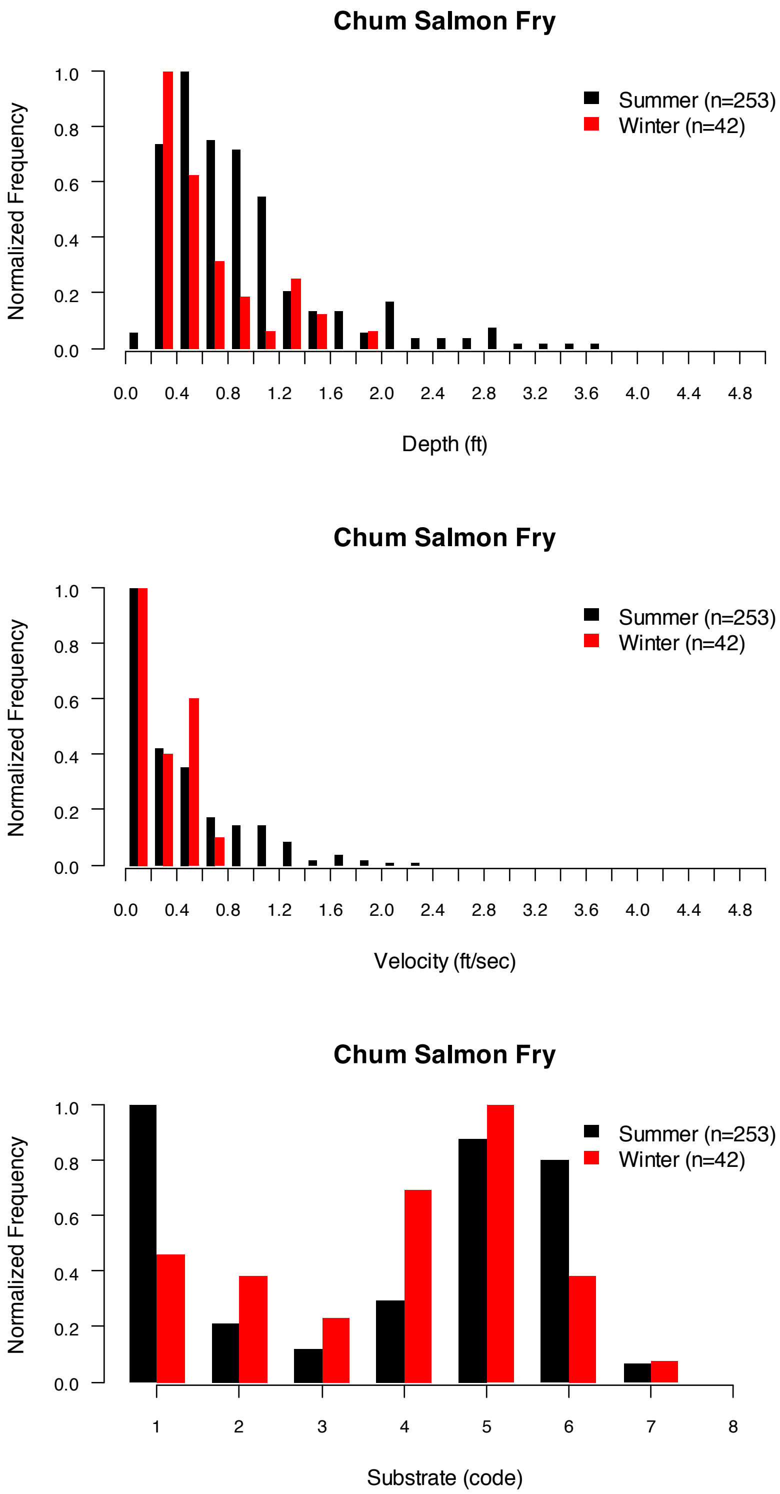

Figure D2-3. Chum salmon fry frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

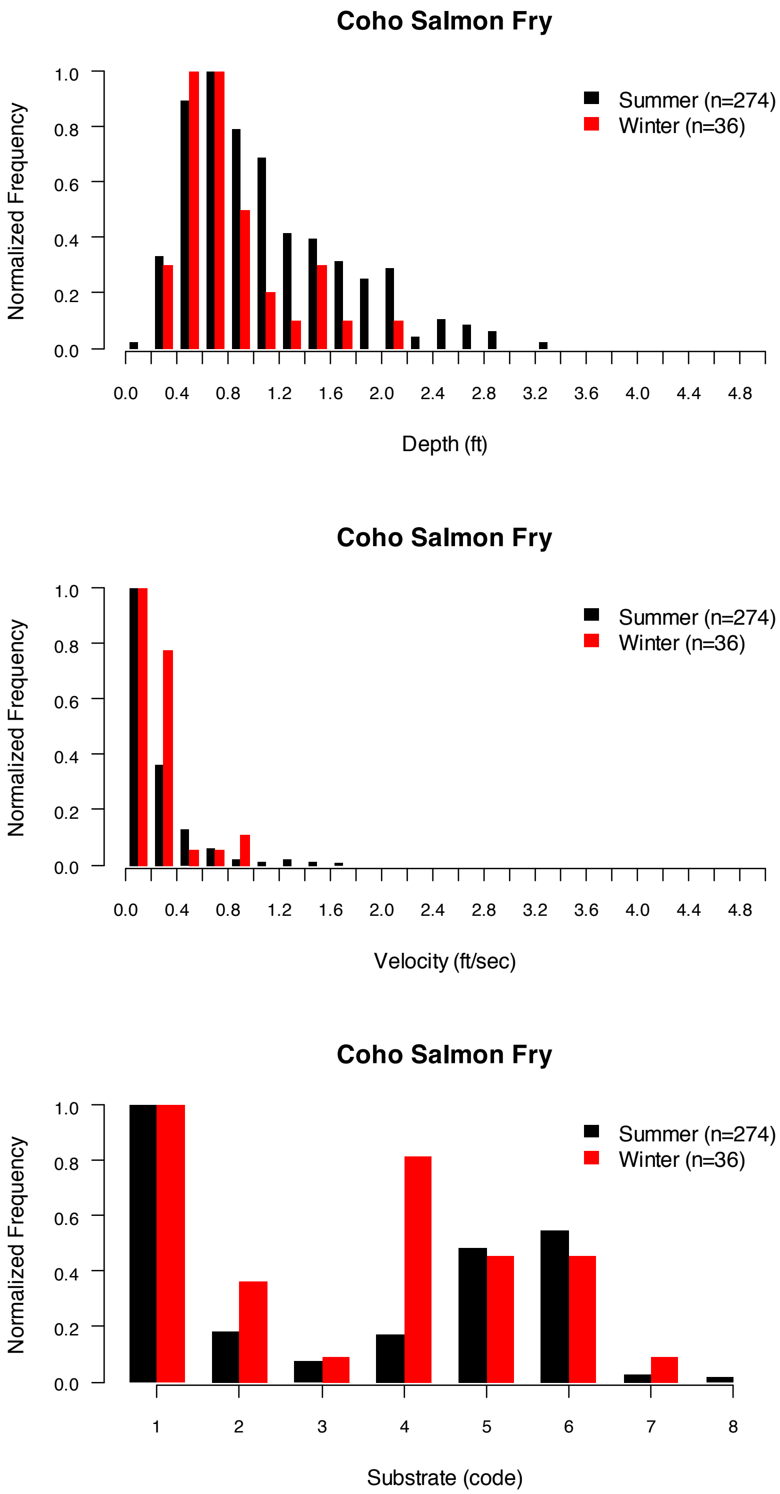

Figure D2-4. Coho salmon fry frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

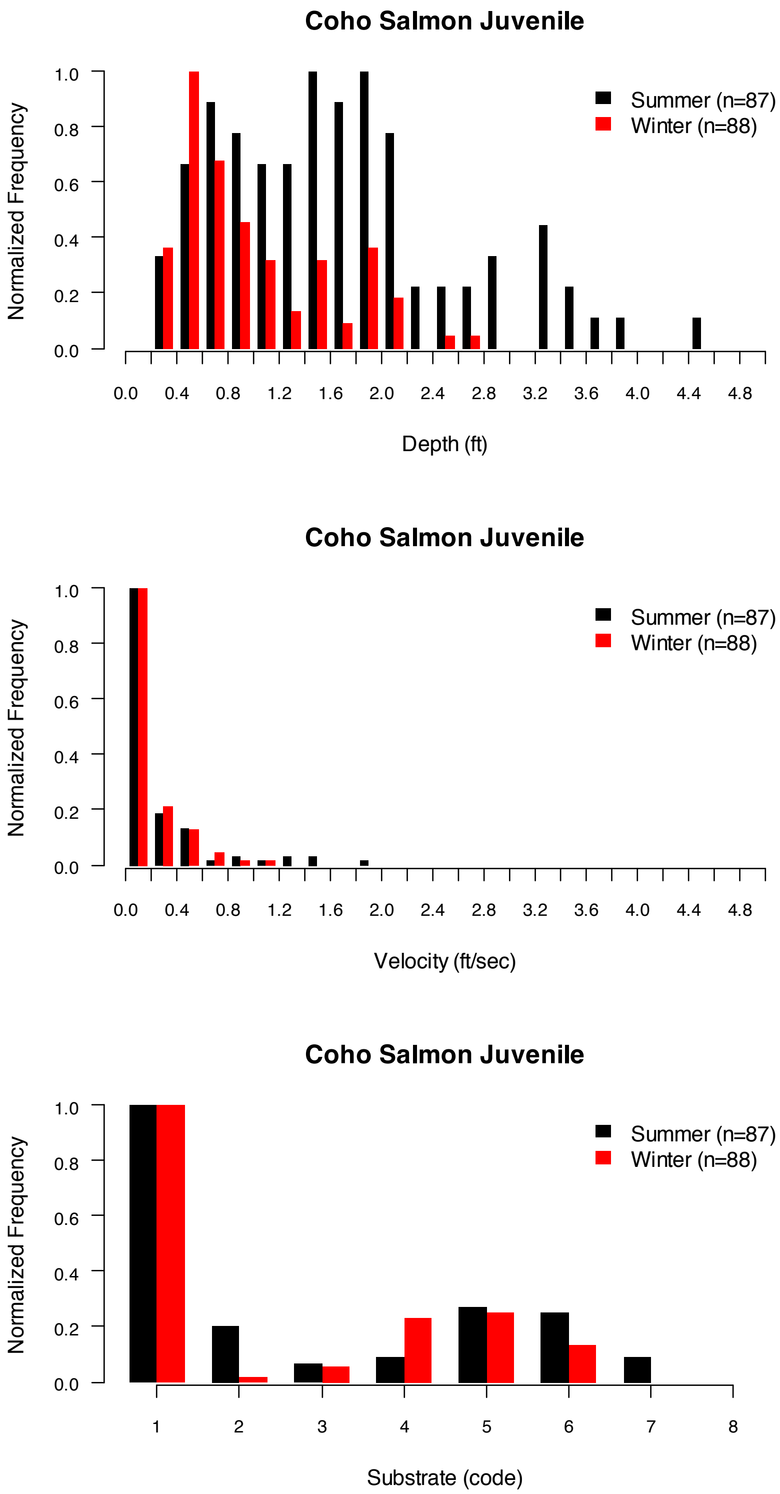

Figure D2-5. Coho salmon juvenile frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

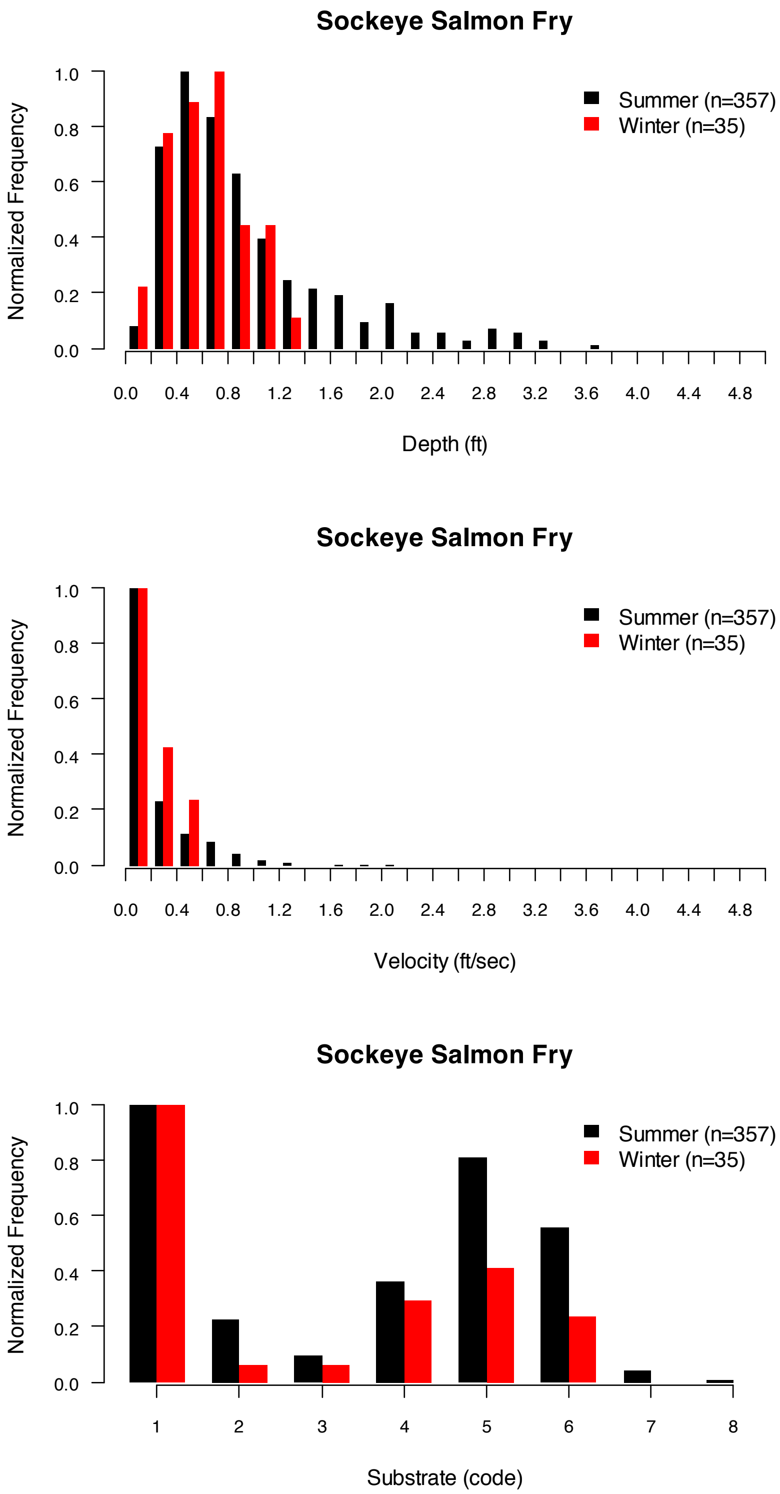

Figure D2-6. Sockeye salmon fry frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

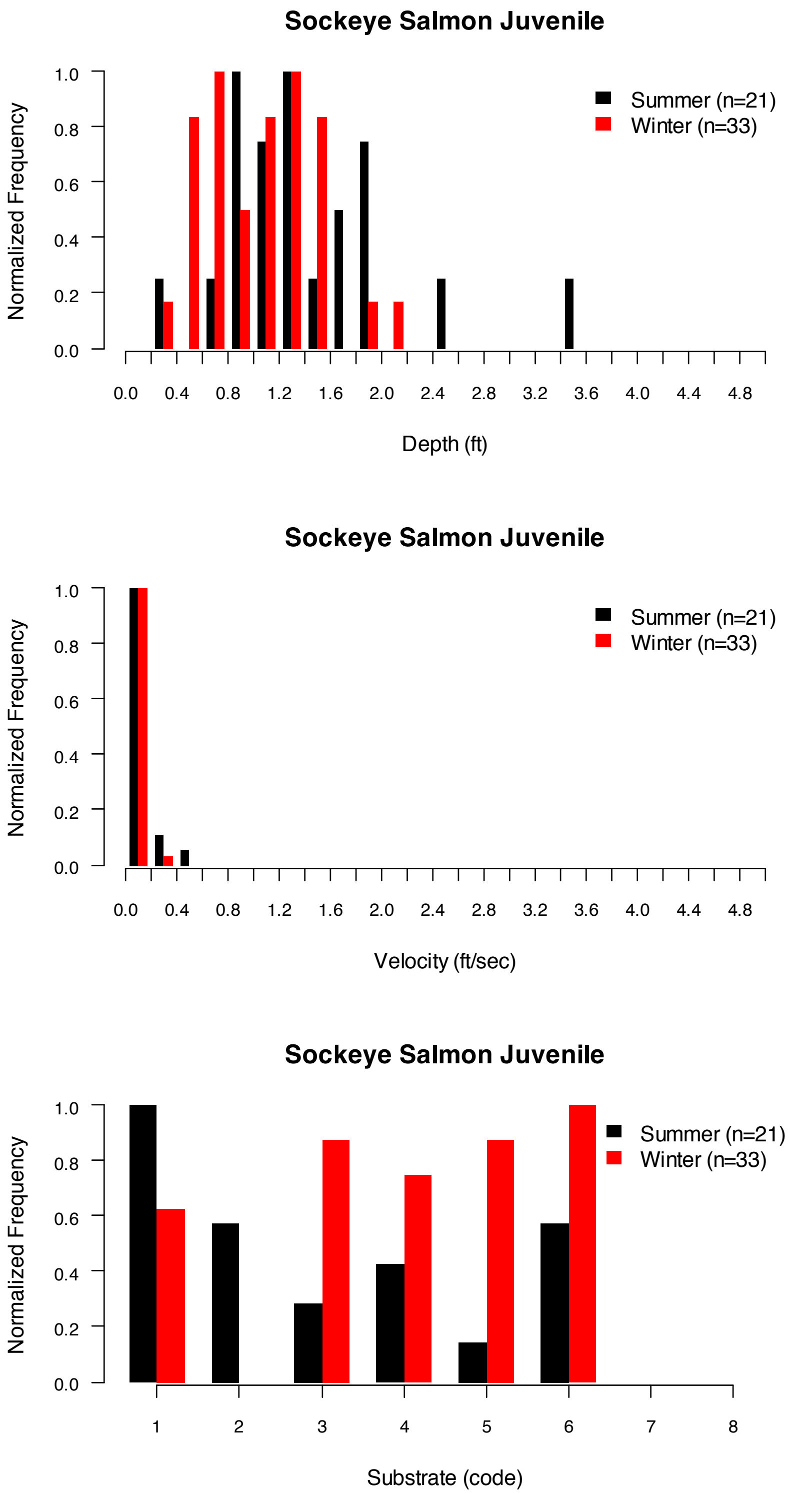

Figure D2-7. Sockeye salmon juvenile frequency distribution of microhabitat use by season: winter (February – April) and summer (May – September) surveys in the Susitna River, Alaska. Data Source: 2013-2014 HSC database.

ATTACHMENT 3: HSC HISTOGRAMS – 1980S AND 2013-2014 COMPARISON

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D Attachment 3

HSC Histograms (1980s Comparison)

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

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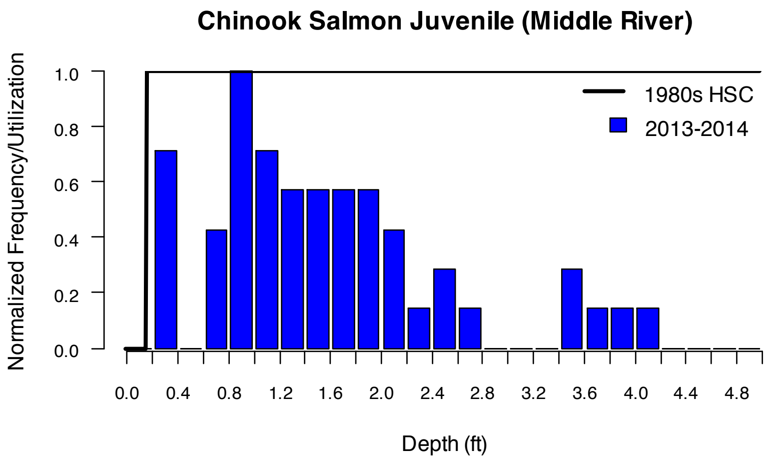


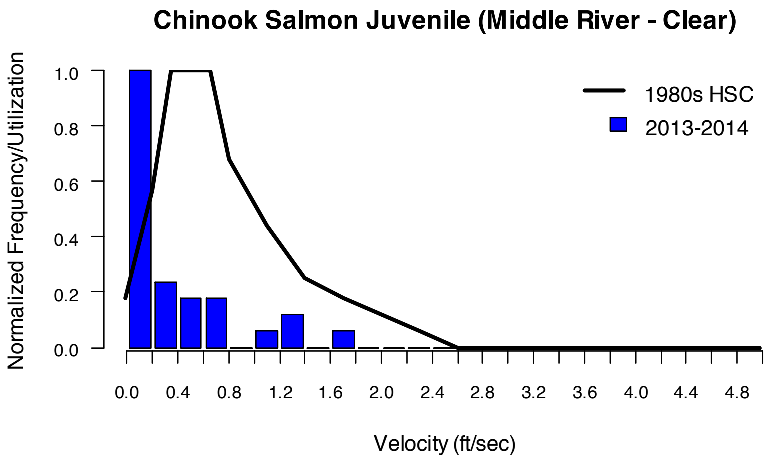
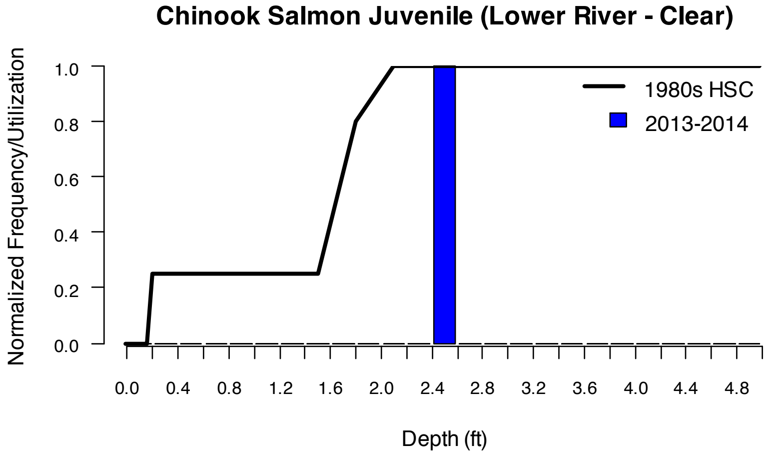


Figure D3-1. Comparison of HSC developed for Chinook salmon juvenile during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984a) for the Middle River Segment of the Susitna River, Alaska in clear water conditions (<30 NTU) and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).



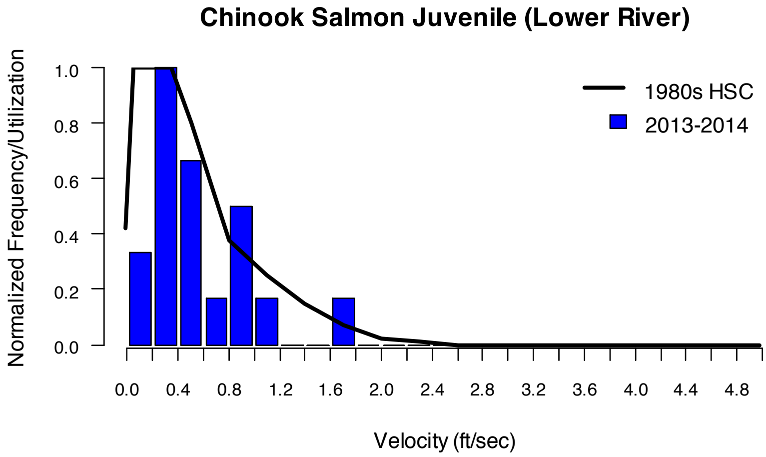


Figure D3-2. Comparison of HSC developed for Chinook salmon juvenile during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984a) for the Lower River Segment of the Susitna River, Alaska in clear water conditions (<30 NTU) and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).

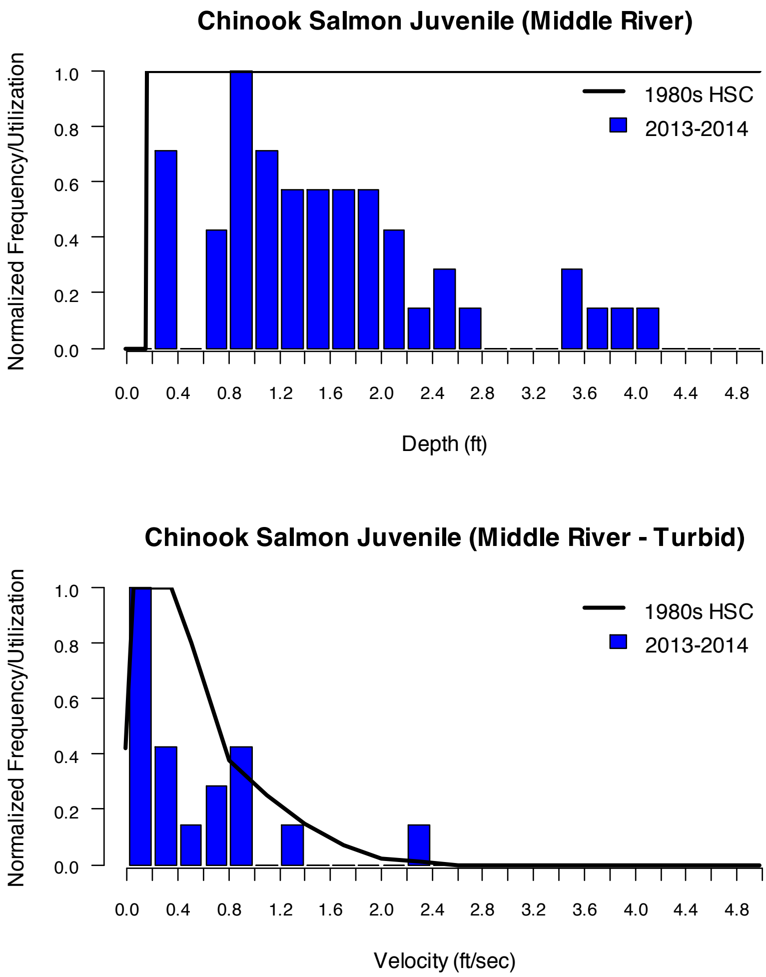
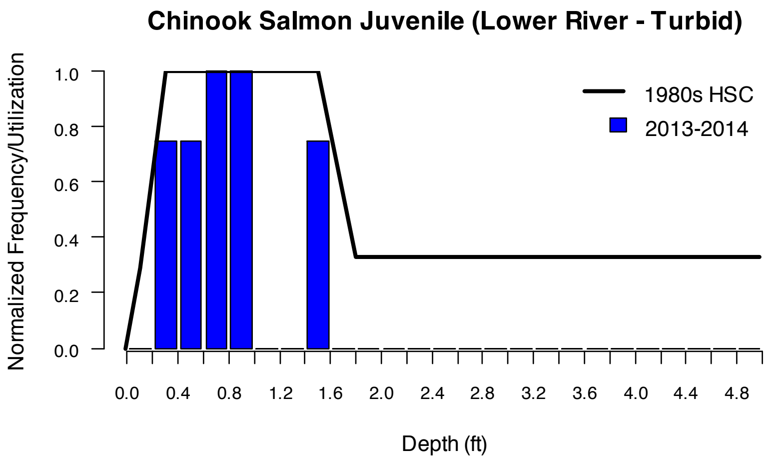


Figure D3-3. Comparison of HSC developed for Chinook salmon juvenile during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984a) for the Middle River Segment of the Susitna River, Alaska in turbid water conditions (>30 NTU) and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).



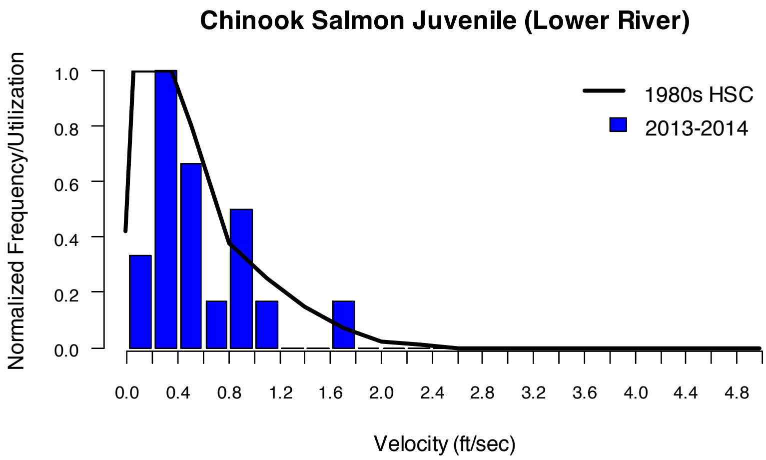


Figure D3-4. Comparison of HSC developed for Chinook salmon juvenile during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984a) for the Lower River Segment of the Susitna River, Alaska in turbid water conditions (>30 NTU) and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).

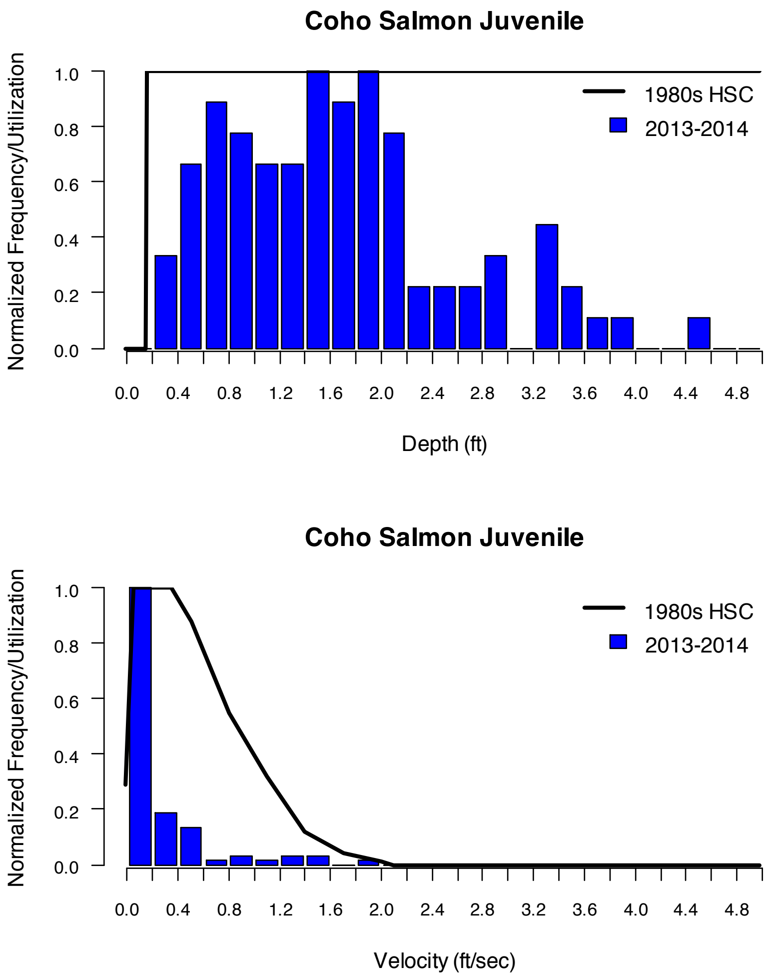


Figure D3-5. Comparison of HSC developed for coho salmon juvenile during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984a) for the Middle River Segment of the Susitna River, Alaska and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (3013-2014 HSC database).

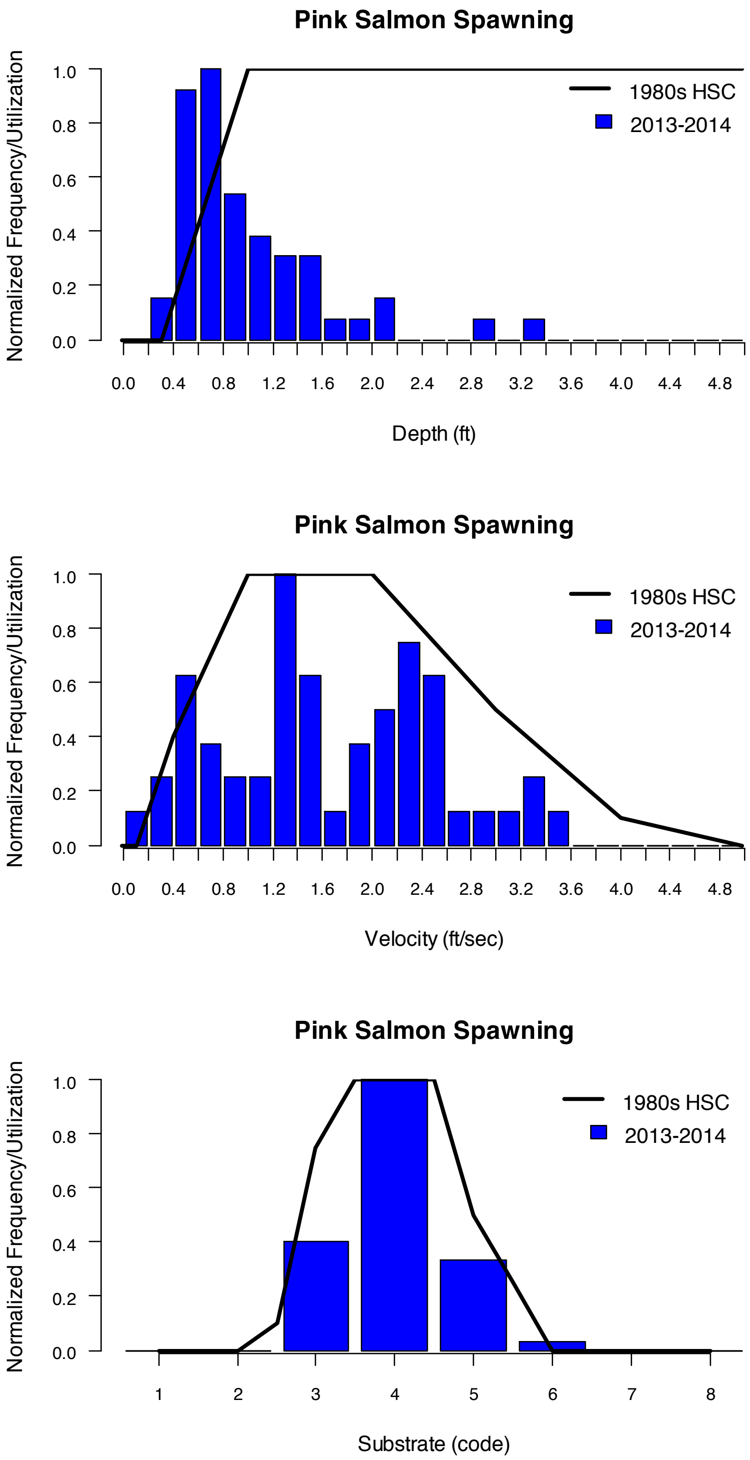
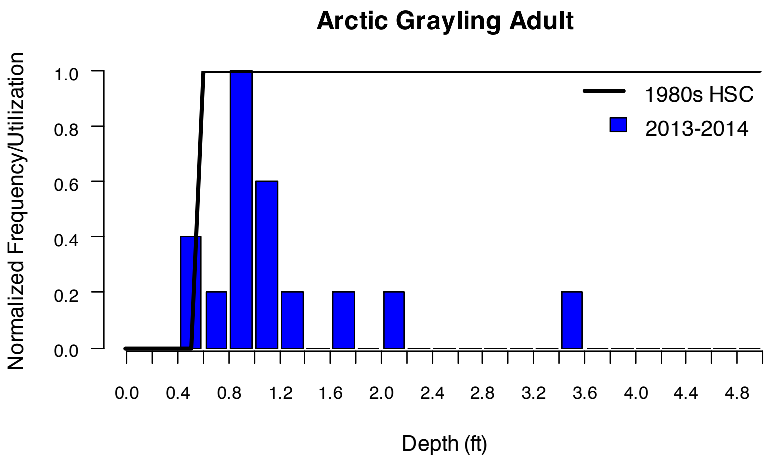


Figure D3-6. Comparison of HSC developed for pink salmon spawning during the 1980s Su-Hydro instream flow studies (Vincent-Lang et al. 1984b) for the Middle River Segment of the Susitna River, Alaska and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top), velocity (middle), and substrate (lower) microhabitat components (2013-2014 HSC database).



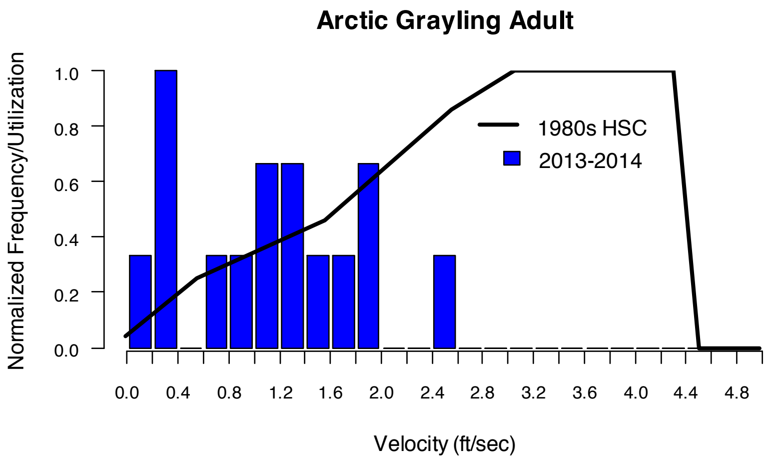


Figure D3-7. Comparison of HSC developed for Artic grayling adult during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984b) for the Middle River Segment of the Susitna River, Alaska and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).

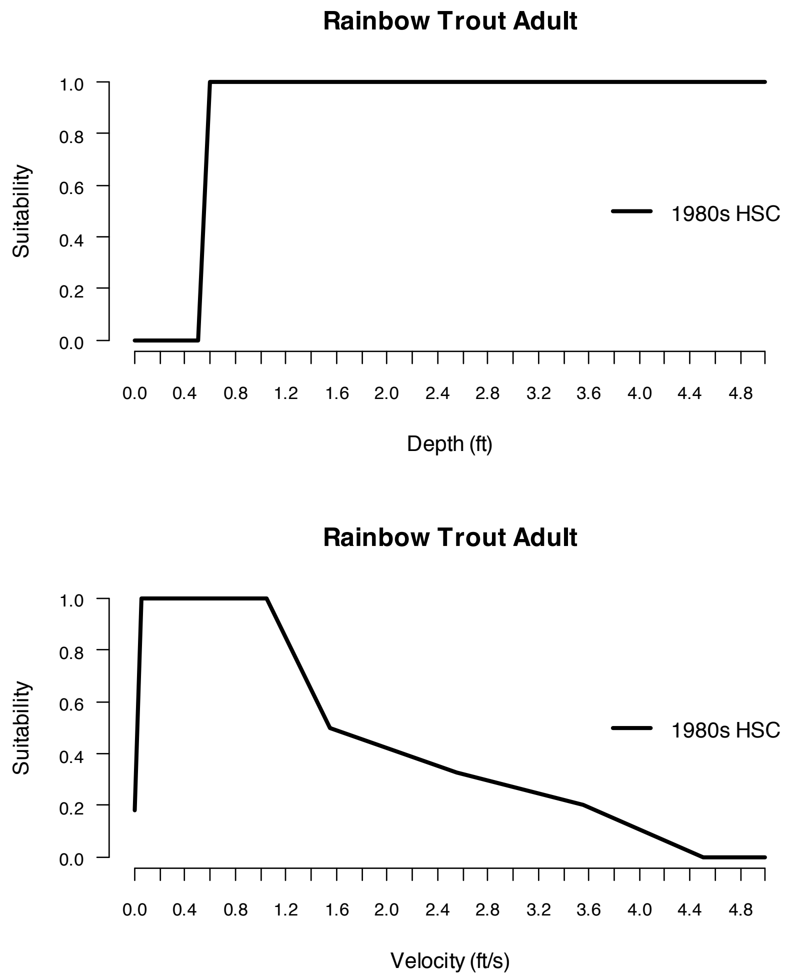
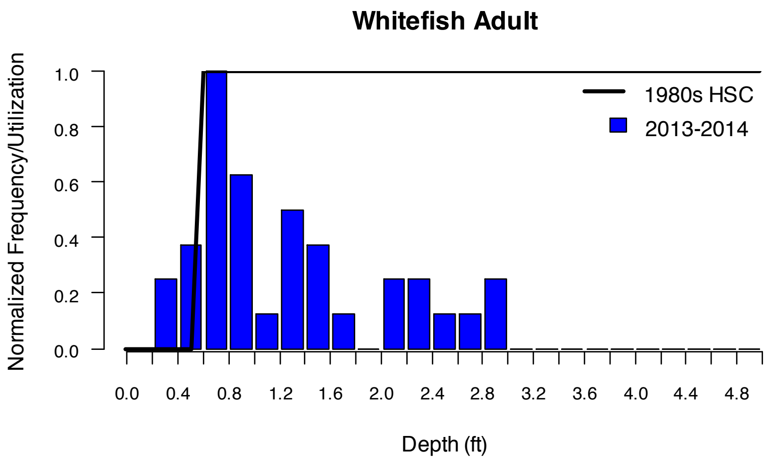


Figure D3-8. Comparison of HSC developed for rainbow trout adult during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984b) for the Middle River Segment of the Susitna River, Alaska and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).



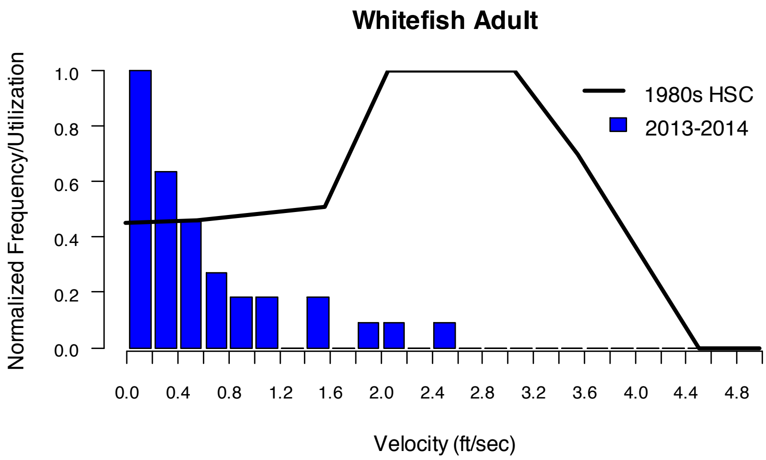


Figure D3-9. Comparison of HSC developed for whitefish adult during the 1980s Su-Hydro instream flow studies (Suchanek et al. 1984b) for the Middle River Segment of the Susitna River, Alaska and histogram plots generated from 2013-2014 HSC observations and normalized to the maximum frequency equal to 1.0 for depth (top) and velocity (lower) microhabitat components (2013-2014 HSC database).

ATTACHMENT 4: 2013-2014 MICROHABITAT USE FREQUENCY DISTRIBUTIONS

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D Attachment 4

2013-2014 Microhabitat Use Frequency Distributions

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

Table D4-1. Frequency distribution (percentiles) of microhabitat use variables for individual fish species and life stages by season (summer and winter) and river segment (lower and upper) collected during 2013 and 2014 surveys of the Susitna River, Alaska.

Species	Life Stage	Variable	Season	River Segment	Percentile				
					0%	25%	50%	75%	100%
Chinook	Fry	Depth (ft)	Summer	Middle River	0.07	0.50	0.80	1.30	3.40
				Lower River	0.25	0.60	0.95	1.30	2.00
				All	0.07	0.50	0.80	1.30	3.40
			Winter	Middle River	0.40	0.50	0.60	1.00	1.60
		Velocity (ft/sec)	Summer	Middle River	0.00	0.07	0.27	0.45	1.73
				Lower River	0.00	0.13	0.50	0.80	2.55
				All	0.00	0.07	0.29	0.50	2.55
			Winter	Middle River	0.03	0.13	0.18	0.22	0.74
		Substrate (code)	Summer	Middle River	1.00	4.00	5.00	6.00	8.00
				Lower River	1.00	1.00	3.00	4.25	6.00
				All	1.00	3.00	5.00	6.00	8.00
			Winter	Middle River	1.00	4.00	4.00	5.00	6.00
	Juvenile	Depth (ft)	Summer	Middle River	0.20	0.80	1.40	2.00	5.00
				Lower River	0.25	0.40	0.73	0.90	2.40
				All	0.20	0.73	1.15	1.85	5.00
			Winter	Middle River	0.20	0.60	0.90	1.19	2.40
		Velocity (ft/sec)	Summer	Middle River	0.00	0.05	0.21	0.68	2.30
				Lower River	0.00	0.28	0.46	0.86	1.70
				All	0.00	0.05	0.28	0.73	2.30
			Winter	Middle River	0.01	0.07	0.08	0.21	0.89
		Substrate (code)	Summer	Middle River	1.00	1.00	2.00	6.00	7.00
				Lower River	1.00	1.00	1.00	4.00	5.00
				All	1.00	1.00	2.00	5.00	7.00
			Winter	Middle River	1.00	1.75	5.00	6.00	6.00

Species	Life Stage	Variable	Season	River Segment	Percentile				
					0%	25%	50%	75%	100%
Chum	Fry	Depth (ft)	Summer	Middle River	0.07	0.40	0.70	1.00	3.60
				Lower River	0.20	0.55	0.75	1.10	2.90
				All	0.07	0.45	0.70	1.00	3.60
			Winter	Middle River	0.20	0.30	0.45	0.81	1.85
		Velocity (ft/sec)	Summer	Middle River	0.00	0.05	0.21	0.50	1.80
				Lower River	0.00	0.21	0.57	0.95	2.33
				All	0.00	0.07	0.32	0.65	2.33
			Winter	Middle River	0.03	0.07	0.21	0.45	0.65
		Substrate (code)	Summer	Middle River	1.00	1.00	5.00	6.00	7.00
				Lower River	1.00	1.00	2.00	4.00	6.00
				All	1.00	1.00	5.00	6.00	7.00
			Winter	Middle River	1.00	2.25	4.00	5.00	7.00
	Spawning	Depth (ft)	Summer	Middle River	0.30	0.80	1.15	1.60	3.30
		Velocity (ft/sec)	Summer	Middle River	0.00	0.06	0.18	0.54	2.33
		Substrate (code)	Summer	Middle River	1.00	4.00	4.00	5.00	6.00

Species	Life Stage	Variable	Season	River Segment	Percentile 0%	25%	50%	75%	100%
Coho	Fry	Depth (ft)	Summer	Middle River	0.07	0.60	0.90	1.40	3.20
				Lower River	0.60	0.85	1.20	1.70	2.90
				All	0.07	0.60	0.90	1.44	3.20
			Winter	Middle River	0.30	0.44	0.68	0.90	2.00
		Velocity (ft/sec)	Summer	Middle River	0.00	0.01	0.13	0.27	1.63
				Lower River	0.00	0.00	0.05	0.18	0.94
				All	0.00	0.00	0.13	0.27	1.63
			Winter	Middle River	0.03	0.12	0.21	0.32	0.93
		Substrate (code)	Summer	Middle River	1.00	1.00	4.00	6.00	8.00
				Lower River	1.00	1.00	1.00	2.00	6.00
				All	1.00	1.00	3.50	5.00	8.00
			Winter	Middle River	1.00	1.00	4.00	5.00	7.00
	Juvenile	Depth (ft)	Summer	Middle River	0.30	0.88	1.58	2.00	4.40
				Lower River	0.40	1.08	1.30	1.60	2.90
				All	0.30	0.90	1.50	2.00	4.40
			Winter	Middle River	0.20	0.50	0.75	1.40	2.70
		Velocity (ft/sec)	Summer	Middle River	0.00	0.01	0.05	0.29	1.95
				Lower River	0.00	0.07	0.17	0.24	0.45
				All	0.00	0.01	0.05	0.30	1.95
			Winter	Middle River	0.00	0.05	0.12	0.24	1.15
		Substrate (code)	Summer	Middle River	1.00	1.00	2.00	5.00	7.00
				Lower River	1.00	1.00	1.00	1.50	4.00
				All	1.00	1.00	1.00	5.00	7.00
			Winter	Middle River	1.00	1.00	1.00	4.00	6.00
	Spawning	Depth (ft)	Summer	Middle River	1.40	1.45	1.50	1.53	1.55
		Velocity (ft/sec)	Summer	Middle River	1.78	1.81	1.83	1.90	1.96
		Substrate (code)	Summer	Middle River	4.00	4.00	4.00	4.00	4.00
Pink	Fry	Depth (ft)	Summer	All	0.15	0.30	0.50	0.93	2.00
		Velocity (ft/sec)	Summer	All	0.00	0.16	0.36	0.55	1.15
		Substrate (code)	Summer	All	1.00	4.50	5.00	5.50	6.00
	Spawning	Depth (ft)	Summer	Middle River	0.30	0.50	0.75	1.20	3.20
		Velocity (ft/sec)	Summer	Middle River	0.05	1.15	1.52	2.33	3.47
		Substrate (code)	Summer	Middle River	3.00	4.00	4.00	4.00	6.00

Species	Life Stage	Variable	Season	River Segment	Percentile 0%	25%	50%	75%	100%
Sockeye	Fry	Depth (ft)	Summer	Middle River	0.07	0.40	0.70	1.10	3.65
				Lower River	0.20	0.68	0.90	1.23	2.90
				All	0.07	0.45	0.70	1.15	3.65
			Winter	Middle River	0.15	0.38	0.60	0.78	1.35
		Velocity (ft/sec)	Summer	Middle River	0.00	0.01	0.07	0.29	1.62
				Lower River	0.00	0.00	0.22	0.59	2.10
				All	0.00	0.00	0.08	0.31	2.10
			Winter	Middle River	0.03	0.07	0.13	0.28	0.57
		Substrate (code)	Summer	Middle River	1.00	1.00	5.00	5.00	8.00
				Lower River	1.00	1.00	1.00	3.00	5.00
				All	1.00	1.00	4.00	5.00	8.00
			Winter	Middle River	1.00	1.00	2.00	5.00	6.00
	Juvenile	Depth (ft)	Summer	All	0.35	0.95	1.25	1.70	3.55
			Winter	Middle River	0.30	0.60	1.00	1.30	2.10
		Velocity (ft/sec)	Summer	All	0.00	0.00	0.05	0.16	0.50
			Winter	Middle River	0.00	0.00	0.03	0.07	0.23
		Substrate (code)	Summer	All	1.00	1.00	2.00	4.00	6.00
			Winter	Middle River	1.00	3.00	4.00	5.00	6.00
	Spawning	Depth (ft)	Summer	Middle River	0.35	0.89	1.20	1.50	3.15
		Velocity (ft/sec)	Summer	Middle River	0.00	0.05	0.13	0.31	2.44
		Substrate (code)	Summer	Middle River	1.00	4.00	4.00	4.00	6.00
Arctic Grayling	Fry	Depth (ft)	Summer	All	0.25	0.89	1.30	1.80	3.75
		Velocity (ft/sec)	Summer	All	0.00	0.05	0.08	0.24	2.97
		Substrate (code)	Summer	All	1.00	1.00	1.00	5.00	7.00
	Juvenile	Depth (ft)	Summer	All	0.20	0.50	0.60	1.08	3.55
		Velocity (ft/sec)	Summer	All	0.01	0.19	0.46	0.77	2.94
		Substrate (code)	Summer	All	1.00	2.00	5.00	6.00	7.00
	Adult	Depth (ft)	Summer	All	0.40	0.80	0.90	1.15	3.40
		Velocity (ft/sec)	Summer	All	0.13	0.54	1.18	1.55	2.50
		Substrate (code)	Summer	All	1.00	3.50	6.00	6.00	7.00
Burbot	Adult	Depth (ft)	Summer	All	0.40	0.93	1.35	2.34	3.00
		Velocity (ft/sec)	Summer	All	0.00	0.00	0.17	1.11	1.85
		Substrate (code)	Summer	All	1.00	1.00	1.50	5.75	7.00
Dolly Varden	Fry	Depth (ft)	Summer	All	0.15	0.30	0.65	0.95	1.80
		Velocity (ft/sec)	Summer	All	0.01	0.08	0.24	0.49	0.79
		Substrate (code)	Summer	All	1.00	2.00	5.00	6.00	7.00

Species	Life Stage	Variable	Season	River Segment	Percentile				
					0%	25%	50%	75%	100%
Longnose Sucker	Fry	Depth (ft)	Summer	Middle River	0.30	0.58	0.95	1.33	2.45
				Lower River	0.40	0.70	0.95	1.15	2.00
				All	0.30	0.60	0.95	1.30	2.45
		Velocity (ft/sec)	Summer	Middle River	0.00	0.01	0.07	0.40	1.80
				Lower River	0.00	0.14	0.27	0.52	0.94
				All	0.00	0.01	0.07	0.48	1.80
		Substrate (code)	Summer	Middle River	1.00	1.00	1.00	4.00	7.00
				Lower River	1.00	1.00	1.00	3.00	5.00
	Fry			All	1.00	1.00	1.00	4.00	7.00
	Juvenile	Depth (ft)	Summer	All	0.20	0.50	0.80	1.40	5.00
	Juvenile	Velocity (ft/sec)	Summer	All	0.00	0.05	0.24	0.51	1.99
	Juvenile	Substrate (code)	Summer	All	1.00	1.00	2.00	5.00	7.00
	Adult	Depth (ft)	Summer	All	0.40	0.90	1.30	2.00	3.00
	Adult	Velocity (ft/sec)	Summer	All	0.00	0.07	0.24	0.57	2.94
	Adult	Substrate (code)	Summer	All	1.00	1.00	2.00	5.00	7.00
Whitefish	Fry	Depth (ft)	Summer	Middle River	0.05	0.65	0.98	1.30	3.20
				Lower River	0.20	0.60	0.80	1.00	2.90
				All	0.05	0.60	0.90	1.25	3.20
		Velocity (ft/sec)	Summer	Middle River	0.00	0.05	0.25	0.61	2.94
				Lower River	0.00	0.00	0.50	0.73	1.34
				All	0.00	0.05	0.29	0.66	2.94
		Substrate (code)	Summer	Middle River	1.00	1.00	2.00	6.00	7.00
				Lower River	1.00	1.00	1.00	2.00	4.00
				All	1.00	1.00	1.00	5.00	7.00
	Juvenile	Depth (ft)	Summer	All	0.20	0.35	0.60	1.00	2.70
		Velocity (ft/sec)	Summer	All	0.00	0.06	0.29	0.62	2.94
		Substrate (code)	Summer	All	1.00	1.00	5.00	6.00	7.00
	Adult	Depth (ft)	Summer	All	0.25	0.68	0.95	1.53	2.90
		Velocity (ft/sec)	Summer	All	0.00	0.09	0.36	0.80	2.55
		Substrate (code)	Summer	All	1.00	1.00	2.00	5.00	7.00

ATTACHMENT 5: UNIVARIATE PREFERENCE HISTOGRAMS

Susitna-Watana Hydroelectric Project

(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

2014-2015 Study Implementation Report

Appendix D Attachment 5

Univariate Preference Histograms

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

November 2015

LIST OF FIGURES

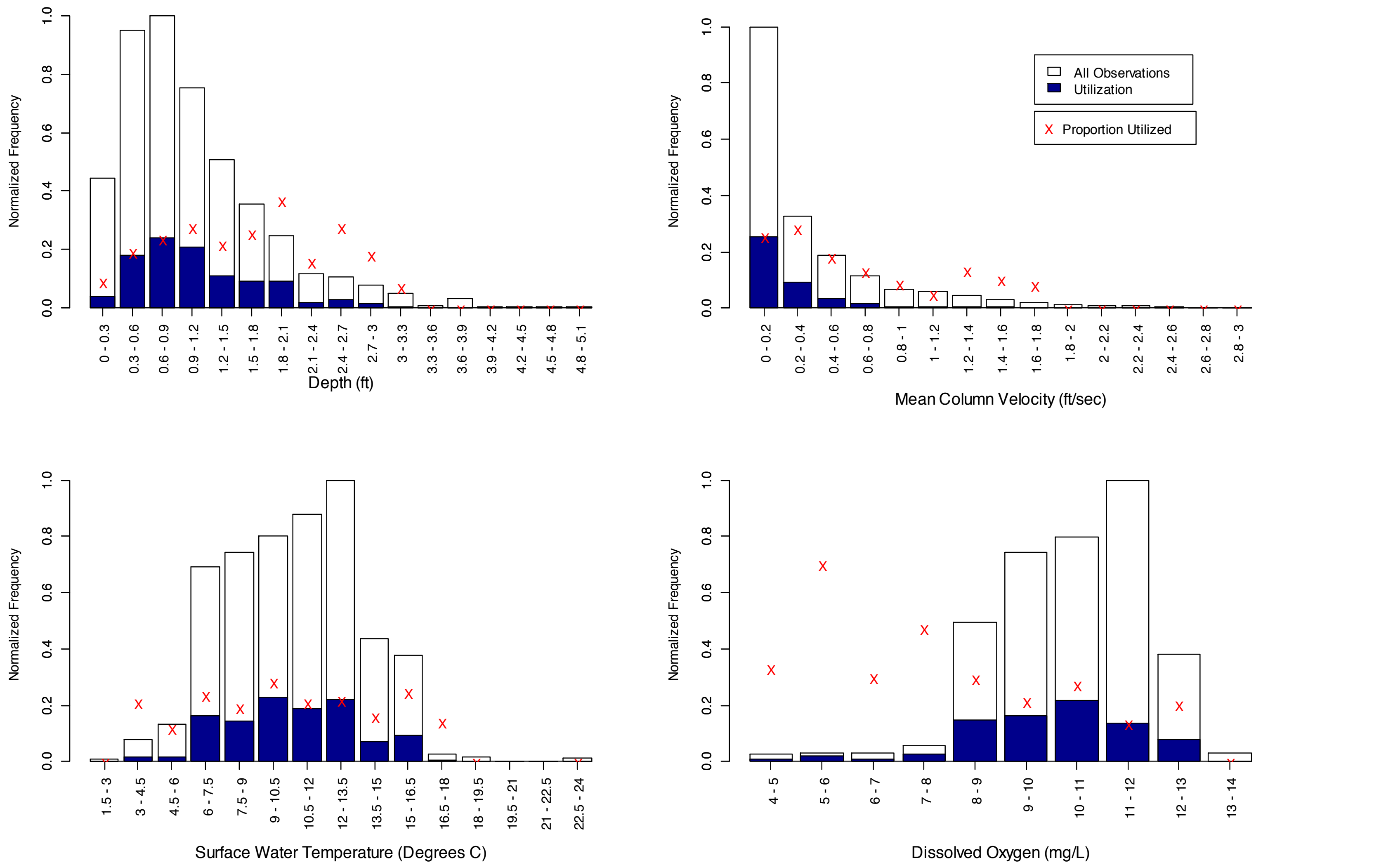


Figure D5-1. Normalized utilization for four continuous habitat variables for Chinook salmon fry.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

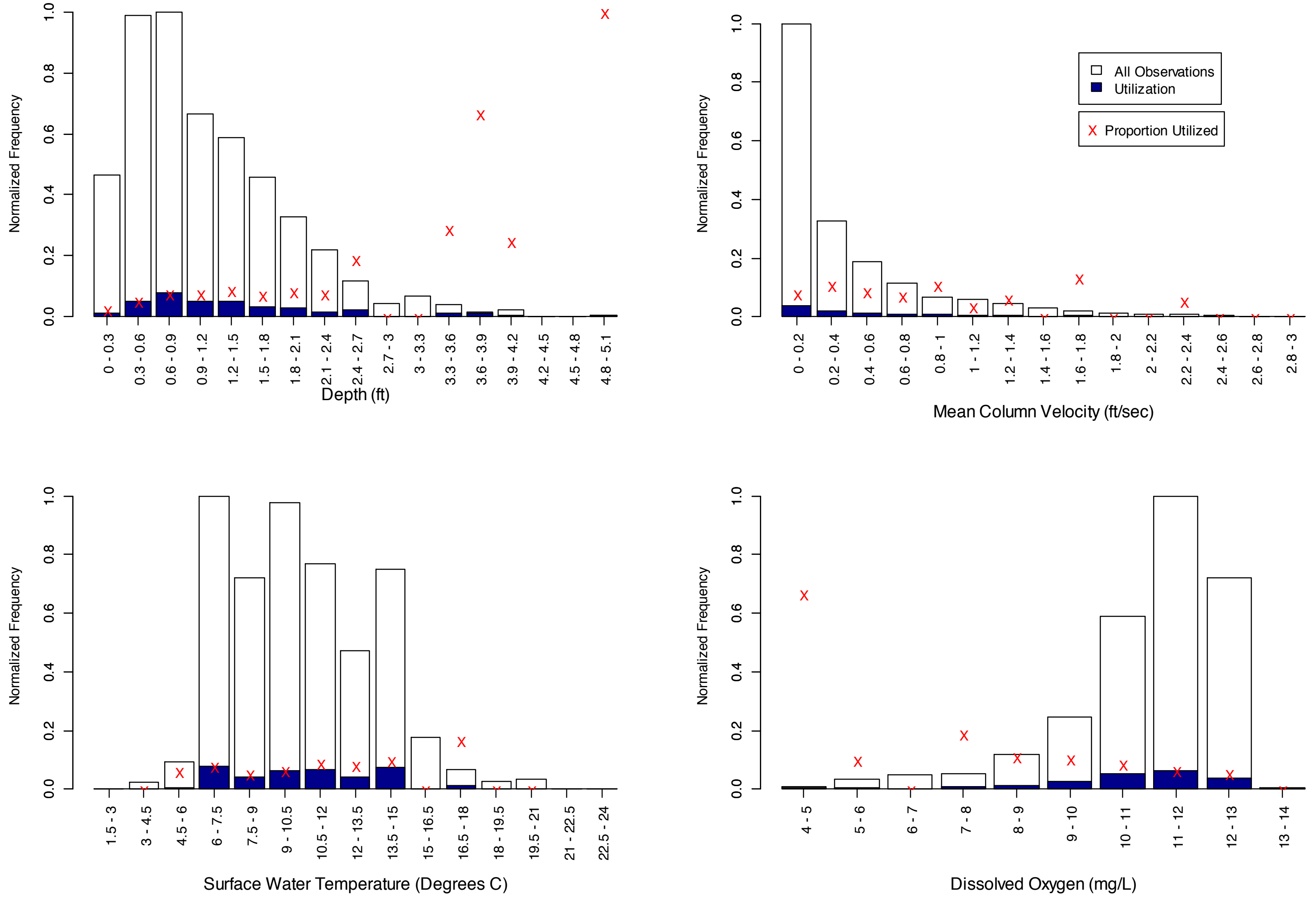


Figure D5-2. Normalized utilization for four continuous habitat variables for juvenile Chinook salmon.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

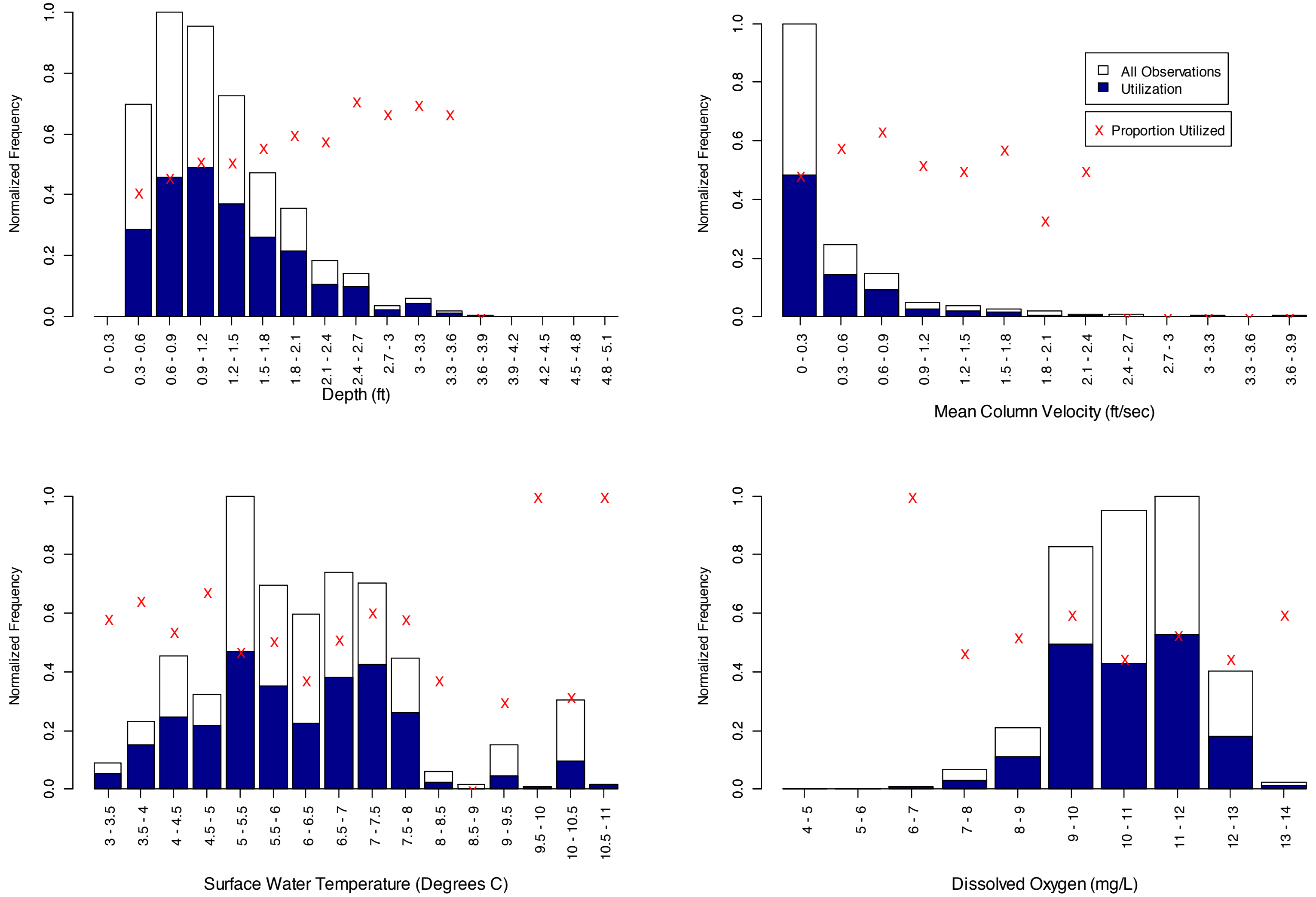


Figure D5-3. Normalized utilization for four continuous habitat variables for spawning chum salmon.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

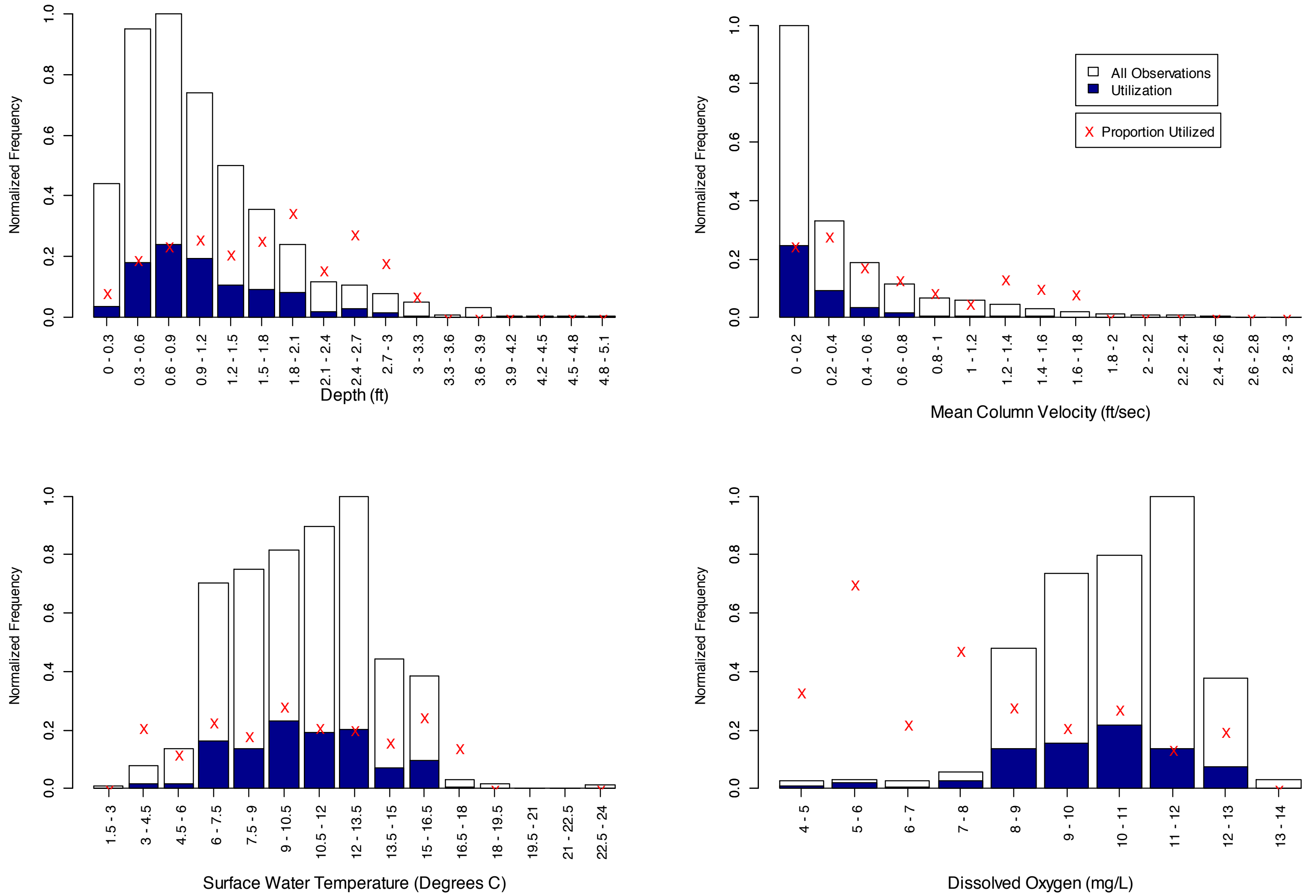


Figure D5-4. Normalized utilization for four continuous habitat variables for coho salmon fry.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

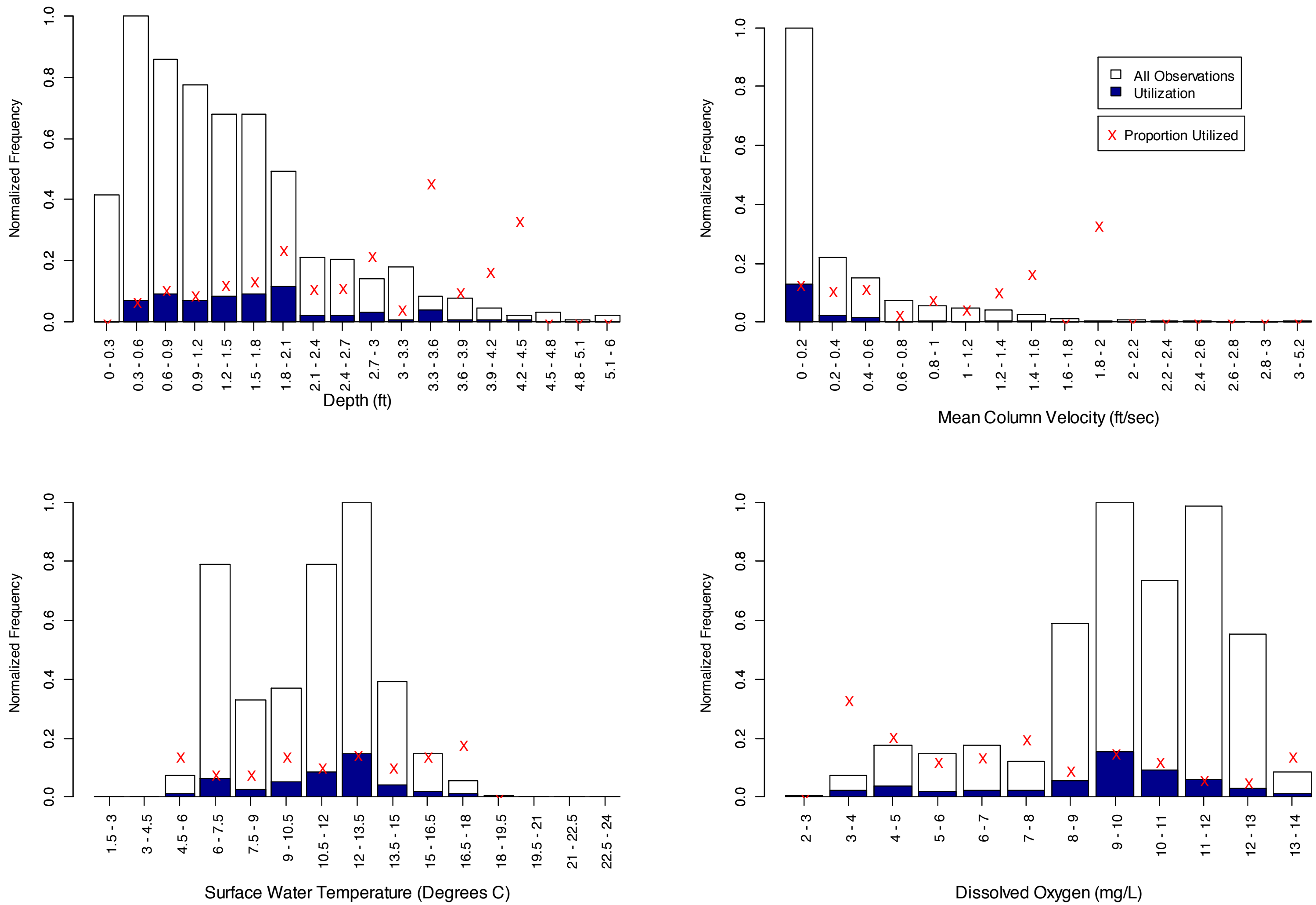


Figure D5-5. Normalized utilization for four continuous habitat variables for juvenile coho salmon.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

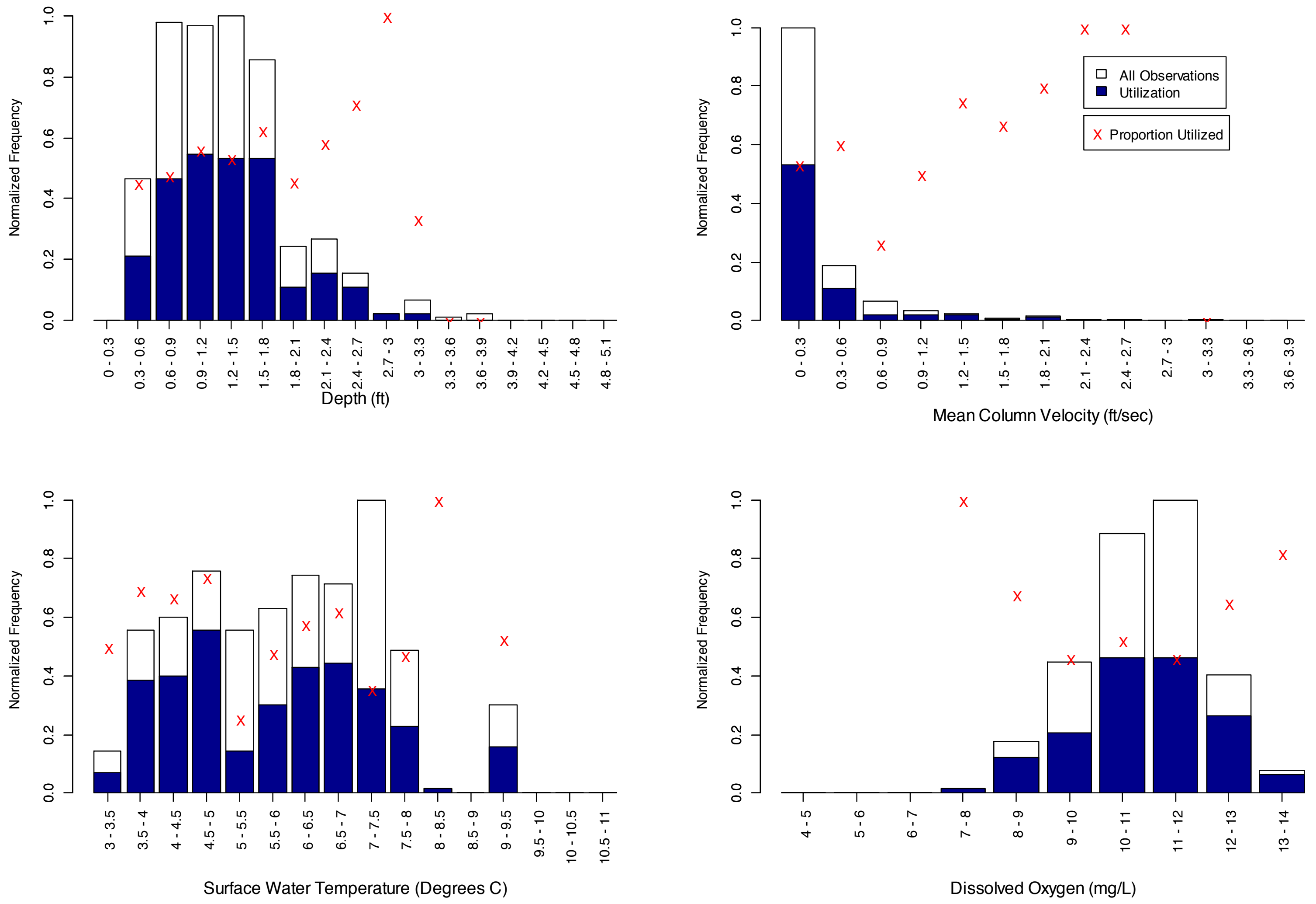


Figure D5-6. Normalized utilization for four continuous habitat variables for sockeye salmon spawning.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

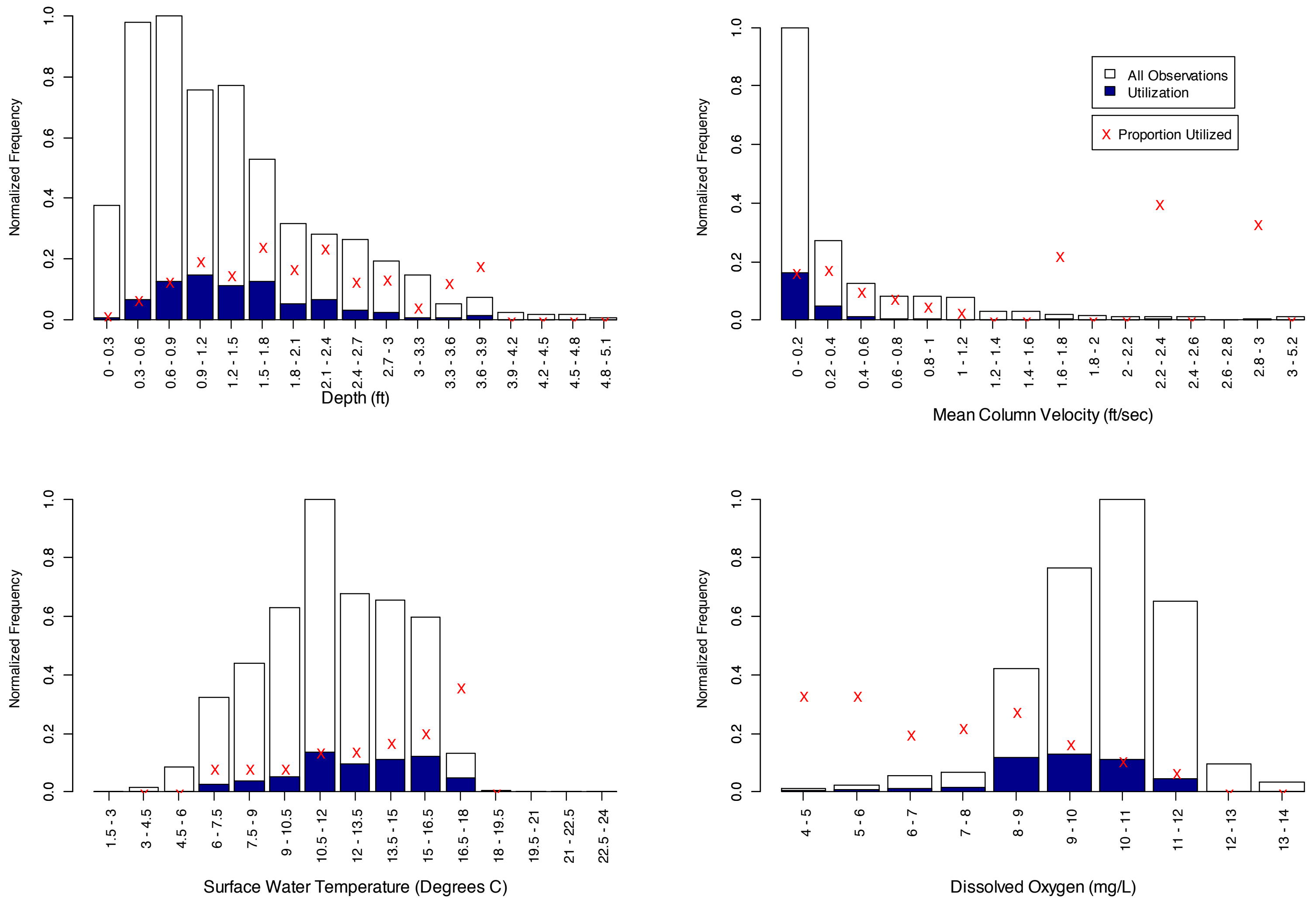


Figure D5-7. Normalized utilization for four continuous habitat variables for Arctic grayling fry.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

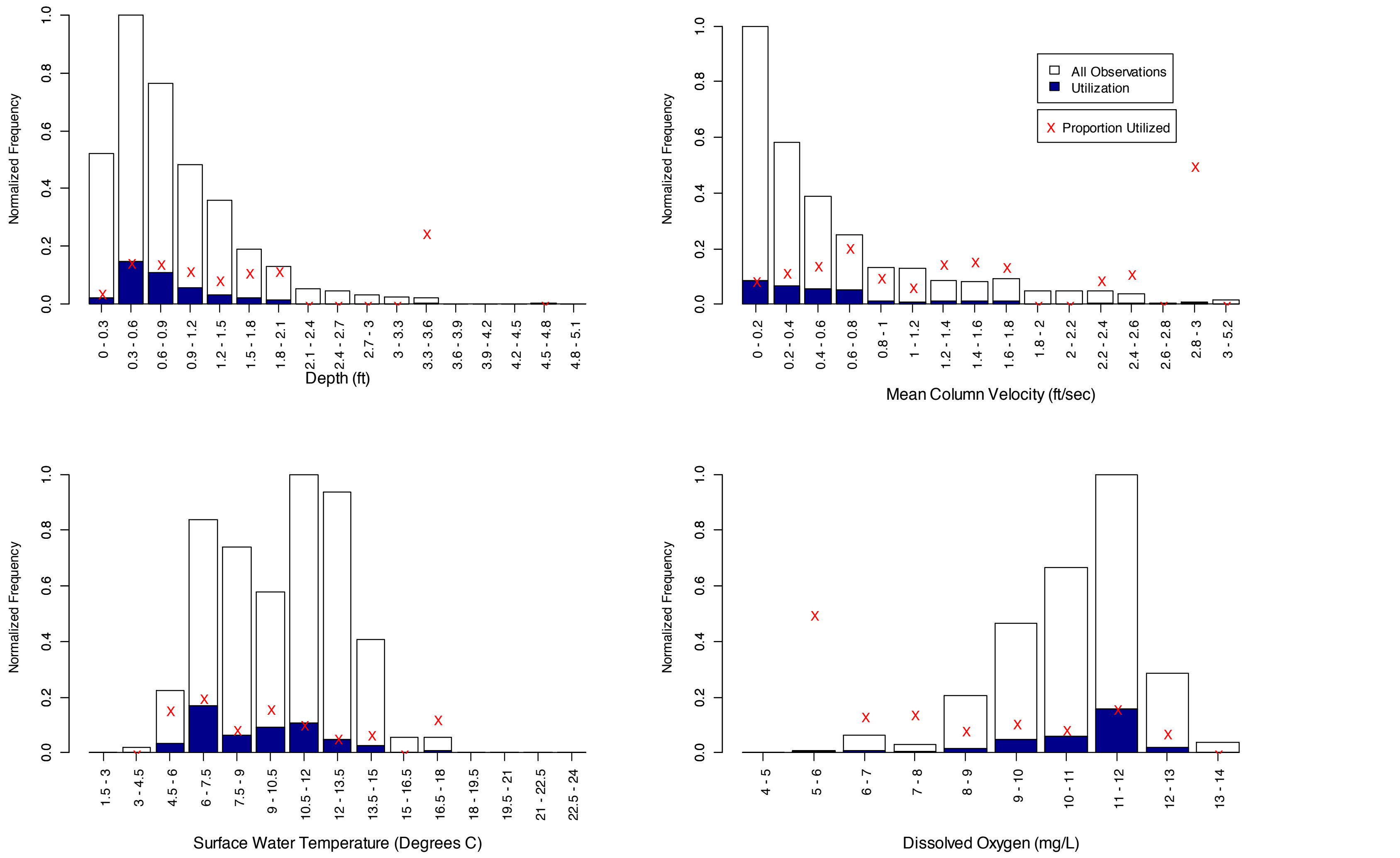


Figure D5-8. Normalized utilization for four continuous habitat variables for juvenile Arctic grayling.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

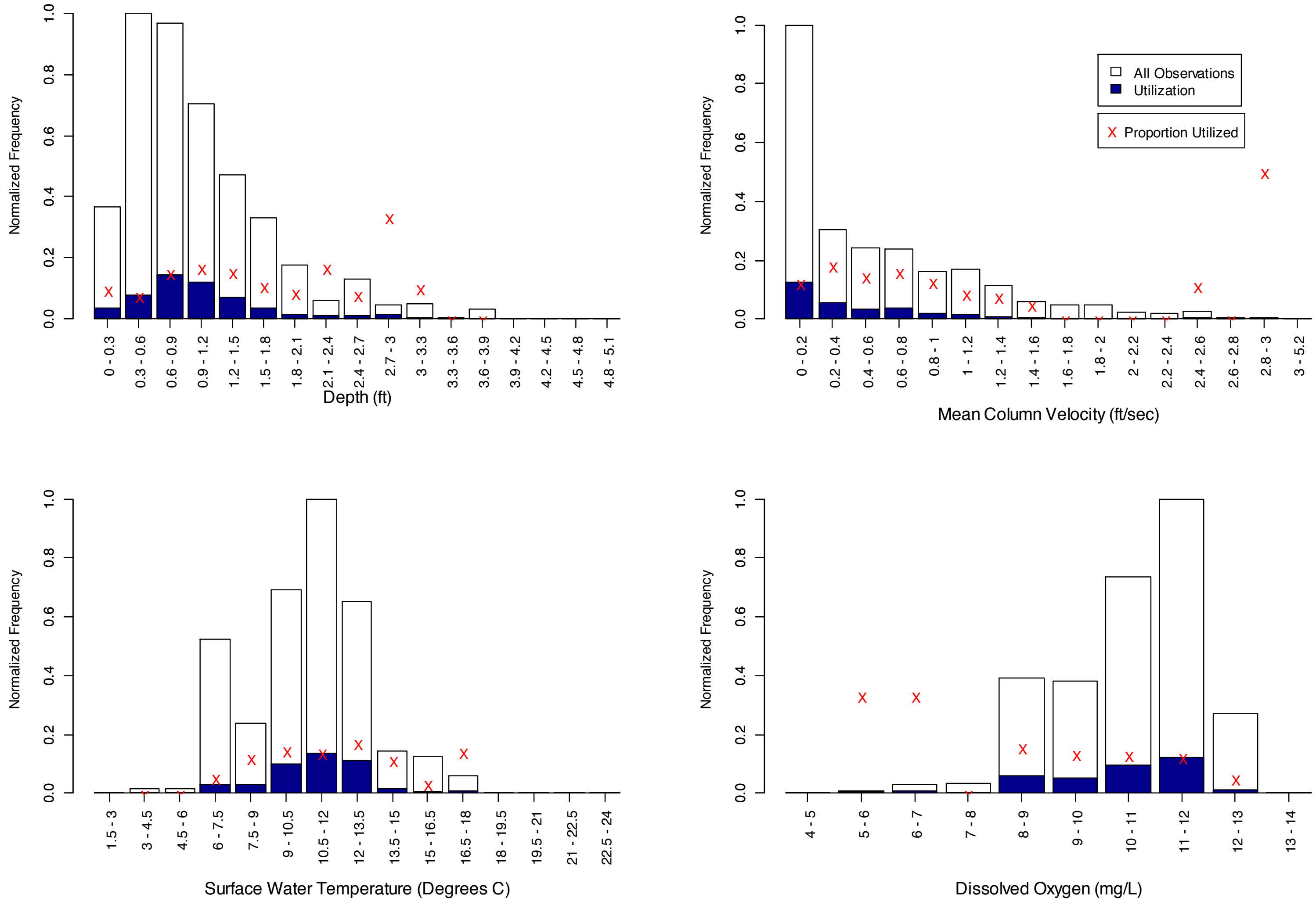


Figure D5-9. Normalized utilization for four continuous habitat variables for whitefish fry.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

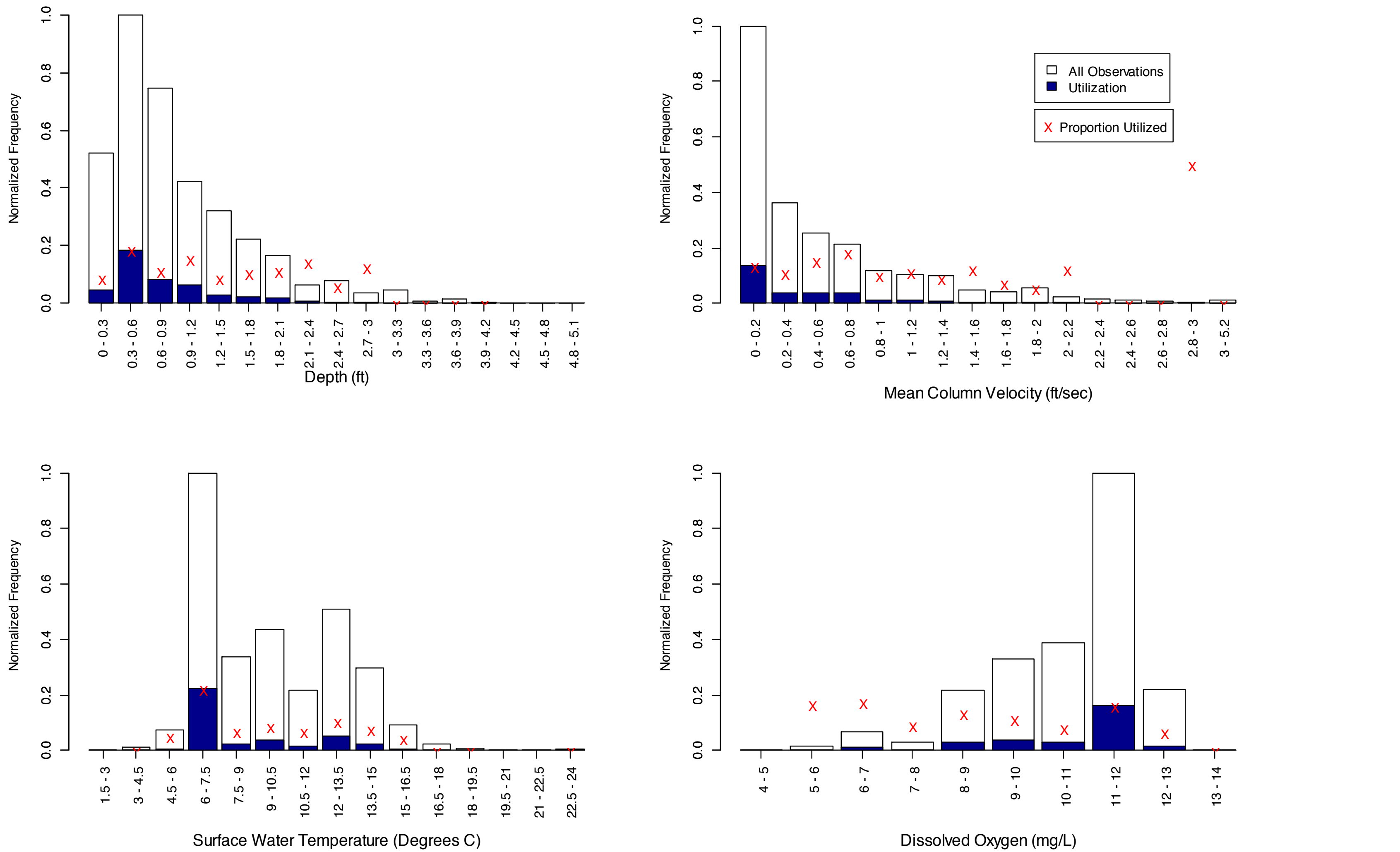


Figure D5-10. Normalized utilization for four continuous habitat variables for juvenile whitefish.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

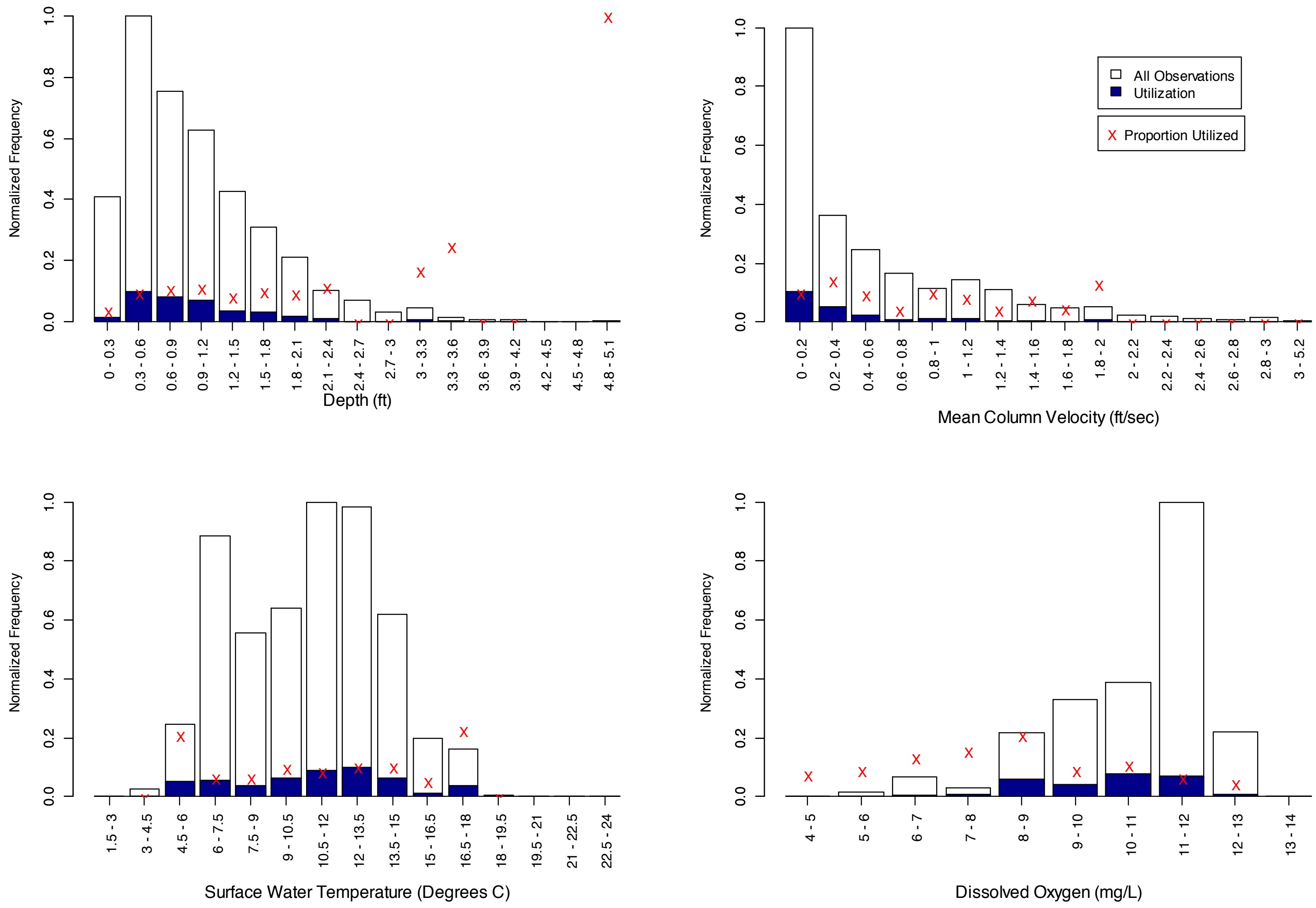


Figure D5-11. Normalized utilization for four continuous habitat variables for juvenile longnose sucker.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.

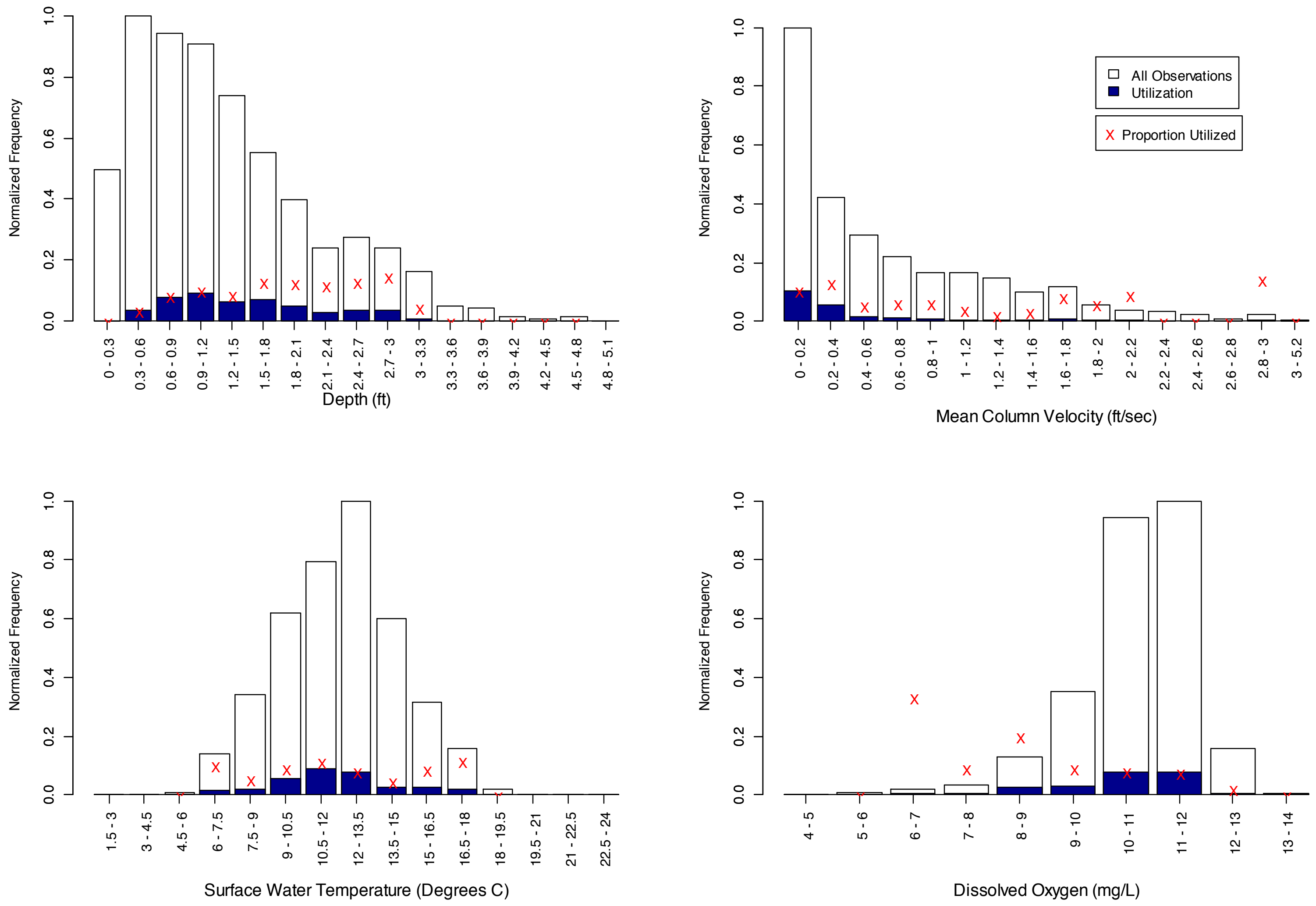


Figure D5-12. Normalized utilization for four continuous habitat variables for adult longnose sucker.

Note: Utilization data are normalized to availability of habitat for sites where fish were observed only.