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Assessment of Chinook Salmon Smolt Habitat Use in the lower Trinity River.

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Abstract. This report summarizes data collections and analyses to assess variation in physical habitat characteristics selected by Chinook Salmon smolts in the Trinity River. Spatially, this study focuses on two mainstem Trinity River reaches located downstream of the confluence of the North Fork Trinity River, each several kilometers in length. This project was initiated to inform the extension of the Trinity River Stream Salmonid Simulator (S3) model from the confluence of the North Fork Trinity River to the confluence with the Klamath River.

Several methods for observing and enumerating juvenile Chinook Salmon were explored, with the goal to compliment habitat models developed for Chinook Salmon fry and parr in the upper portion of the Trinity River mainstem. Methods applying various sonar camera technologies were deemed ineffective for the intended needs of the project. To complete the project, direct-observation snorkel counts we chosen as the data collection method.

Time spent conducting field sampling methodology trials and elevated flows causing turbid waters too dark for effective sampling caused delays in implementation of the data collection. Eventually, assessments of habitat use were collected at the desired sites, but during a single week in August. The single week of sampling is generally thought to be too short to capture temporal variation in habitat use. Additionally, the August period of collection is rather late in the period of time when juvenile Chinook Salmon inhabit the Trinity River, and too few wild fish may have been present to accurately reflect the habitat selection of larger juveniles.

The counts of Chinook Salmon juveniles from the survey reflect very low numbers, with nearly 80% of the counts recorded as zeros. A statistical analysis of the counts suggests that juveniles in the lower river select habitat locations according to proximity to escape cover or river edge, but not according to the depth or velocity of the water flowing through the habitat area. These results are caveated with notes on the seasonally late and narrow window in which sampling occurred. However, the results are potentially relevant for actively migrating fish that might not be rearing in habitat areas, but rather using the mainstem river as a migration corridor to the Pacific Ocean.

Introduction

The Trinity Stream Salmonid Simulator model (S3) was initially constructed for the mainstem River between Lewiston Dam and the North Fork Trinity River (hereafter: restoration reach). This allowed for applications of S3 within the section of river under direct restoration activities via the Trinity River Restoration Program (TRRP). The S3 model will contribute significantly to the TRRP Decision Support System (DSS), which is an adaptive management monitoring, research, and planning tool. Additionally, the S3 model will be extended to the mainstem Trinity River confluence with the Klamath River. This extension will allow the Trinity S3 model to link directly to the Klamath S3 model, and facilitate further extensions of the S3 model (e.g., spawning salmon migration). Though much of the model structure and physical inputs required to construct the lower Trinity S3 model will be leveraged from the upper river model, development of several lower river model components is necessary. One of those components is the habitat selection behavior of Chinook Salmon smolts in the lower river, and is the focus of this report.

A comprehensive assessment of habitat use has been completed in the restoration reach (Rupert et al. in review; Som et al. 2018), and so this Task first sought to address the question: does it appear that habitat use by smolts differs in the lower river, as compared to similar or smaller juveniles in the upper river? Structurally, the lower river contains a different assemblage of physical habitat characteristics from that which exists in the upper river, and hence were not sampled or evaluated in prior TRRP juvenile habitat studies. Of particular interest was collection of fish use data for riverine conditions not found in the upper river, thereby directing this effort to isolate physical variable ranges that do not exist or were not sampled in the upper river in previous studies (e.g., deeper water).

Methods

Site Selection

Fish habitat use data were obtained at two sections of river between the Trinity River confluences with the North Fork Trinity and Klamath Rivers (Figure 1). Habitat use data were collected at these riverine sections because they are also the locations of 2-dimensional hydrodynamic model (2DHM) construction. These 2DHMs are being constructed to aid in the development of the lower river S3 model, and each contain a suite of contrasting habitat unit morphologies and gradients. To select the

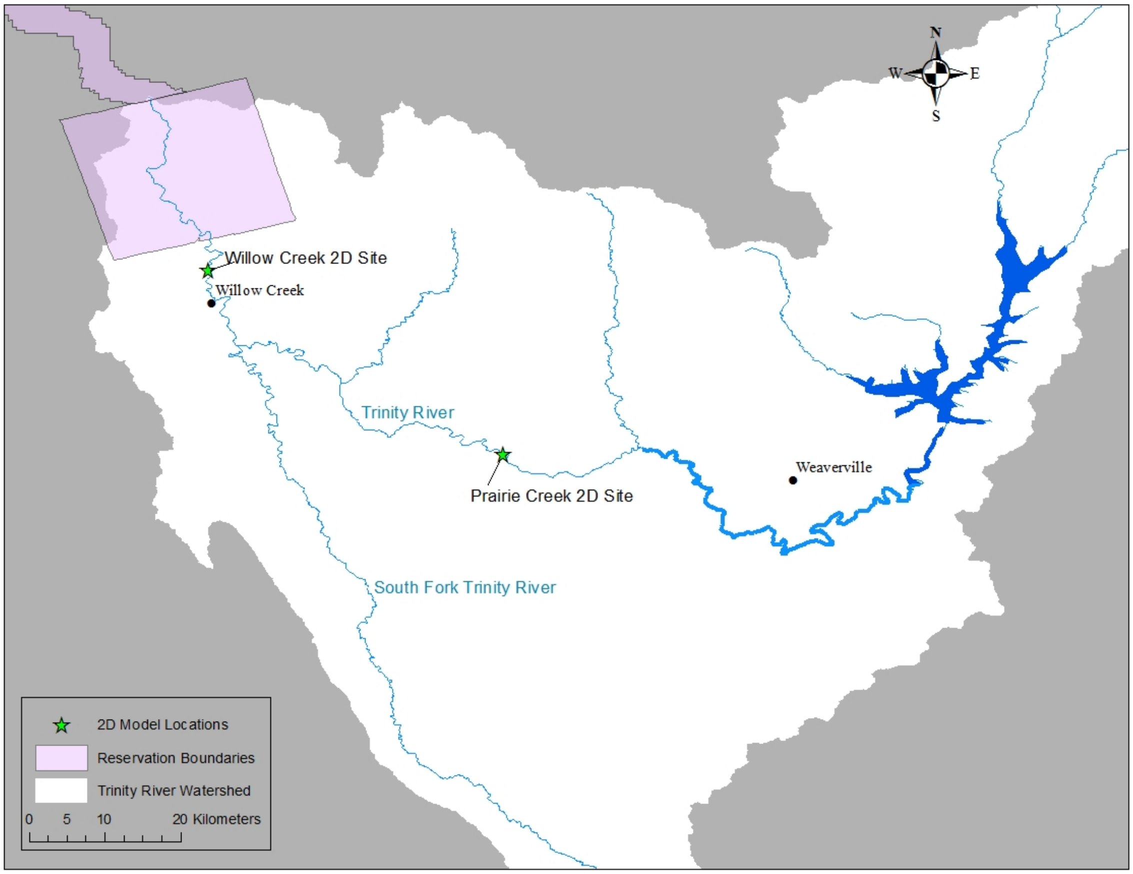

Figure 1. Location of the two downriver 2-dimensional hydrodynamic model (2DHM) sites on the Trinity River. These 2DHM sites were also the sections of river from which the individual sampling sites were selected. The restoration reach is located downstream of the reservoirs and is shown as bolded riverline.

sections, the river was first divided into two major reaches. The first reach is defined by a bedrock-confined canyon, contains steep gradients, and has an alluvial bed. It begins at the downstream end of the restoration reach, with the confluence of the North Fork Trinity, and ends at the confluence of the South Fork Trinity. The second reach begins at the South Fork Trinity confluence and ends in Weitchpec where the Trinity River joins the Klamath River. This reach has wider alluvial valleys, large gravel bars and floodplains, and deep pools. Selection of sites within these reaches was achieved based on a number of factors including mesohabitat composition, accessibility and safety, and resulted in a section approximately 2km in length for the canyon reach (Prairie Creek Site), and a section of approximately 3km in length for the valley reach (Willow Creek Site).

Fish Observation

Recent upper river habitat assessments have been completed via snorkeling surveys. However, the lower river sites contain habitat units with sections of deeper and faster water than exists in the restoration reach. Also, these reaches of the river can experience elevated turbidity levels during much of the rearing period from February through July. The combination of turbid waters and elevated flows throughout the rearing period made snorkel surveys potentially unsafe, or ineffective at observing juvenile salmonid habitat use. After several planning meetings, it was decided that sonar technology would be explored as a way to observe habitat use in the lower sites. Accordingly, an Aris 1200 (http://www.soundmetrics.com/Products/ARIS-Sonars/ARIS-Explorer-1200) Explorer sonar device was obtained, and its efficacy in enumerating juvenile salmonids in open water was investigated. The unit had a 28° x 14° (width x height) field of view. It could be pointed directionally by manually turning the sonar (like a periscope). Similar acoustic sonars have been successfully used for juvenile fish studies, especially in turbid conditions (Adams et al. 2015; Shen et al. 2012). The Yurok Tribe owns the ARIS 1200, and deemed it worthy of investigation for enumerating juvenile salmonids in the Trinity River. For the field trials, the ARIS 1200 unit was mounted to the bow of a jet boat. ARIS 1200 field trials were conducted in early May 2016. Representatives from the Yurok Tribe, Hoopa Valley Tribe and USFWS were present. During trials, images were displayed using the ARIS software on a Panasonic Toughbook field laptop. Initial calibration was conducted with a fishing lure that was similar in size (~50mm) to a juvenile Chinook Salmon encountered during the spring when these trials were conducted. The lure was passed through the sonar unit field of view. The trial started with the ARIS 1200 unit placed in 0.8 m of water, and settings were adjusted until the lure was easily detectable between 2 and 5m away from the jet boat.

After the initial calibration, the next test was conducted at the mouth of Horse Linto Creek, a location known to be inhabited by juvenile fish during that time. The jet boat was held in an eddy downstream of the creek inlet, about 3 – 4m away from the moving water. An area about 5m long and 3m wide was scanned, by slowly rotating the sonar from one side to the other. The depth in this field ranged from 1 - 2.5m. Juveniles were consistently observed with counts ranging from 8 – 18 individuals.

The next test involved the ARIS 3000 (http://www.soundmetrics.com/Products/ARIS-Sonars/ARIS-Explorer-3000), loaned to us by Sound Metrics. This model was better geared for smaller subjects at shorter distances. The unit had an adjustable field of view and could be pointed directionally by mechanically turning the sonar. The ARIS 3000 field trial included attempts to observe juvenile Chinook Salmon as they were released as part of the mark-recapture effort for the Willow Creek rotary screw trap project (Petros et al. 2017). The marked fish were released slowly from a 5 gallon bucket into a deep eddy, around 2m from the sonar on the jet boat. Surveyors were able to observe the mass of fish via the sonar at time of release, but the fish quickly disappeared as they spread beyond the field of view, and enumerating individuals was not possible.

Although some moderate success in identifying and enumerating juvenile fish was achieved, there were also many limitations identified. First, the sonar could not distinguish between species, and enumerating fish in groups was very difficult. It was also difficult to find and track fish in depths greater than 2m, and the ability to observe fish in deeper water was a principal reason this approach was considered. Also, the nature of the water velocities made it difficult to control the jet boat and ensure an accurate survey was being conducted. After two days of field testing, all project partners agreed that neither the ARIS 1200 or 3000 sonar units were going to meet the needs of the proposed study.

With the sonar units proving unacceptable, and other observation methods dismissed by the project partners, it was decided to return to snorkel sampling to obtain data for this study. The study design could not replicate that applied in the restoration reach because the 2DHMs had not yet been constructed (i.e., required to optimize sample site locations, Som et al. 2018) but sampling locations were still selected taking regression optimality (Som et al. 2014; Alexander et al. 2016) aspects into account.
It was important to capture habitat use variation according to physical characteristics that occurred across the two reaches where the surveys would take place. The first level of stratification occurred at the meso-habitat level (Newson et al. 2000). We wanted to ensure samples were taken from pool, riffle, and run meso-habitat types. The process of selecting survey locations began with aerial photo imagery. At each meso-habitat type that was selected for sampling, actual survey locations were selected according to distance from bank (ensuring samples near and far), and also spaced near the upstream, middle, and downstream portions of each meso-habitat unit. These spatial positioning decisions acted as a proxy for capturing variation in depth, velocity, and distance from cover, all variables necessary to evaluate if lower river fish were using habitat that appeared different than that available in the upper river.

Snorkel surveys were conducted over 4 days in August 2016, with each site requiring 2 days for data collection. Sample units were snorkeled by beginning at the down-current end and moving up-current enumerating juvenile salmonids along the path. Sample units were generally 10m long, but ranged from 5 to 30m and were up to 2.5m wide depending on water clarity. In units with low water clarity, or in fast water where a bubble curtain impeded the view, the width was reduced to include only a distance of visibility (this occurred at 70 of 288 sampling locations). After the fish count at each sample unit, a representative depth, velocity, distance to bank, and distance to cover were measured. Attributes such as meso-habitat type, substrate type, and type of cover were also recorded.

Statistical Analysis

For this study, replicate samples were not collected at each site, and therefore the N-mixture modeling framework conducted in the upper river study could not be replicated with these lower river data. Instead, the single location point counts were treated as relative abundances. For reasons addressed in the Discussion, the data contained a much higher proportion of zeros than previous fish-habitat data, with almost 80% of the observed counts recorded as zero salmonids. For this reason, count-based statistical models were not employed. Instead, analyses focused on estimating if the probability a sample unit was occupied was related to the suite of physical habitat variables collected in the upper river.

We applied the binary logistic form of a generalized linear mixed regression model (GLMM),

$$log\left(\frac{\pi}{1-\pi}\right) = X\beta + \alpha; \alpha \sim N(0, \sigma_\alpha^2),$$

where π is a vector containing the probability each location contains smolts, X is a design matrix of explanatory variable values for all locations, β is a vector of fixed-effects parameter values, and α is a vector of random effect values controlling for correlation among all samples collected within the same meso-habitat unit. Given its flexibility for fitting GLMMs, we opted for a Bayesian methodology. We constructed each model likelihood, and specified prior distributions using BUGS language, and called JAGS (Plummer 2017) from R statistical software (R Core Team 2016) via the contributed package jagsUI (Kellner 2016) to use Markov chain Monte Carlo (MCMC) simulation to draw samples from the posterior distribution of the parameters. For all regression parameters, we specified vague mean-zero Gaussian priors with precision values equaling 0.00001. For the habitat unit random effects standard deviation, we specified a uniform (a,b) prior (Gelman 2006) with a = 0 , and b = 10. We ran three simultaneous MCMC chains and retained 3000 samples per chain after a burn-in of 10000 iterations and a thinning rate of 5 (i.e., 9000 MCMC samples per parameter were retained for inference). Convergence of the MCMC chains was assessed visually from the traceplots and quantitatively using Rhat statistics (Gelman et al. 2014).

To evaluate the relative evidence for various combinations of physical attributes effecting the probability of smolt presence at the sampled locations, we commenced with a model selection procedure. We applied the deviance information criterion (DIC) which is an appropriate method for comparing models fit using Bayesian methods (Spiegelhalter et al. 2002), and which like the more commonly known Akaike information criterion (AIC) combines a measure of fit quality with a penalty for model complexity. Additionally, relative differences of DIC values among candidate models can be interpreted similarly to AIC values, where models with criterion values within 2-4 units of each other can be considered competing models garnering comparable support. In situations where multiple models arise as competing models, it is common to select the least complicated (fewest number of parameters) model as that to proceed with inference.

Candidate models included various combinations of main effects and interactions among the physical variables found to strongly relate to habitat use in the upper river: water depth, velocity, and distance to cover. All candidate models also included the random effect to account for correlation among sampling locations within each meso-habitat unit, the size of the location sampled, and a fixed effect to test for differences in the probability of smolt observance between the Prairie Creek and Willow Creek sites. In more complex sampling designs or analyses, site-level effects are often treated as random effects. However, there are only two levels of this categorical variable, which is too few for estimating random effects parameter values (Gelman 2006). Finally, an additional model was considered where distance to cover was replaced by distance to bank. This candidate model was formulated with applications to the S3 Model (Perry et al. in review) in mind. To inform predictions of the holding capacity of habitat units, the S3 model requires a habitat model that relates physical conditions to the quality and quantity of habitat. In the restoration reach, this model relies on distance to cover, which is a variable that is not generated from 2D hydrodynamic models, and is not easily gleaned from remotely sensed data. Thus, the framework of available information to inform habitat models in the lower river may not include distance to cover. Hence, a model incorporating distance to bank was considered as distance to bank is much easier to generate. For each of the candidate models, the associated X and β matrices were structured accordingly. To assess strength of evidence for the effect of variables on the probability of smolt presence, we relied on 95% credible intervals for each parameter. When a parameter equals zero, it signifies that changes in an explanatory variable have no effect on the probability of smolt presence. Parameter credible intervals that overlap zero suggest it's likely that a parameter's value could be zero, and are interpreted as evidence that changes in a variable neither increase nor decrease the probability of smolt presence.

Results

In all, fish counts were collected at 288 locations within the two 2D sites. At the Willow Creek location there were 155 samples collected, and 133 samples were collected at the Prairie Creek location. The physical variable values measured at the sampling locations ranged from 0.06 to 7.62m for water depth, from 0.0 to 0.46 m/sec for velocity, 0.0 to 152m for distance to cover, and 0.0 to 46m for distance to bank. Among all sampling locations, counts of all juvenile salmonids ranged from 0 to 62 individuals, and counts of juvenile Chinook Salmon smolts ranged from 0 to 48 individuals. Traceplots and Rhat statistics (all no larger than 1.01) revealed that all 3 chains for each parameter had converged and were sampling stationary posterior distributions.

The model selection results suggest that more complicated models including interactions among the physical variables are not supported (Table 1). Additionally, the model selection results suggest that a model including distance to bank, along with depth and velocity, is just as supported, if not more than, the model containing distance to cover. Given it had the lowest overall DIC score, we will select the model with distance to bank as the best supported model, but because the model including distance to cover is within 4 AIC units, we will also discuss the parameter estimates from that model.

For the selected model and these data, there was no evidence that the probability of Chinook Salmon smolt presence varied between the Willow Creek and Prairie Creek sites (Table 2), strong evidence that the probability of smolt presence increased with increasing sampling location area (Table 2), and also evidence that the probability of smolt presence varied at the meso-habitat unit level (Table 2). In regards to physical variables, there was no evidence to suggest the probability of smolt presence varied according to velocity, little evidence that presence varied according to depth, but strong evidence that the probability of smolt observance decreased as distance to bank increased (Table 2). It is worth noting that the model ranked as second best was identical to the chosen model except that distance to cover was included instead of distance to bank. The parameter estimate for the distance to cover variable was similar to that for distance to bank, and the fact that the difference in DIC scores between the two models is less than 4 suggests they garner similar support.

Table 1. Results of the model selection exercise. Abbreviations include water depth ("D"), velocity ("V"), distance to cover ("D2C"), and distance to bank ("D2B"). The asterisk (*) signifies the interaction among multiple variables, and Δ represents the change in units relative to the best overall (lowest) DIC value.

Main Effects	Interactions	DIC	ΔDIC
D, V, D2B		249.7	0.0
D, V, D2C		252.8	3.1
D, V, D2C	D*D2C	254.3	4.6
D, V, D2C	D*V	254.7	5.0
D, V, D2C	D*V, D*D2C	256.6	6.9
D, V, D2C	D*V, D*D2C V*D2C	258.1	8.4
D, V, D2C	D*V, D*D2C V*D2C, D*V*D2C	258.9	9.2

Table 2 Posterior summaries of parameters from the selected model. Estimates include the "Estimate" which is the mean of the posterior distribution for each parameter, the "LCL" which is the lower limit of a 95% credible interval for each parameter, and the "UCL" which is the upper limit of a 95% credible interval for each parameter. The ΔWillow Creek parameter represents the estimated change in the intercept value relative to the value for Prairie Creek. All numeric variables were centered and scaled prior to MCMC sampling to aid in numeric stability. All numeric values presented in this table are on the scale of the linear predictor (logit).

Variable	Estimate	LCL	UCL
Prairie Creek	-2.63	-4.44	-1.36
ΔWillow Creek	0.03	-1.80	1.93
Depth	0.34	-0.06	0.76
Velocity	-0.15	-0.62	0.30
Dist. to Bank	-0.74	-1.34	-0.21
Area	0.43	0.07	0.84
σ_α	2.47	1.43	3.96

Discussion

When this work was proposed, it was believed that a method for efficiently sampling fish in deeper waters would be implemented. Despite research and field trials, an adequate alternate sampling method was not found, and the sampling method applied in previous TRRP fish-habitat assessments, snorkeling, was employed. Greater depths in the lower river reaches posed limitations to data collection as direct observation efficacy could vary considerably between transects. Factors such as aspect of the transect relative to the position of the sun, depth and shape of bubble curtains, vegetation density, and substrate size can all affect direct observation counts. In optimal situations, fish can be positively identified at a depth of about 2.5m.

In our analyses, it was not found that depth and velocity were generally associated with the probability a location contained smolts. This difference, compared to the upper river fish-habitat assessments, could be attributed to several factors. One possible factor, is that larger fish (i.e., smolts) are not as limited by the depth or velocities of water because these fish are physically able to use a broader range of physical conditions. Additionally, the extremely high proportion of zero-counts in these data lend caution to interpretation of any results. This is because even though some fish were observed, we can reasonably expect that there were many locations that would have included smolts had there been more smolts to occupy these riverine locations. Statistically, this is represented as variation in physical conditions (explanatory variables) without variation in the response variable (very high proportion of zero – counts). In this kind of scenario, statistical models are less able to provide evidence for factors important to habitat use.

Due to the extended amount of time researching and evaluating field methods, and the prolonged high flows and resulting high turbidity, there is also very little temporal variation in the data. It should be assumed that Chinook Salmon of smaller size early in the year, or when coupled with a larger local population, use different habitats than larger sized Chinook Salmon just prior to emigrating. Another confounding factor is the presence of hatchery Chinook Salmon in the river during the sampling period. It is unknown what proportion of the fish observed were of hatchery origin, and how this may affect habitat selection. In-river temperatures during the summer also likely relate to habitat selection.

In general, the project was not able to provide the exact information to the S3 downriver development that was originally proposed. There was a substantial preponderance of zero counts in these data, and there are a myriad of reasons why this may have occurred. High discharge and high turbidity made for poor visibility during most of the juvenile outmigration. When visibility improved enough to snorkel, most juvenile fish had left the system, so densities were low. This increased the probability of snorkeling in a location with few or no fish holding or rearing. This is compounded by the larger river corridor being surveyed when compared to the study conducted in the upper Trinity River. Despite these shortcomings, it remains to be seen if the lack of higher quality data will hamper the lower river S3 model development. There are several options that the modeling team can consider. First, the upper river habitat model could be applied in the lower river, with the parr model being applied to lower river smolts. Second, it could be hypothesized that the smolts in the lower river are actively migrating towards the ocean, and not subject to density dependent dynamics like rearing juveniles experience. Finally, it could be hypothesized that habitat is not limited in the lower river. These options, and certainly others, will be considered by the modeling team when constructing the lower Trinity S3 model.

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References

Adams, N. S., C. Smith, J. M. Plumb, G. S. Hansen, and J. W. Beeman. 2015. An evaluation of fish behavior upstream of the water temperature control tower at Cougar Dam, Oregon, using acoustic cameras, 2013 (No. 2015-1124). US Geological Survey.

Alexander, J., J. L. Bartholomew, K. Wright, N. A. Som, and N. J. Hetrick. 2016. Integrating models to predict distribution of the invertebrate host of myxosporean parasites. Freshwater Sci. 35(4): 1263-1275. doi:10.1086/688342.

Gelman, A. 2006. Prior distributions for variance parameters in hierarchical models. Bayesian Analysis. 1(3): 515-533.

Gelman, A., J. B. Carlin, H. S. Stern, D. B. Dunson, and A. Vehtari, D. B. Rubin. 2014. Bayesian Data Analysis. CRC Press, Boca Raton, FL, third edition.

Kellner, K. (2016). jagsUI: A Wrapper Around 'rjags' to Streamline 'JAGS' Analyses. R package version 1.4.2. https://CRAN.R-project.org/package=jagsUI.

Newson, M. D., and C. L. Newson. "Geomorphology, ecology and river channel habitat: mesoscale approaches to basin-scale challenges." Progress in Physical Geography 24.2 (2000): 195-217.

Perry, R.W., E. C. Jones, J. M. Plumb, N. A. Som, N. J. Hetrick, T. B. Hardy, J. C. Polos, A. Martin, J. Alvarez, and K. De Juilio. In Review. Application of the Stream Salmonid Simulator to Trinity River Chinook Salmon: U.S. Geological Survey Open-File Report 2018-XXXX, XX.

Petros, P., W.D. Pinnix, and N.J. Harris. 2017. Juvenile Salmonid Monitoring on the Mainstem Trinity River, California, 2016. Hoopa Valley Tribal Fisheries Department, Yurok Tribal Fisheries Program, and U. S. Fish and Wildlife Service, Arcata Fish and Wildlife Office. Arcata Fisheries Data Series Report Number DS 2017-51, Arcata, California.

Plummer, M. 2017. JAGS: Just Another Gibbs Sampler. https://sourceforge.net/projects/mcmc-jags/.

R Core Team. 2016. R: A language and environment for statistical computing. R Foundation for statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Rupert, D., N.A. Som, W.D. Pinnix, P. Petros, and K. DeJuilio In Review. The Use of Small 2-Dimentional Habitat Zones and Dual-Diver Snorkel Surveys to Model the Habitat Use and Preferences of Juvenile Salmonids in the Trinity River, California. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office, Arcata Fisheries Data Series Report Number DS 201X-XX, Arcata, California.

Shen, W., L. Yang, J. Zhang, and G. Peng. 2012. The survey of fishery resources and spatial distribution using DIDSON imaging sonar data. In 6th Computer and Computing Technologies in Agriculture (CCTA) (No. Part I, pp. 366-375). Springer.

Som, N.A., P. Monestiez, J. M. Ver Hoef, D. L. Zimmerman, and E. E. Peterson. 2014. Spatial sampling on streams: principles for inference on aquatic networks. Environmetrics 25(5): 306-323. doi:10.1002/env.2284.

Som, N.A., R. W. Perry, E. C. Jones, K. De Juilio, P. Petros, W. D. Pinnix, and D. L. Rupert. 2018. Canadian Journal of Fisheries and Aquatic Sciences 75(7): 1048-1058. doi.org: 10.1139/cjfas-2017-0027.

Spiegelhalter, D J., N. G. Best, B. P. Carlin, and A. Van Der Linde. 2002. Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society: Series B (Statistical Methodology). 64(4) 583-639. doi: 10.1111/1467-9868.00353.