# REDD MONITORING AND MAPPING
IN THE
# ENGLEBRIGHT DAM REACH
# OF THE LOWER YUBA RIVER, CA

## SUMMARY REPORT
SEPTEMBER 12, 2011 – DECEMBER 19, 2011

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Prepared for: The U. S. Army Corps of Engineers

by

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# 1. INTRODUCTION

The lower Yuba River in Yuba County, California extends about 38.6 km (24 mi) from Englebright Dam, the first impassible fish barrier on the river, downstream to the confluence with the Feather River near Marysville, California. The lower Yuba River is host to a number of native fishes, including Federally- and State-protected species like spring-run Chinook salmon and Central Valley steelhead. In 2007, the National Marine Fisheries Service issued a Biological Opinion that required the United States Army Corps of Engineers (USACE) to develop a long-term gravel augmentation program downstream of Englebright Dam to restore quality spawning habitat to the area. A pilot gravel injection of 500 tons was subsequently placed below the Narrows 2 powerhouse in November 2007, and a larger gravel injection effort was undertaken again during November 2010 – January 2011 as part of the long-term stream rehabilitation approach. A total of 5,500 tons of gravel substrates have been injected downstream of Englebright Dam for the purpose of rehabilitation and restoration of spawning habitat. The implementation of a long-term augmentation program is intended to improve the overall ecological functionality of the river channel by providing gravel and cobble suitable for anadromous salmonid adult spawning, embryo incubation, and survival.

The purpose of this summary report is to detail the temporal and spatial use of spawning substrates directly downstream of Englebright Dam by Chinook salmon, and to provide supplemental data for a more robust rehabilitation and monitoring effort currently being completed by Dr. Greg Pasternack at the University of California, Davis.

## 1.1. Objectives

- Evaluate the spatial and temporal distribution of Chinook salmon redds in the Englebright Dam study area.
- Estimate the number of Chinook salmon redds located in the Englebright Dam study area.
- Estimate the level of redd superimposition for Chinook salmon in the Englebright Dam study area.
- Examine attributes for each individual redd encountered during the surveys; including the physical redd measurements, substrate and habitat characterizations.

# 2. FIELD METHODS

## 2.1. General Survey Methods

Approximately 1.6 kilometers (1 mile) of the lower Yuba River was surveyed to assess the temporal and spatial distribution of Chinook salmon spawning. Surveys were conducted by two divers wearing drysuits, mask/snorkel and fins. Divers searched for, and identified, Chinook salmon spawning (redds) on the lower Yuba River from the Narrows 2 Powerhouse to approximately 0.4 kilometers (0.25 miles) downstream of the confluence with Deer Creek. Divers entered the river from the upstream end of the survey area near the powerhouse and systematically searched for evidence of Chinook salmon spawning. Each surveyor scanned the river bed from the shore to the middle of the river, working downstream. When redds were located, positional data and abiotic measurements were recorded for each observation. Surveyors were able to mark redds in water depths < 1.2 meters (4 feet).

### 2.2. Survey Location

The survey area was located at the uppermost reach of the lower Yuba River from the Narrows 2 Powerhouse to approximately 0.4 kilometers (0.25 miles) downstream of the confluence of Deer Creek (Figure 1).

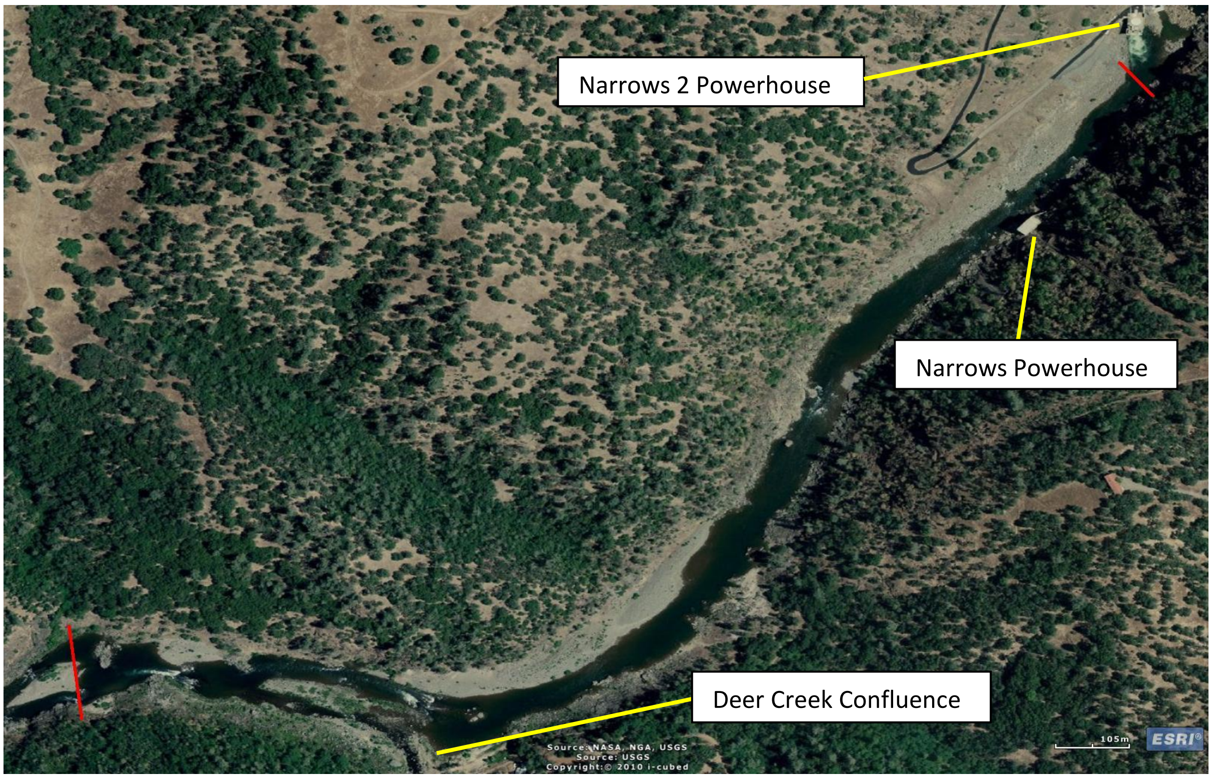


**Figure 1. Aerial image of the Englebright Dam study area (marked by red boundary lines) in the lower Yuba River, CA.**

### 2.3. Survey Period

The survey period began on September 12, 2011 and ended December 19, 2011.

### 2.4. Sampling Frequency

Surveys were conducted weekly.

### 2.5. Sample Size

For estimates of total abundance, spatial and temporal distribution of Chinook salmon redds, the sample size for the Chinook salmon redd surveys was the number of weekly surveys conducted for the entire survey period.

### 2.6. Redd Location

The following abiotic data were recorded during each survey: 1) survey date; 2) surveyors' initials; 3) survey section; 4) number of crews; 5) specific crew identification (Crew A or B); 6) weather; 7) stream flow; and 8) secchi disk depth. Flow data were obtained from the Yuba River Smartsville gage through the California Department of Water Resources' (CDWR) online California Data Exchange Center (CDEC).

Each redd was consecutively numbered through the sampling season. For each redd observed, the following data were recorded: 1) a positional data point taken at the center of the redd's pit with a unique identifying number (i.e., Date + plus redd number; e.g. 20110926-001); 2) the time of observation; 3) redd species identification; 4) number of fish observed on the redd; 5) comments regarding observable redd superimposition (i.e., redd overlap); and 6) any additional comments.

A handheld global positioning system (GPS) manufactured by Trimble Navigation Limited® (GeoExplorerXT®) and a data dictionary were used to record positional and abiotic data for each redd observation. In addition, surveyors marked each redd with a fluorescent-colored bed marker to ensure that redds observed during previous surveys were not double-counted.

### 2.7. Redd Area Measurements

The physical dimensions of each observed redd were measured using a fiberglass extendable rod demarcated at every 0.1 meters (0.49 feet) according to the procedures identified in Figures 2 and 3, and Table 1.

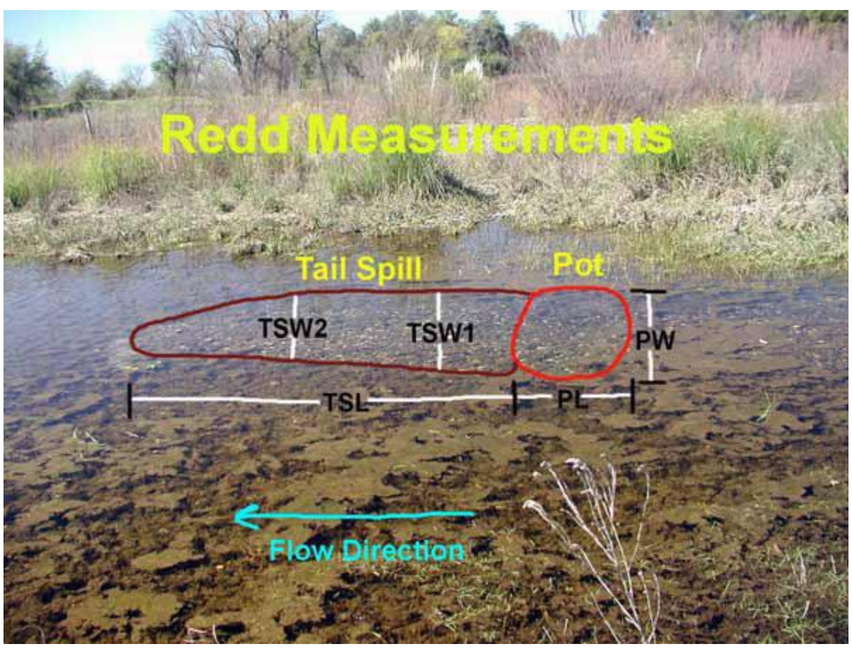


**Figure 2. Illustration of redd measurements (PL = pot length; PW = pot width; TSL=tailspill length; TSW2 and TSW1 = tail-spill widths), as presented in Hannon and Deason (2005).**

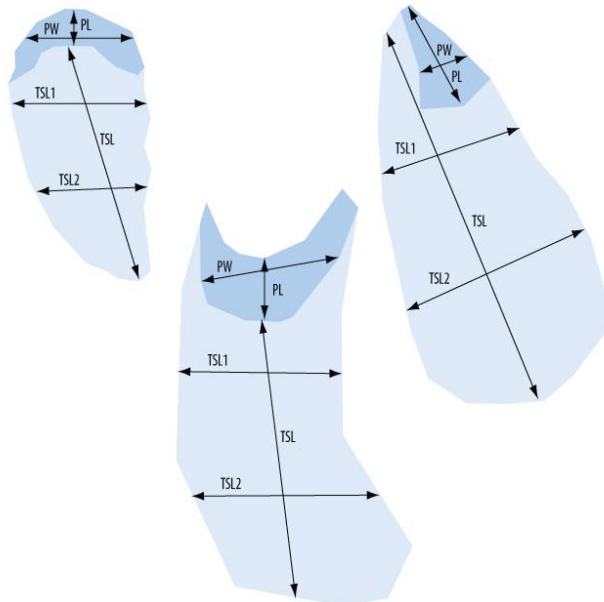


**Figure 3. Measurements for unusually shaped redds (PL=pot length, PW=pot width, TSL=tail-spill length, TSL1 and TSL2=tail-spill widths). Illustration reproduced from Gallagher *et al.* (2007).**

**Table 1. Description of redd dimension measurements.**

| | |
|---|---|
| Pot Length (PL) | Total length of the pot parallel to the stream flow, and should be measured in meters (to the nearest cm) from the top to bottom edge. When the pot is irregularly shaped, estimate the total length as accurately as possible. |
| Pot Width (PW) | Maximum width of the pot perpendicular to the stream flow or pot length in meters (to the nearest cm). When the pot is irregularly shaped, estimate the total length as accurately as possible. |
| Tail Spill Length (TSL) | Total length of the tail spill parallel to the stream flow (in meters to the nearest cm). Measurements will be taken from the top edge (i.e., downstream edge of the pot) to bottom edge of the tail spill. |
| Tail Spill Width 1 (TSW1) | Maximum width of the tail spill perpendicular to the stream flow or pot length (in meters to the nearest cm). Measurements will be taken from one edge to the other, about one-third of the distance downstream from the top edge of the tail spill |
| Tail Spill Width 2 (TSW2) | Maximum width of the tail spill perpendicular to the stream flow or pot length (in meters to the nearest cm). Measurements will be taken from one edge to the other, about two-thirds of the distance downstream from the top edge of the tail spill. |

## 2.8. Habitat Utilization Characterization

At each fresh redd located, measurements of mean water column velocity, nose velocity[1], total water depth and visual estimates of substrate composition were made to approximate habitat conditions prior to gravel disturbance caused during redd construction. All measurements were taken 0.15 meters (0.49 feet) upstream of the leading edge of the pit along the mid-line of the redd, unless field personnel determined

[1] The nose velocity was taken at a predetermined distance of 0.15 meters above the undisturbed streambed to represent the velocity present at a fish's position during redd construction

that measurements adjacent to the mid-point of the pit were more representative of undisturbed conditions for that specific location. The specific locations of the measurements were recorded on the data dictionary.

Total water depths were measured in English units to the nearest 0.01 meter (0.03 feet) with a top-setting wading rod. Water velocities were measured with a Marsh-McBirney water velocity meter to the nearest 0.01 meters/second (0.03 feet/second) parallel to the current according to methods described by Trihey and Wegner (1981). Mean water column velocity was measured at 60% of the distance from the surface in depths less than 0.77 meters (2.5 feet). In water between 0.77 meters (2.5 feet) and 1.22 meters (4 feet) deep, water velocities were measured at 20% and 80% of the total water depth, then were averaged to obtain mean column velocity (Buchanan and Somers 1969). Velocities at 20%, 60%, and 80% were measured and averaged in depths greater than 1.22 meters (4 feet), or where the velocity distribution in the water column was inconsistent. In addition to mean water column velocities, "nose velocities" were measured 0.15 meter (0.49 feet) above the undisturbed streambed.

Redd substrate composition was visually estimated as percentage composition (to the nearest 10 percent) of each of eight size categories (Table 2). Visual estimation of substrate sizes were taken along the *B* axis of the substrate elements.

**Table 2. Substrate classification that links statistical properties of lower Yuba River bed material grain size distributions and physical habitat suitability (unpublished data - Yuba Accord RMT 2010).**

| Class | Particle Size Range (mm) | Habitat suitability |
|---|---|---|
| Bedrock | No alluvium | Periphyton only |
| Boulder Field* | D>256 | Chinook salmon and steelhead trout fry, parr, and smolt cover and foraging |
| Large Cobble | 128<D<256 | Chinook salmon and steelhead trout fry and parr cover and foraging |
| Cobble | 90<D< 128 | Chinook salmon spawning, embryo incubation, and fry cover |
| Medium Gravel/Small Cobble | 32<D<90 | Chinook salmon and steelhead trout spawning, embryo incubation, and fry cover |
| Fine Gravel | 2<D<32 | Steelhead trout spawning and embryo incubation |
| Sand | 0.0625<D<2 | |
| Silt/Clay | D<0.0625 | Submerged Aquatic Vegetation |

# 3. DATA ANALYSIS METHODS

## 3.1. Redd Survey Efficacy

The duration and number of days required to implement this redd survey were evaluated, including temporal sampling periods and causal descriptions for missed surveys.

## 3.2. Abundance

An evaluation and comparison of the spatial and temporal redd distributions, including temporal distributions of redd superimposition for Chinook salmon was performed. Correlative analyses using simple linear regression of GIS-based spatial outputs for mapped Chinook salmon redds was completed to assess the location and number of fresh redds observed during the study period. Evaluations included: 1) spatial distribution of the spawning locations over the study period; and 2) changes in the weekly temporal distributions of spawning locations over the study period.

Weekly and cumulative indices of Chinook salmon redd superimposition were estimated using GIS-based spatial output. Ellipse buffers were created for each individual redd using the mean physical measurements of all redds included in the sample size. The magnitude of redd superimposition was estimated using ArcGIS to quantify the percent overlap of each redd constructed in the surveyed area by measuring the degree of elliptical buffer overlap. Redd superimposition within each strata was expressed as the frequency of individual redds that exhibited overlap versus the total number of redds observed in the survey area. A correlative analysis using simple linear regression of the weekly index of superimposition frequency for Chinook salmon redds was performed.

Redd data were used to enumerate Chinook salmon redds in the study area. The temporal and spatial distributions of spawning Chinook salmon were identified using the number of redds observed and the redd locations documented for each survey stratum through the survey period.

Dates associated with percentile expressions (1%, 10%, 25%, 50%, 75%, 90% and 99%) of the cumulative temporal distribution of Chinook salmon spawning were identified by fitting an asymmetric logistic function to the cumulative temporal distribution of fresh redds from the redd survey data (Richards 1959):

$$\sum_{i=1}^{D_i=n} Y_i(\%) = 100 \times \left( \frac{1}{1+\exp(\alpha + \beta \times D_i)} \right)^{\frac{1}{\delta}};$$

where $\sum_{i=1}^{D_i=n} Y_i(\%)$ is the percentage of the cumulative temporal distribution of each run of Chinook salmon from day 1 through time $D_i$, and α, β and δ are parameters (*i.e.* constants) that describe the shape of the resulting relative cumulative curve. The values of these parameters were obtained through non-linear least squares estimation. Once the asymmetric logistic function curve was fitted to the data, the dates at which a particular percentage (X) of Chinook salmon spawning ($\hat{D}_{X\%}$) was identified using the inverse estimation:

$$\hat{D}_{X\%} = \frac{\log_e\left(\frac{100}{X^{\delta}} - 1\right) - \alpha}{\beta};$$

where α, β and δ were the parameter values obtained from the asymmetric logistic function, and *X* was the percentage of interest (e.g., 1%, 10%, 25%, 50%, 75%, 90% and 99%). For example, the resulting estimates of $\hat{D}_{10\%}$, $\hat{D}_{25\%}$, $\hat{D}_{50\%}$, $\hat{D}_{75\%}$ and $\hat{D}_{90\%}$ summarized the characteristics of the corresponding temporal distribution of spawning Chinook salmon.

Chinook salmon redd positional data were analyzed to determine if the observed spawning locations were randomly distributed along the longitudinal profile of the study area utilizing protocols developed by Wyrick and Pasternack (2011). A line was manually drawn in ArcGIS that approximated the center of the geomorphically-active channel for the entire length of the study area. Station lines were then drawn at a longitudinal spacing of 6.1 meters (20 feet) that radiated perpendicularly from the centerline to a total width distance of 609.6 meters (2,000 feet[2]). Each station line was used to create a box (bin) that measured 6.1 meters (20 feet) by 609.6 meters (2,000 feet) in size and was compiled to form a station buffer shapefile consisting of 275 bins. Coordinate data for each redd location was added to the station buffer shapefile to assign a longitudinal station to each location. Stations were plotted with location frequencies to create a graphical representation of the longitudinal distribution within the Englebright Dam study area of the lower Yuba River. Because an equal chance exists of a random point occurring anywhere along the length of the river, a plot of the longitudinal frequency distribution for a random dataset should be approximately uniform. If the observational data exhibits a non-uniform frequency distribution, then an ordered, non-random plot demonstrating preferential selection should result.

### 3.3. Diversity

Redd attribute data were used to examine Chinook salmon redd physical attributes. Redd size was described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of redd measurements).

Redd attribute data were used to examine microhabitat features encountered at Chinook salmon redd locations. Redd microhabitat features were described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of measurements).

Redd attribute data were used to examine substrate characterizations for Chinook salmon. Substrate characterizations were described using standard metrics (*e.g.* maximum, minimum, mean, median and variance of substrate characterizations).

## 4. RESULTS

### 4.1. Redd Survey Efficacy

Redd surveys began on September 12, 2011 following preliminary field reconnaissance surveys that observed Chinook salmon adults staging near gravel substrates. Redd surveys continued uninterrupted through December 19, 2011. Results were tabulated for each weekly stratum including the number of days required to complete the survey, the Secchi depth measurement, the minimum, maximum and mean of flows and temperature at the USGS Smartsville gage and the number of Chinook salmon redds observed (Table 3).

[2] This width was chosen to completely encapsulate the channel flow widths at high flow stages.

**Table 3. Weekly survey results in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

| Week | Survey Days | Secchi Depth (m) | Smartsville Flow (cfs) | | | Smartsville Temp. (°C) | | | Number of Chinook Salmon Redds Observed |
|---|---|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Mean | Min. | Max. | Mean | |
| 9/12/2011 | 1 | 3.5 | 816 | 833 | 829 | 6.8 | 12.0 | 10.5 | 0 |
| 9/19/2011 | 1 | 3.5 | 828 | 835 | 832 | 7.1 | 12.0 | 10.3 | 0 |
| 9/26/2011 | 1 | 3.5 | 830 | 876 | 853 | 9.2 | 12.1 | 11.0 | 8 |
| 10/3/2011 | 1 | 3.5 | 864 | 882 | 871 | 11.3 | 12.5 | 12.0 | 13 |
| 10/10/2011 | 1 | 3.5 | 860 | 873 | 864 | 9.9 | 12.1 | 11.4 | 18 |
| 10/17/2011 | 1 | 3.5 | 859 | 958 | 909 | 11.5 | 13.3 | 12.4 | 7 |
| 10/24/2011 | 1 | 3.5 | 956 | 961 | 958 | 10.3 | 13.0 | 12.1 | 14 |
| 10/31/2011 | 1 | 3.5 | 960 | 1,003 | 975 | 11.2 | 11.9 | 11.5 | 16 |
| 11/7/2011 | 1 | 3.5 | 972 | 999 | 982 | 8.4 | 11.2 | 10.2 | 3 |
| 11/14/2011 | 1 | 3.5 | 945 | 1,012 | 982 | 9.5 | 10.2 | 9.8 | 3 |
| 11/21/2011 | 1 | 3.5 | 946 | 962 | 957 | 9.8 | 10.2 | 9.9 | 2 |
| 11/28/2011 | 1 | 3.5 | 957 | 966 | 961 | 8.6 | 9.9 | 9.2 | 3 |
| 12/5/2011 | 1 | 3.5 | 912 | 957 | 928 | 7.8 | 9.2 | 8.6 | 0 |
| 12/12/2011 | 1 | 3.5 | 909 | 915 | 912 | 7.4 | 8.5 | 8.0 | 0 |
| 12/19/2011 | 1 | 2.0 | 816 | 909 | 854 | 6.6 | 7.7 | 7.2 | 0 |

### 4.2. Abundance

A total of 87 Chinook salmon redds were observed during the survey period. Peak observations of Chinook salmon redds occurred on October 10, 2011 when 18 Chinook salmon redds were observed in the Englebright Dam study area of the lower Yuba River. An aerial image of the study area including spatial raster data for all cumulative redd observations were prepared (Figure 4).

**Figure 4. Aerial image of the survey area (red boundary lines) with cumulative redd observations (yellow markers) from September 12, 2011 to December 19, 2011 in the lower Yuba River, CA.**

Correlative analysis *via* simple linear regression was used to analyze potential relatedness between spatial/temporal distributions and redd abundance. Analyses indicated weak relationships between the temporal/spatial distributions and the observed abundance of Chinook salmon redds. The resulting regressions described 13% and <1% of the observations, respectively (Figures 5 and 6).

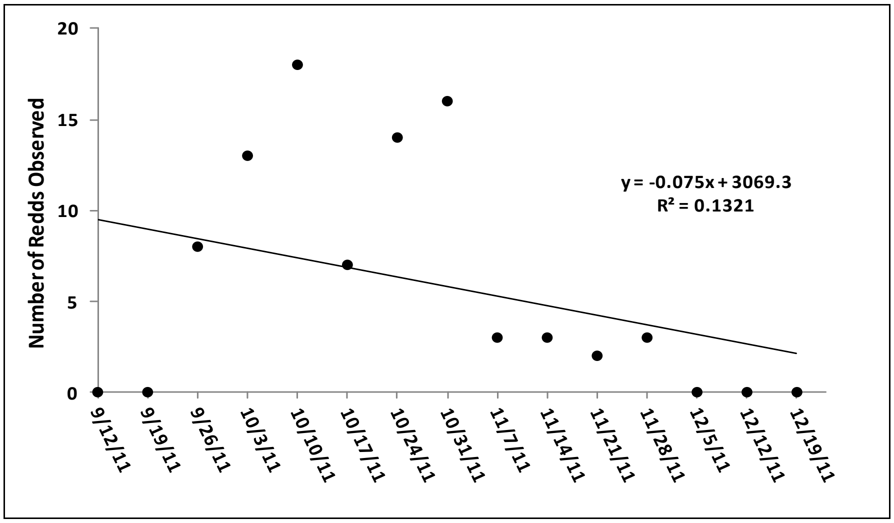


**Figure 5. Simple linear regression of the weekly number of observed Chinook salmon redds by survey date in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

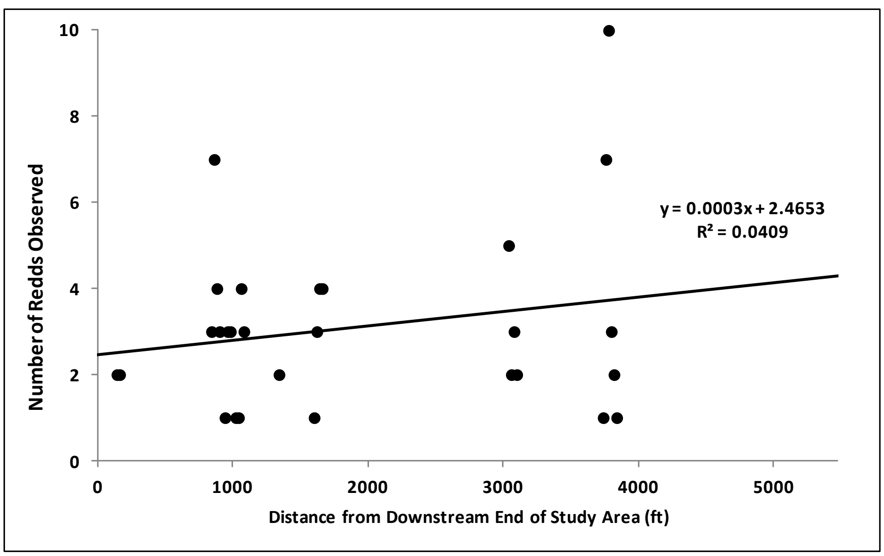


**Figure 6. Simple linear regression of the weekly number of observed Chinook salmon redds by location in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

Redd superimposition analysis using ArcGIS demonstrated that 60% (52 of 87 total) Chinook salmon redds exhibited a measureable degree of superimposition (Table 4). Nine redds were found to have a level of superimposition greater than 50% (Appendix A, Tables A1-A4).

**Table 4. Weekly Chinook salmon redd superimposition frequency in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

| Week | Number of New Redds in Analysis | Number Superimposed on Previous Redds | Superimposition Frequency (%) |
|---|---|---|---|
| 9/12/2011 | 0 | 0 | N/A |
| 9/19/2011 | 0 | 0 | N/A |
| 9/26/2011 | 8 | 0 | 0.0 |
| 10/3/2011 | 13 | 2 | 15.4 |
| 10/10/2011 | 18 | 3 | 16.7 |
| 10/17/2011 | 7 | 3 | 42.9 |
| 10/24/2011 | 14 | 9 | 64.3 |
| 10/31/2011 | 16 | 6 | 37.5 |
| 11/7/2011 | 3 | 3 | 100.0 |
| 11/14/2011 | 3 | 2 | 66.7 |
| 11/21/2011 | 2 | 2 | 100.0 |
| 11/28/2011 | 3 | 2 | 66.7 |
| 12/5/2011 | 0 | 0 | N/A |
| 12/12/2011 | 0 | 0 | N/A |
| 12/19/2011 | 0 | 0 | N/A |

Correlative analysis *via* simple linear regression of the calculated Chinook salmon superimposition frequency for each weekly stratum exhibited a strong relationship between variables moving through the survey period. The resulting regression described nearly 71% of the observations (Figure 7).

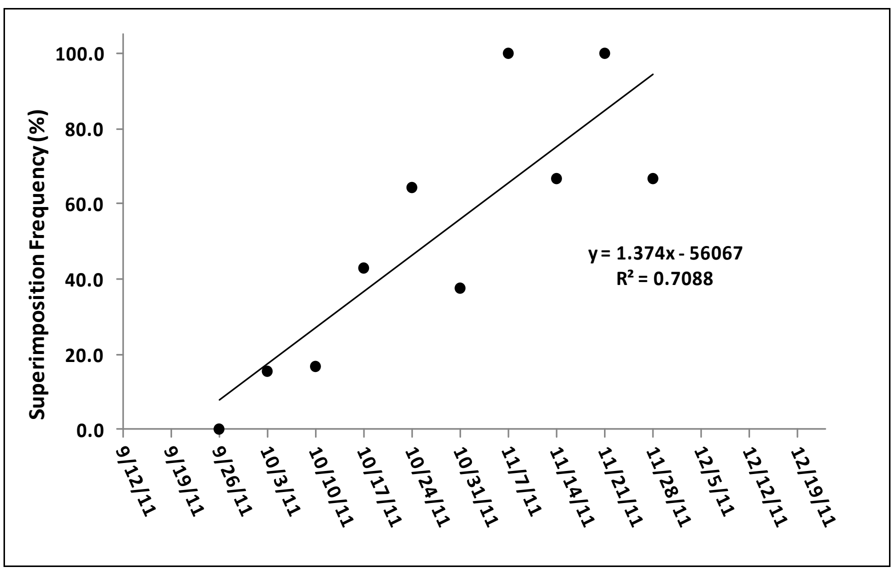


**Figure 7. Simple linear regression of the weekly frequency of superimposition for Chinook salmon in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

A fitted asymmetric logistic function predicted that 50% of Chinook salmon spawning was observed by October 17, 2011, with 90% of the observations occurring by November 14, 2011 (Figure 8).

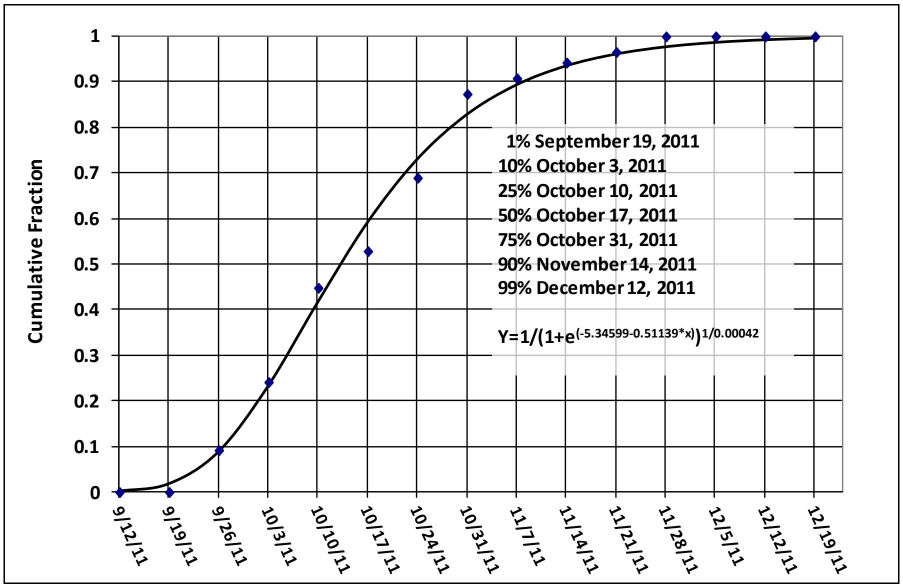


**Figure 8. Cumulative temporal distribution of observed Chinook salmon redd abundance in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

The predicted date associated with the percentile expressions for Chinook salmon was plotted against mean daily flow and water temperatures for each corresponding stratum (Figure 9). The resulting figure illustrated varied flow and temperature at the USGS Smartsville gages through the percentile expressions.

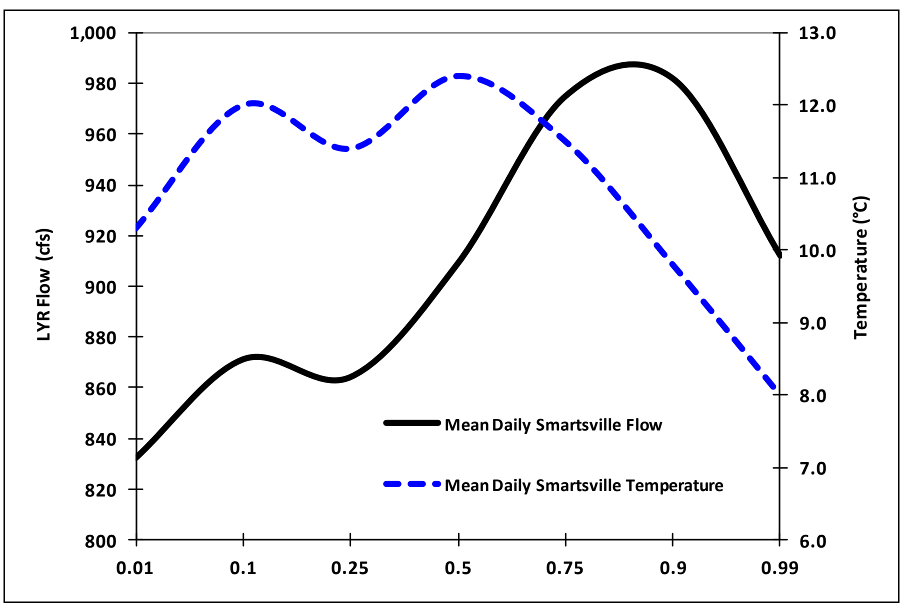


**Figure 9. Mean daily flow and mean daily temperature at the USGS Smartsville gage through the percentile expressions (1%, 10%, 25%, 50%, 75%, 90% and 99%) for Chinook salmon redd abundance in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

Spatial analysis of Chinook salmon redd positional data demonstrated a non-random distribution within the longitudinal length of the survey area. The resulting plot exhibited a non-uniform distribution, suggesting that selective preference influenced the location of redd construction (Figure 10).

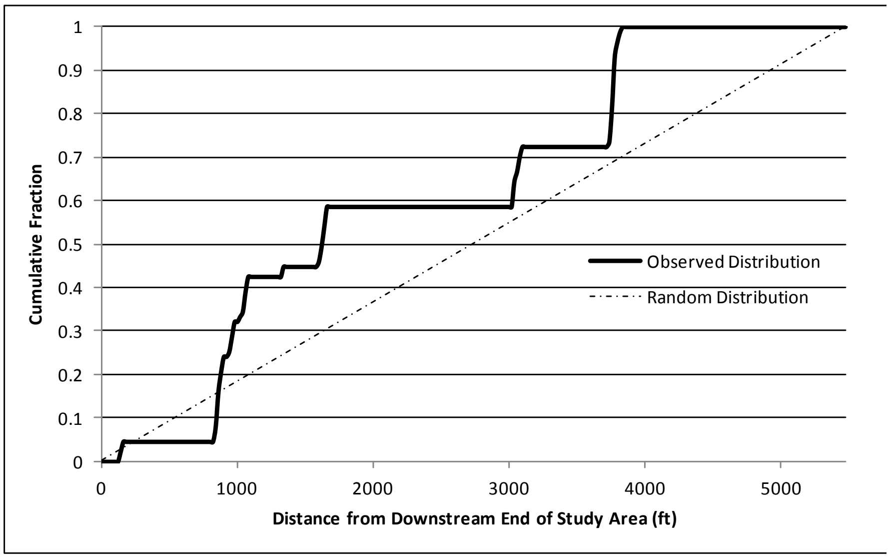


**Figure 10. Cumulative plot of the longitudinal distribution of Chinook salmon redd locations in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

## 4.3. <u>Diversity</u>

Physical size measurements collected at each observed Chinook salmon redd identified that the mean pot length was 1.1 ±0.09[3] meters (3.6 ±0.30 feet) and the mean pot width was 1.5 ±0.13 meters (4.9 ±0.43 feet). The mean tail spill length was 1.8 ±0.12 meters (5.9 ±0.39 feet), the mean tail spill width #1 was 1.5 ±0.12 meters (4.9 ±0.39 feet) and the mean tail spill width #2 was 1.3 ±0.09 meters (4.3 ±0.30 feet). The mean depth was 0.49 ±0.06 meters (1.6 ±0.20 feet), the mean nose velocity was 0.27 ±0.03 meters/second (0.89 ±0.10 feet/second) and the mean water column velocity was 0.39 ±0.04 meters/second (1.3 ±0.13 feet/second) (Table 5).

**Table 5. Descriptive statistics for the physical size measurements (m) and microhabitat features of sampled Chinook salmon redds in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

| | Pot Length | Pot Width | Tail Spill Length | Tail Spill Width #1 | Tail Spill Width #2 | Depth (m) | Nose Velocity (m/sec) | Mean Velocity (m/sec) |
|---|---|---|---|---|---|---|---|---|
| Sample Size | 83 | 83 | 82 | 83 | 82 | 86 | 84 | 85 |
| MIN | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.05 | 0.01 | 0.01 |
| MAX | 2.1 | 2.8 | 2.8 | 2.6 | 2.0 | 1.16 | 0.94 | 1.15 |
| MEAN | 1.1 | 1.5 | 1.8 | 1.5 | 1.3 | 0.49 | 0.27 | 0.39 |
| MEDIAN | 1.1 | 1.5 | 1.9 | 1.6 | 1.4 | 0.42 | 0.23 | 0.36 |
| VARIANCE | 0.2 | 0.4 | 0.3 | 0.3 | 0.2 | 0.09 | 0.03 | 0.03 |
| STD DEV | 0.4 | 0.6 | 0.6 | 0.5 | 0.4 | 0.29 | 0.16 | 0.18 |
| CONFIDENCE | 0.09 | 0.13 | 0.12 | 0.12 | 0.09 | 0.06 | 0.03 | 0.04 |

[3] All confidence interval values were calculated at 95%.

Substrate characterizations for Chinook salmon redds identified that gravel and fine cobble comprised the majority of observations. Substrate observations for gravel were represented by 35.88 ±4.57%, whereas fine cobble represented 29.29 ±3.11% of the characterizations for Chinook salmon redds (Table 6).

**Table 6. Descriptive statistics for the substrate characterization percentages of sampled Chinook salmon redds in the Englebright Dam study area of the lower Yuba River, CA from September 12, 2011 to December 19, 2011.**

| | Bedrock | Boulder >256mm | Lg. Cobble 128-256 mm | Cobble 90-128 mm | Fine Cobble 32-90 mm | Gravel 2-32 mm | Sand 0.0625-2 mm | Silt/Clay <0.0625 mm |
|---|---|---|---|---|---|---|---|---|
| Sample Size | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| MIN | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| MAX | 0% | 60% | 60% | 60% | 60% | 80% | 0% | 0% |
| MEAN | 0% | 4.24% | 11.65% | 18.94% | 29.29% | 35.88% | 0% | 0% |
| MEDIAN | 0% | 0% | 0% | 20% | 30% | 40% | 0% | 0% |
| VARIANCE | 0% | 1.65% | 3.16% | 2.24% | 2.14% | 4.63% | 0% | 0% |
| STD DEV | 0% | 12.85% | 17.78% | 14.96% | 14.62% | 21.51% | 0% | 0% |
| CONFIDENCE | N/A | 2.73% | 3.78% | 3.18% | 3.11% | 4.57% | N/A | N/A |

## 5. DISCUSSION

Weather and flow conditions during the survey period were favorable for visual-type encounter surveys. Clear skies and relatively low flows with low suspended turbidity levels provided optimum conditions for field reconnaissance and redd observation. Secchi readings measured during weekly surveys generally exceeded actual water depths in the survey area and thus provided a clear view of the river bed during field data collections.

Spatial redd observations were found to have little correlation with weekly survey strata, but cumulative temporal distributions followed a distinct pattern and an asymmetric logistic function fit temporal distributions well. Most importantly, distributional spatial data identified redds located in some areas where previously suitable spawning gravels did not exist prior to USACE gravel injections. Although additional analysis into this observation is beyond the scope of this report, a more thorough evaluation of gravel use associated with USACE gravel injections is currently underway by Dr. Greg Pasternack at U.C. Davis and will provide additional information regarding the use of USACE gravel injections. Additional investigations into the latitudinal distributions (*e.g.* morphological unit distributions), substrate elements, bed topography, depth, flow, cover and other fluvial geomorphic indicators associated with Dr. Pasternack's evaluation will provide a more comprehensive and robust level of analysis.

Measureable levels of redd superimposition were evident from survey data analyses. Superimposition levels were tightly correlated with cumulative survey strata (*i.e.* superimposition frequency increased as the spawning period progressed), suggesting a strong preference for select spawning areas and subsequent superimposition of previously constructed redds. Analysis of redd observations along the longitudinal extent of the survey area also found distributions to be non-random and that a selective preference for specific spawning areas was evident.

The survey period encompassed by this report adequately captures known spawning periods for Chinook salmon in the lower Yuba River. However, spawning by Central Valley steelhead and resident trout populations are known to occur during the winter and spring months (McEwan 2001) and thus, observations during the survey period did not include any observations of steelhead or resident trout redds.

# 6. ACKNOWLEDGEMENTS

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## 8. APPENDIX A

Table A1. Chinook salmon redd superimposition magnitude within each stratum including cumulative totals in the surveyed reaches of the lower Yuba River, CA from the week of September 12, 2011 to the week of October 3, 2011.

| Percentage of Redd Overlap | 9/12/2011 | | 9/19/2011 | | 9/26/2011 | | 10/3/2011 | |
|---|---|---|---|---|---|---|---|---|
| | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative |
| 0-5% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-10% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 10-15% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15-20% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20-25% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25-30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-35% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35-40% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 40-45% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 45-50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50-55% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55-60% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60-65% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 65-70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70-75% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75-80% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80-85% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85-90% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90-95% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 95-100% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |

Table A2. Chinook salmon redd superimposition magnitude within each stratum including cumulative totals in the surveyed reaches of the lower Yuba River, CA from the week of October 10, 2011 to the week of October 31, 2011.

| Percentage of Redd Overlap | 10/10/2011 | | 10/17/2011 | | 10/24/2011 | | 10/31/2011 | |
|---|---|---|---|---|---|---|---|---|
| | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative |
| 0-5% | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 7 |
| 5-10% | 0 | 2 | 0 | 4 | 0 | 6 | 0 | 8 |
| 10-15% | 2 | 2 | 0 | 2 | 2 | 5 | 0 | 6 |
| 15-20% | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 20-25% | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 25-30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 30-35% | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 35-40% | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 40-45% | 0 | 2 | 0 | 3 | 0 | 4 | 0 | 6 |
| 45-50% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 50-55% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55-60% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60-65% | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 2 |
| 65-70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70-75% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 75-80% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 80-85% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85-90% | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 2 |
| 90-95% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 95-100% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | 2 | 8 | 0 | 13 | 2 | 29 | 0 | 38 |

Table A3. Chinook salmon redd superimposition magnitude within each stratum including cumulative totals in the surveyed reaches of the lower Yuba River, CA from the week of November 7, 2011 to the week of November 28, 2011.

| Percentage of Redd Overlap | 11/7/2011 | | 11/14/2011 | | 11/21/2011 | | 11/28/2011 | |
|---|---|---|---|---|---|---|---|---|
| | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative |
| 0-5% | 0 | 7 | 0 | 7 | 0 | 7 | 0 | 9 |
| 5-10% | 0 | 8 | 0 | 10 | 0 | 10 | 0 | 8 |
| 10-15% | 0 | 7 | 0 | 7 | 0 | 7 | 0 | 7 |
| 15-20% | 0 | 2 | 0 | 3 | 0 | 5 | 0 | 5 |
| 20-25% | 0 | 3 | 0 | 3 | 0 | 3 | 0 | 3 |
| 25-30% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-35% | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| 35-40% | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 40-45% | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| 45-50% | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 2 |
| 50-55% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 55-60% | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 |
| 60-65% | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 4 |
| 65-70% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 70-75% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| 75-80% | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| 80-85% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 85-90% | 0 | 2 | 0 | 2 | 0 | 2 | 0 | 2 |
| 90-95% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 95-100% | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | 0 | 42 | 0 | 46 | 0 | 50 | 0 | 52 |

Table A4. Chinook salmon redd superimposition magnitude within each stratum including cumulative totals in the surveyed reaches of the lower Yuba River, CA from the week of December 5, 2011 to the week of December 19, 2011.

| Percentage of Redd Overlap | 12/5/2011 | | 12/12/2011 | | 12/19/2011 | |
|---|---|---|---|---|---|---|
| | Within Stratum | Cumulative | Within Stratum | Cumulative | Within Stratum | Cumulative |
| 0-5% | 0 | 9 | 0 | 9 | 0 | 9 |
| 5-10% | 0 | 8 | 0 | 8 | 0 | 8 |
| 10-15% | 0 | 7 | 0 | 7 | 0 | 7 |
| 15-20% | 0 | 5 | 0 | 5 | 0 | 5 |
| 20-25% | 0 | 3 | 0 | 3 | 0 | 3 |
| 25-30% | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-35% | 0 | 4 | 0 | 4 | 0 | 4 |
| 35-40% | 0 | 1 | 0 | 1 | 0 | 1 |
| 40-45% | 0 | 4 | 0 | 4 | 0 | 4 |
| 45-50% | 0 | 2 | 0 | 2 | 0 | 2 |
| 50-55% | 0 | 0 | 0 | 0 | 0 | 0 |
| 55-60% | 0 | 1 | 0 | 1 | 0 | 1 |
| 60-65% | 0 | 4 | 0 | 4 | 0 | 4 |
| 65-70% | 0 | 0 | 0 | 0 | 0 | 0 |
| 70-75% | 0 | 2 | 0 | 2 | 0 | 2 |
| 75-80% | 0 | 0 | 0 | 0 | 0 | 0 |
| 80-85% | 0 | 0 | 0 | 0 | 0 | 0 |
| 85-90% | 0 | 2 | 0 | 2 | 0 | 2 |
| 90-95% | 0 | 0 | 0 | 0 | 0 | 0 |
| 95-100% | 0 | 0 | 0 | 0 | 0 | 0 |
| TOTALS | 0 | 52 | 0 | 52 | 0 | 52 |