APPENDIX I
SPECIFIC SAMPLING PROTOCOLS AND PROCEDURES FOR CONDUCTING ADULT CHINOOK SALMON AND STEELHEAD REDD SURVEYS

Yuba River Chinook Salmon and Steelhead Redd Surveys

Background

Anadromous salmonids in the lower Yuba River include Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). The California Department of Fish and Game (CDFG) conducted annual reconnaissance-level Chinook salmon redd surveys in the lower Yuba River from 2000 through 2005. These surveys were conducted during late-August through September to document the initial time of redd construction for early spawning Chinook salmon (presumably spring-run Chinook salmon). Initial Chinook salmon redd construction was observed in the Garcia Gravel Pit Reach (primarily above Parks Bar) by mid-September each year.

The lower Yuba Accord's River Management Team (RMT) conducted a 2008-2009 pilot redd survey to obtain information to be used in the development of a methodology to provide the data necessary to address the goals specified in the lower Yuba River Monitoring and Evaluation Program (M&E Program).

Redd counts have been used widely to estimate or provide indices of adult salmonid escapement or abundance, and examine the spatial and temporal distribution of spawning adult salmonids. Redd counts are the primary metric used for monitoring salmonids in Washington and Oregon (Boydstun and McDonald 2005, as cited in Gallagher *et al.* 2007). Since the 1950s, redd counts have been used in Idaho for relative abundance estimates and examining trends in abundance (Elms-Cockrum 1999, as cited in Kucera and Orme 2007). Chinook salmon redds varied spatially and temporally over a large wilderness basin in Idaho from 1995-2003 (Isaack and Thurow 2006).

Redd superimposition occurs when later arriving female salmonids dig redds on top of existing redds. Redd superimposition can occur when spawning gravel is limited and can cause substantial mortality to eggs deposited in a redd before redd superimposition occurred (Hayes 1987; McNeil 1964). Spawning gravel availability has been found to be an important factor limiting Chinook salmon populations in streams where dams capture sediments and reduce supply of gravel to downstream reaches (EA Engineering Science and Technology 1992).

Redd surveys conducted in the lower Yuba River will obtain data on Chinook salmon and steelhead redd attributes (i.e., redd size (area, m^2)), as well as abundance, and spatial and temporal spawning distribution. Redd surveys will be conducted throughout the spawning seasons of spring-run, fall-run, and late fall-run Chinook salmon and steelhead throughout the lower Yuba River ("extensive area" redd surveys).

In addition, data pertaining to redd location and size will be obtained to develop indices of redd superimposition using geographic information system (GIS) analyses for the Chinook salmon runs and steelhead in the lower Yuba River.

Goals of the redd surveys conducted in the lower Yuba River include: (1) evaluate and compare the spatial and temporal distribution of redds and redd superimposition over the spawning seasons for the Chinook salmon runs and steelhead spawning in the lower Yuba River; (2) compare the magnitude (and seasonal trends) of lower Yuba River flows and water temperatures with the spatial and temporal distribution of redds (and rates of redd superimposition) for the Chinook salmon runs and steelhead; (3) estimate the total annual abundance of adult fall-run Chinook salmon and steelhead in conjunction with angler surveys and Vaki Riverwatcher data; and (4) establish a long-term data set to be used to evaluate habitat utilization by the Chinook salmon runs and steelhead in the lower Yuba River under variable biotic and abiotic conditions.

1.0 Survey Location

The lower Yuba River 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. Approximately 33.6 km (20.9 mi) of the 38.6 km (24 mi) of the total length of the lower Yuba River will be surveyed during the extensive area redd surveys. About 1.1 km (0.7 mi) of the lower Yuba River located immediately below the first set of riffles downstream of Deer Creek to the top of Narrows Pool will not be surveyed due to rugged and dangerous conditions in the steep canyon known as the Narrows. Additionally, an approximate 3.2 km (2 mi) section of the lower Yuba River from Simpson Lane Bridge to the confluence with the Feather River will not be regularly surveyed because redds have not been observed during past surveys. This section of the river will be surveyed once during peak Chinook salmon spawning to ascertain that this section is, in fact, not being utilized for spawning.

The area of the lower Yuba River to be surveyed for redds includes four major reaches (**Table 1**).

Table 1. Lower Yuba River redd survey reaches.

Reach	**Location**	**Kilometers**	**(Miles)**
1	Englebright Dam to 1st set of riffles below Deer Creek	1.4	0.9
2	Narrows Pool to SR 20 Bridge	6.4	4.0
3	SR 20 Bridge to Daguerre Point Dam	9.7	6.0
4	Daguerre Point Dam to Simpson Lane Bridge	16.1	10.0
Total		**32.2**	**20.9**

2.0 Survey Period

With implementation of the Yuba Accord, the adult Chinook salmon and steelhead redd surveys will be considered a long-term monitoring effort. Extensive redd surveys are anticipated to be conducted annually for at least five years, from 2009/2010 through 2013/2014. The RMT will review the data and reports on an annual basis, and determine whether the overall duration of the redd surveys should be adjusted.

Reconnaissance-level redd surveys will begin on or about August 1 each year to document the initiation of spawning activity in the lower Yuba River. Prior redd surveys have documented the initiation of spawning activity from about mid-August to mid-September. Relatively few redds have generally been observed until spawning activity begins in earnest, typically from late-September to early-October. Hence, reconnaissance-level redd surveys will be conducted from approximately August 1 until the first redd is observed each year.

Extensive area redd surveys will begin the week after a redd is first observed during the reconnaissance-level redd survey and extend through about May 1 (or until newly constructed redds are no longer observed). This duration will encompass the spawning seasons of spring-run, fall-run, and late-fall run Chinook salmon, and steelhead.

3.0 Sampling Frequency

Reconnaissance-level redd surveys will be conducted weekly (in conjunction with the roving surveys associated with Acoustic Tracking - see *Appendix D: Specific Sampling Protocols and Procedures for Acoustic Tagging*). During the reconnaissance-level redd survey, <u>survey weeks with zero redds encountered are important and must be documented.</u>

Data obtained from the 2008-2009 pilot redd survey were evaluated to determine the sampling frequency for the extensive area redd surveys. Evaluation of these data utilized the temporal distribution of spawning activity and a simulation approach. A full description of the 2008-2009 pilot survey data evaluation is presented in **Attachment 1**.

The extensive area redd surveys will be conducted weekly beginning the week after a redd is first observed during the reconnaissance-level redd survey through the portion of the season encompassing the majority of Chinook salmon spawning activity. Prior redd and carcass surveys indicate that the majority of Chinook salmon spawning activity occurs through December, with reduced amounts of Chinook salmon spawning continuing through late-March, and steelhead spawning extending through April. From the 2008-2009 pilot redd survey data and a simulation approach, a weekly sampling frequency was found to result in the most precise and accurate (least biased) estimates of spawning activity (see Attachment 1). Therefore, weekly extensive area redd surveys will be conducted from the initiation of spawning activity through December each year.

For the last portion of the extensive area redd survey (i.e., January 1 through May 1), surveys will be conducted bi-weekly (see Attachment 1) to obtain required data in a most cost-effective manner.

Redd area measurements will be conducted to examine redd superimposition throughout the lower Yuba River for the Chinook salmon runs and steelhead. Evaluation of Chinook salmon redd areas (m^2) calculated for the 2008-2009 index area indicated that redd area significantly differed ($r^2 = 0.24$, $P < 0.01$) over the course of the majority of the spawning activity (mid-September through December). Therefore, a sampling design specifically addressing redd area estimation is necessary for the extensive area redd surveys.

A systematic sampling design will be used to collect redd area measurement data during the extensive area redd survey, where every 17th sampling unit (redd) will be included in the sample for redd area measurements (see **Attachment 2**). Systematic sampling is often used for ease of execution and convenience (Hansen *et al.* 2006). In addition, systematic samples are usually spread more evenly over the population, so population attributes can be estimated more precisely than simple random sampling (Hansen *et al.* 2006).

4.0 Sample Size

For estimates of total abundance, spatial and temporal distribution of Chinook salmon (by specific run) and steelhead redds, the sample size for the extensive redd surveys is the number of weekly or bi-weekly surveys conducted for the entire survey each year.

The sample size for redd area measurements will be the total number of redds measured at a frequency of every 17th redd observed.

5.0 Survey Protocols and Procedures

5.1 Preseason Planning – Lead Biologist Responsibilities and Coordination Activities

At least one month in advance of the reconnaissance-level redd survey (beginning approximately August 1), preseason planning activities for the extensive area redd surveys will be initiated by the lead biologist. Preseason preparations include: (1) developing the annual survey schedule; (2) obtaining all necessary equipment; and (3) training all survey personnel.

During July each year, a planning meeting will be held with the RMT to review the survey procedures and logistics. The purpose of this meeting is two-fold: (1) to verify that all necessary preparations and planning arrangements have been completed for that year's redd surveys; and (2) to provide an opportunity to make adjustments to the survey timing, logistics or approach if new information becomes available or if deemed necessary by the RMT.

5.2 Data Collection and Sampling Techniques

The observation of redds and species-specific redd identification is affected by the visibility of the substrate. Substrate visibility can be reduced by turbidity, surface disturbance, and other conditions including wind, fog, high flows, and angle of the sun. Visibility will be improved by surveyors wearing polarized sunglasses. Visibility will be measured each survey day using a secchi disk.

5.2.1 Species-specific redd identification

Initially, an established size criterion will be used to distinguish between Chinook salmon and steelhead redds. A redd that is less than 1.56 m long and less than 1.37 m wide will be considered a steelhead redd. Redds larger than this length and width will be considered a Chinook salmon redd. This criterion was used to classify 129 Chinook salmon redds with 96% accuracy and 28 steelhead redds with 53% accuracy in the lower Yuba River (USFWS 2008). Uncertainty regarding species-specific redd identification using this size criterion initially will be addressed by examining the timing of spawning, gravel size, and the location of the redd in the river channel during the annual redd surveys.

Uncertainty regarding species-specific redd identification will be reduced by comparing the physical dimensions and locations for all known redds (i.e., redds which were positively identified with one species or another building or guarding them). During the extensive area redd surveys, each redd observed with an adult building or guarding them will be measured, and the species identified and recorded. After several years of data collection, if a sufficient number of known redds are identified, then the size criterion will be re-calculated and applied to each year of the extensive area redd surveys.

Differentiating between steelhead redds and Sacramento sucker (*Catostomus occidentallis*) and Pacific lamprey (*Lampetra tridentata*) spawning nests is of concern because these three species clean the gravel during spawning. Suckers do not typically spawn until late-March and April, and are generally visible during their spawning season. Steelhead redds are generally easy to distinguish, because they create a noticeable pit and tail spill in the gravel during redd construction. DeHaven (2002; as cited by CDWR 2003) often found it difficult to distinguish Pacific lamprey spawning nests from steelhead redds. The Oregon Department of Fish and Wildlife (1999) distinguish lamprey spawning nests and steelhead redds using redd/nest dimension measurements. A steelhead redd is distinguished by a longer length than width and the tailings are evenly distributed downstream by the current (**Figure 1**). Lamprey spawning nests generally have a neat and round appearance, with a conical bowl (**Figure 2**). The unique characteristic of a lamprey spawning nest is the placement of the tailings upstream from the nest (**Figure 3**). Lamprey excavate their spawning nests by sucking onto the gravel and then depositing it outside the nest. **Figure 4** shows a lamprey spawning nest with tailings from the nest placed perpendicular to the flow. Based on the 2008/2009 pilot redd survey in the lower Yuba River, lamprey were observed spawning in late-March and early-April in the most downstream sampling reach of the lower Yuba River, where sand was the subdominant substrate.

Figure 1. Steelhead redd (ODFW 1999).

Figure 2. Lamprey nest (ODFW 1999).

Figure 3. Lamprey nest, note placement of excavated rocks upstream and perpendicular to flow (ODFW 1999).

Figure 4. Lamprey nest showing placement excavated debris to the side of the nest (ODFW 1999).

5.2.2 Extensive area redd surveys

The extensive area redd surveys will be conducted using four kayaks and two survey crews, each crew with two surveyors. Each surveyor will scan the river from the shore to the middle of the river, working downstream. Side channels in the survey area may require walking.

Prior to conducting a survey, the following data will be recorded: (1) survey date; (2) surveyors' initials; (3) survey section; (4) number of crews; (5) specific crew identification (Crew A or B); (6) weather; (7) streamflow (cfs); and (8) secchi disk depth (ft) (**Attachment 3**). Flow data will be obtained from the Yuba River Smartsville and Marysville gages through the California Department of Water Resources' (CDWR) online California Data Exchange Center (CDEC). The Smartsville gage will be used for flows above Daguerre Point Dam (DPD) and the Marysville gage for flows below DPD. Visibility will be measured using a secchi disk at the top of the survey section.

Each observed redd will be consecutively numbered from the very first redd observed during the extensive area redd survey through the entire redd sampling season to identify those redds to be measured for redd size (area m^2). For each new redd observed throughout the sampling season, the following data will be recorded (Attachment 3): (1) a GPS (Trimble GeoExplorer XT) location taken at the center of the redd's pit with a unique identifying number (i.e., Date + plus redd number; e.g. 082908-001); (2) total dimensional area (using a GPS) for areas appearing to contain multiple redds with no clear boundaries (i.e., mass aggregate spawning); (3) habitat type (i.e., pool, riffle, run, or glide); (4) substrate composition of ambient habitat based on substrate size immediately upstream of the pit (**Table 2**); (5) redd species identification; (6) number of fish observed on the redd; (7) location information (i.e., side channel or main channel); (8) comments regarding observable redd superimposition (i.e., redd overlap); and (9) any additional comments.

The path undertaken by each surveyor down the river will be recorded using Garmin GPSMAP 60Cx GPS units to document specific locations of the river surveyed.

Visual estimation of dominate/subdominant substrate sizes will be along the B axis of the substrate elements. Prior to conducting redd surveys, each surveyor will become familiar with visual substrate size estimation using a gravel template.

The GPS (Trimble GeoExploerXT) and a data dictionary will be used to ensure redds counted during the previous survey weeks are not double-counted. In addition, surveyors will mark each redd at the pit with a painted rock.

Table 2. Wentworth (1922) substrate and size range.

Classification	Particle Size Range (mm)	Classification Number
Boulder	>256	6
Coarse Cobble	128-256	5
Fine Cobble	64-128	4
Gravel	2-64	3
Sand	0.0625-2	2
Silt/Clay	<0.0625	1

5.2.2.1 Redd Area Measurements

Each observed redd will be consecutively numbered from the very first redd identified in the extensive area redd surveys through the entire redd sampling season to identify those redds to be measured for redd size (area m^2). For every 17^{th} redd encountered, the, physical dimensions will be measured. In addition to the data described in **Section 5.2.2,** surveyors will collect and record redd area data for each 17^{th} redd using a fiberglass extendable rod demarcated at every 0.1 m according to the procedures identified in **Figures 5** and **6,** and **Table 3.**

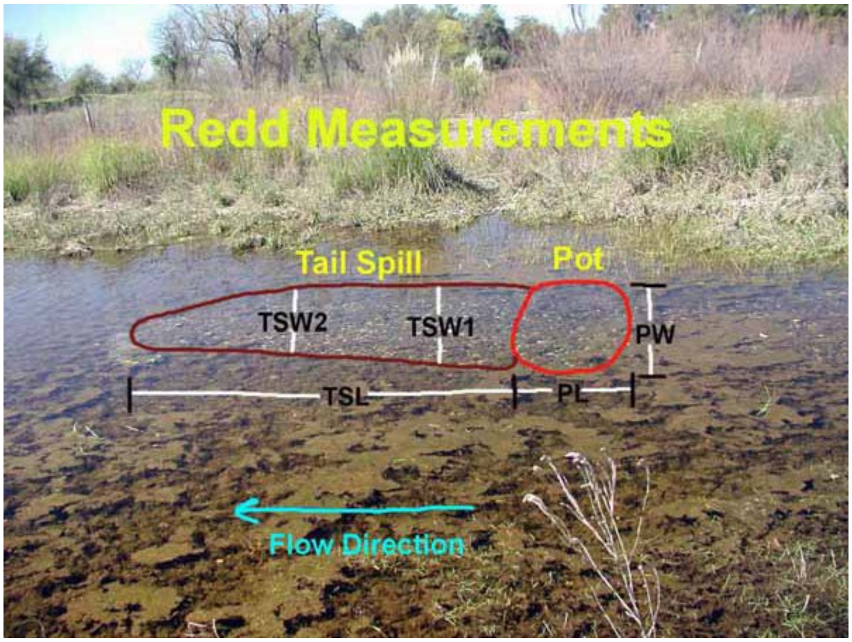

Figure 5. Illustration of steelhead redd measurements (PL = pot length; PW = pot width; TSL = tail-spill length; TSW2 and TSW1 = tail-spill widths,), as presented in Hannon and Deason (2005).

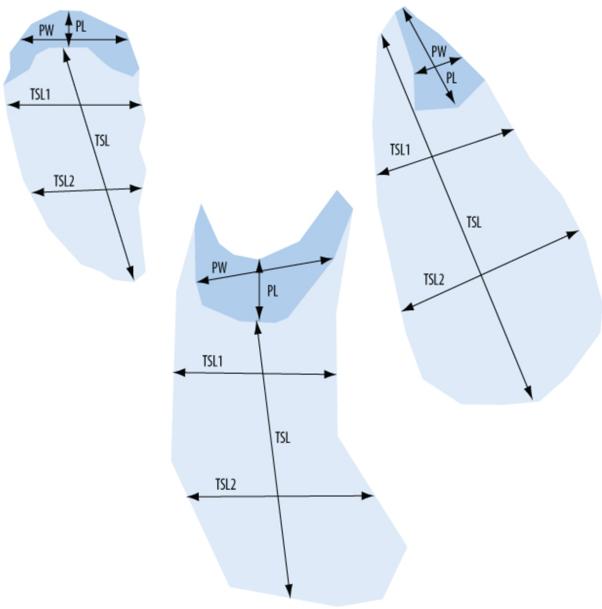

Figure 6. Measurements for unusually shaped redds (PL = pot length, PW = pot width, TSL = tail-spill length, TSL1 and TSL2 = tail-spill widths). Illustration reproduced from Gallagher *et al*. 2007.

Table 3. Description of redd dimension measurements displayed on Figures 5 and 6.

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.

5.3 Field Gear Decontamination

New Zealand mudsnails (*Potamopyrgus antipodarum*, NZMS) were first discovered in California (Owens River) in 1999. The NZMS has the ability to adapt to new ecosystems and alter food web dynamics. Controlling the spread of the NZMS is a top priority for the California Department of Fish and Game. CDFG needs to ensure that their employees are not spreading NZMS in the course of carrying out their duties. Therefore, a field gear decontamination protocol for NZMS has been developed and will be used for gear used in the lower Yuba River.

The following procedures for decontaminating field gear (i.e., waders, wading boots, boot insoles, nets, wading sticks, or anything else that comes into contact with the water) developed by CDFG (2008) will be followed prior to entering a new body of water or at the end of the day, whichever occurs first. Freezing field gear will be the first option if a freezer is available. Freezing has no adverse effect on field gear or on the environment, and is the most cost effective means of decontamination.

5.3.1 Freezing Procedure

1) Place field gear into a new large plastic bag and seal before placing into the vehicle. Any surface that comes in contact with field gear can become contaminated.

2) Upon returning to a CDFG office, place the plastic bag containing the field gear into a freezer (<0 °C) for a minimum of six hours.

5.3.2 Immersion Procedure

1) If field gear is not going to be decontaminated on site, place the field gear into a new large plastic bag and seal before placing into the vehicle.

2) Place all field gear that came in contact with water into a container of sufficient size to allow gear to be completely immersed in decontamination solution.

3) Pour decontamination solution (5% Sparquat) into container to allow complete immersion of all field gear. If necessary, weigh down the gear to ensure the gear is completely immersed. To make the decontamination solution, use a ratio of 7 oz of Sparquat to 1 gallon of water.

4) Soak field gear in decontamination solution for a minimum of 15 minutes.

5) Remove field gear from the decontamination solution and inspect gear to ensure that all debris that could contain NZMS has been removed. Use a stiff brush to remove any debris that remains on the field gear.

6) Rinse field gear with fresh water. Do not use water from the sampling site. Using water from the sampling site will contaminate your field gear. Rinse water should not be allowed to enter a storm drain or water body.

7) Decontamination solution must be disposed of into a sanitary fill for proper waste treatment. Decontamination solution cannot be dumped on the ground under any circumstances. Decontamination solution cannot be disposed into a septic system. Five-gallon disposal containers will be provided to personnel for use in disposing decontamination solution. Decontamination solution can be disposed of at the CDFG Regional office.

5.3.3 Spray Bottle Procedure

1) Create a decontamination solution that contains 10% Sparquat (900ml of water and 100ml of Sparquat).

2) Liberally spray field gear until gear is completely saturated. Ensure that hard to reach areas are sprayed thoroughly.

3) Allow decontamination solution to remain on field gear for a minimum of 15 minutes.

4) Rinse sampling gear with fresh water. Do not use water from the sampling site. Using water from the sampling site will contaminate the field gear.

5) Rinse water should not be allowed to enter a storm drain or water body.

The spray bottle procedure should not be used except under very extreme circumstances when freezing or immersion procedures cannot be completed. Contact time and concentration of decontamination solution from spray bottle procedures cannot be guaranteed, which does not ensure 100% mortality of NZMS.

5.4 Watercraft Decontamination

California's waterways currently face the challenge of invasion by quagga mussels *(Dreissena bugensis)* and zebra mussels *(Dreissena polymorpha)*. Zebra mussels, a species native to Eastern Europe, were first introduced in the United States through ballast water released into the Great Lakes in the late 1980s. Quagga mussels soon followed.

In January 2007, quagga mussels were discovered in Lake Mead and later in the Colorado River. They now infest water bodies in Riverside, San Diego and Orange counties. In January 2008, zebra mussels were discovered in the San Justo Reservoir in San Benito County.

Preventing the spread of quagga and zebra mussels is a top priority for CDFG. CDFG needs to ensure that their employees are not spreading quagga and zebra mussels in the course of carrying out their duties. Therefore, the following watercraft decontamination protocol for quagga and zebra mussels has been developed for immediate implementation by all CDFG employees (CDFG 2008).

1) Prior to leaving the launch facility; remove all plants and mud from the watercraft, trailer, and equipment. Dispose of all material in the trash.

2) Prior to leaving the launch facility; drain all water from the watercraft and dry all areas, including the motor, motor cooling system, live wells, bilges, and lower end unit.

3) Upon return to Regional facilities or local office, pressure wash the watercraft and trailer with 140 °F water, including all of the boat equipment (i.e., ropes, anchors, etc.) that came into contact with the water. (Pressure washers are available at the Region office for boat decontamination.)

4) Flush the engine with 140 °F water for at least 10 minutes and run 140 °F water through the live wells, bilges, and all other areas that could contain water.

5) For areas that cannot be washed, but have come into contact with the water, spray or wipe the areas with a solution of 4% muriatic acid.

6) Wash all field gear with 140 °F water or a decontamination solution that contains a 6% chlorine solution.

7) To ensure 100% mortality the water needs to be 140 °F at the point of contact or 155 °F at the nozzle.

Anyone with questions regarding the acquisition of chemicals, require proper training to implement these protocols, or need a field gear decontamination kit, call (916) 358-2895 (Mr. Jason Roberts; CDFG; Environmental Scientist) or (916) 358-2943 (Mr. Joseph Johnson; CDFG; Senior Environmental Scientist).

5.5 Quality Assurance/Quality Control Processes

A chain of custody and review process will occur for all data sheets. Surveyors in the field will review data sheets to verify all data has been collected, and they will record their initials on all data sheets and place them into a “data to be entered” binder. Subsequently, personnel that enter the data into a database will date and initial the data sheets and place them into an “entered data” binder. Following this, personnel will complete a final review the data entered into the database against the data sheets for quality assurance/quality control purposes and initial and date the bottom of the data sheet.

Although handheld GPS data recorders will be used in the field, a paper copy of the data will also be collected in the field and used to check the GPS data for errors.

6.0 Logistics

6.1 Personnel

Redd survey personnel will be responsible for conducting redd surveys according to this protocols and procedures. Copies of this protocols and procedures will be provided to all survey personnel prior to the onset of field data collection activities. All survey personnel will be expected to maintain complete survey field notes per this protocols and procedures.

6.1.1 Qualifications

To successfully complete data collection associated with this study, the lead personnel conducting the work will have the following minimum qualifications: a related 4-year college degree (e.g., fisheries biology or biology) and a minimum of 2 years of professional experience in fisheries field surveys. Specifically, personnel will have experience with:

- ❑ Use of various fish and fish habitat sampling techniques
- ❑ Use of aerial photographs as a field mapping base
- ❑ Use of GPS equipment
- ❑ Design and analysis of biological field studies

The data collection methods will be conducted by two person (minimum) monitoring teams to facilitate safe and efficient data collection. At least one of the team members of the monitoring team will have the minimum qualifications as stated above and will be conducting the survey.

Redd survey personnel should be in such physical shape as to allow for extended and at times strenuous hiking while carrying equipment and personal gear that may weigh 20 pounds or more. Personnel must be able to swim. Survey personnel should expect to work extended daily hours as necessary to complete described surveys. Prior to the initiation of survey work, all survey personnel will have had to complete several training sessions on field collection techniques and safety. All necessary training will be provided during the preseason preparation and training period.

6.1.2 Training

This protocols and procedures will be available to all redd survey personnel to promote consistency among survey efforts and to address safety concerns. New hires will be scheduled to go on surveys with experienced redd survey personnel and receive training in the field. Safety, aspects of landowner relations, trespassing regulations, and redd count protocol training for all survey crew members will be scheduled and conducted prior to initiating the field season. Safety training for field crews will include first aid, wilderness medicine, swift water rescue training, boat safety, and wader safety training. Specialized training for using all-terrain vehicles, four-wheel drive vehicles, boats, or other equipment needed for conducting redd surveys will occur during the pre-field season period. Redd survey protocol training will include time for personnel to read and become familiar with the specifics of field procedures, redd identification, and data management.

6.2 Schedule

The timing of field surveys will be important in both the collection of relevant data and the interpretation of results. The following is a synopsis of the preparatory efforts, fieldwork, and analyses that will be completed over the course of an annual survey season.

June through July 31

- ❑ Conduct pre-season preparations and planning (e.g., hire field crews, logistics coordination, scheduling redd surveys, equipment maintenance and testing)
- ❑ RMT Planning Group Coordination
- ❑ Conduct Field Personnel Technical Training
- ❑ Conduct Field Personnel Safety Training

August 1 through December 31

- ❑ Conduct Reconnaissance-level Redd Surveys
- ❑ Conduct Extensive Area Redd Surveys

January 1 through May 1

- Conduct the Extensive Area Redd Survey Bi-weekly

May 2 through June

- Finalize Data QA/QC and Compilation
- Data Analysis and Interpretation of Results
- Prepare Draft Annual Monitoring Report
- RMT Planning Group Review of Draft Monitoring Report
- Prepare Final Annual Monitoring Report

6.3 Cost

Total cost for the annual Chinook salmon and steelhead trout extensive area redd surveys is estimated to be $67,606.34 (**Table 4**). The cost estimate reflects funding allocations for equipment, personnel time, travel, training, and administrative overhead for conducting the extensive area redd survey. Yearly cost may very depending on if equipment can be reused from year-to-year such as the Trimble GPS units.

Table 4. Estimated budget for annual extensive area redd survey.

Annual Lower Yuba River Redd Survey Budget								
LABOR	# of Surveys	days/survey	total days	hrs/day	total hrs	labor rate/hr	# of personnel	
Tech	22	3.5	77	8	616	$14.28	3	$26,389.44
Biologist	22	3.5	77	8	616	$39.24	1	$24,171.84
								Subtotal
								$50,561.28
TRANSPORTATION	# of Surveys	days/wk	total days	miles/day	total miles	rate	# DFG vehicles	
Vehicles	22	4	88	50	4400	$0.59	2	$5,192.00
EQUIPMENT	item	price	number					
	FV 700R/GMRS Motorola Radios	$49.99	2					$99.98
	5mm Reg. Stocking Foot Waders	$59.99	4					$239.96
	5mm Tall/Stout Stocking Foot Waders	$64.99	4					$259.96
	Guidewear Felt Sole Wading Boots	$69.99	4					$279.96
	Comfort Mesh Vest Type III PFD	$39.95	4					$159.80
	Helly Hansen Roan Anorak Rain Jacket	$64.95	4					$259.80
	Large Roll Top Dry Bags	$24.99	4					$99.96
	Bending Branches Slice Angler Kayak Paddle	$129.99	4					$519.96
	Aluminum Kayak Carriers	$79.99	2					$159.98
	First Aid Kit	$54.10	1					$54.10
	Stearns Cold Water Neoprene Gloves	$17.10	4					$68.40
	Rite in the Rain Copier Paper	$26.20	2					$52.40
	Redi-Rite Clipboard	$25.40	2					$50.80
	Trimble GeoXT Handheld GPS Unit	$4,495.00	2					$8,990.00
	Waterproof plastic case for GPS	$34.00	2					$68.00
	Fiberglass extendable measuring rod	$70.00	2					$140.00
	Spray paint	$7.00	10					$70.00
	Secchi disk	$40.00	2					$80.00
	Weighted Rope with gradations for secchi disk	$40.00	2					$80.00
	Polarized Sunglasses	$30.00	4					$120.00
								Subtotal Equipment
								$11,853.06
						Grand Total:		$67,606.34

6.4 Equipment

Redd Surveys	
• 4 Kayaks & paddles	• Waterproof plastic case for GPS unit
• 2 Trimble Geoexplorer GPS units, with data dictionary loaded	• Data Box
• Chest Waders or Wading Boots	• Data sheets
• Wetsuit(s)/mask(s)	• Pencils
• Boots	• Duct tap
• Gloves	• Motorola handheld radios
• Survey Protocols and Procedures	• Data Sheets
• Waterproof Camera	• Secchi Disk
• Brimmed Hat	• Field Notebook
• Dry Cloth (to dry off equipment, etc.)	• Polarized Sunglasses
• Cellular or Satellite Phone	• Decontamination Solution
• Contact and Emergency Phone Numbers	• Swift Water Safety Gear
• Food and Water	• First Aid Kit
• UC Davis Key	• Lifejackets/Other Personal Floatation Devices (inflatable)
• Sunscreen	• Fiberglass extendable measuring rod (0.1 m)
	• Cans of Bright Colored Spray Paint

7.0 Data Management

7.1 Data Entry and Data Processing

A relational database will be developed using Microsoft Access to manage all of the data collected during the redd surveys. A metadata document will be developed for the database that contains at least: 1) a data dictionary and description of all of the codes; 2) a list of all of the fields in each table; 3) units of measure for each field; 4) description of how the tables are related; 5) description of the purpose of each table; and 6) step-by-step explanation of the process to enter data and use any developed queries.

Data on the data sheets will be entered into the relational database and quality assurance and quality control steps will be taken for data entry as described in Section 5.5. Additional quality assurance and quality control (QA/QC) procedures will include a series of queries designed to test if all redds were observed at least once, to look for duplicate records, and to sort individual redd observations by date to ensure that a date of first observation exists in the database. A record of data entry errors will be kept and used to identify and alleviate common problems.

Data stored in the relational database that is needed for GIS analyses will be exported from the database to GIS software.

7.2 Data Storage and Archival Procedures

All original data sheets will be photocopied, well organized, clearly labeled, and archived. Photo copied datasheets will be used for data entry.

Reports will be prepared annually and archived. Electronic versions of the data sets, as well as hardcopies of reports, will be submitted to the RMT Planning Group.

- ❑ Raw Data Electronic Storage Format (Software): Microsoft Access
- ❑ Processed Data Electronic Storage Format (Software): Microsoft Excel, Access, ArcMap

Electronic files and print copies of the field data sheets will be located at:

Yuba County Water Agency
1220 F Street
Marysville, CA 95901-4226

California Department of Fish and Game
2545 Zanella Way, Suite F
Chico, CA 95928

Data Retrieval Contact: M&E Lead Biologist – Colin Purdy
Telephone Number: (530) 895 - 5522
Email Address: CPurdy@dfg.ca.gov

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ATTACHMENT 1

Assessment of the Influence of Redd Survey Sampling Frequency on the Estimation of Redd Abundance and Timing of Redd Construction

Redd surveys are an important component of the Lower Yuba River Accord M&E Program. They will provide the data for one method to evaluate the abundance of Chinook salmon and steelhead spawning in the lower Yuba River (M&E Sections 3.1.2.2, 3.1.2.3, 3.1.2.5, 3.1.3.4, 3.1.3.5) and the timing of spawning (M&E Sections 3.1.2.8, 3.1.3.3, 3.3.2.6, 3.3.3.1), as well as to determine the presence and timing of distinct Chinook salmon runs spawning in the river (M&E Sections 3.1.2.1, 3.1.2.7).

The evaluation of the data obtained during the 2008-2009 Pilot Yuba River Chinook Salmon and Steelhead Redd Survey (hereinafter referred as the Pilot Survey) by aerial and ground-based surveys indicated that the ground-based redd surveys were the most cost effective survey to be implemented as long-term extensive-area redd surveys. However, the most adequate sampling frequency for the long-term extensive-area survey still remains to be identified. The survey sampling frequency (*i.e.*, how many times during the year the three lower Yuba River reaches will be monitored for newly built Chinook salmon and steelhead redds) will affect the accuracy and precision of any estimate of overall abundance, the spatial and temporal distribution of spawning, and the likelihood of separating Chinook salmon runs. Surveys with high sampling frequency (*e.g.*, surveys performed every week within the year) will increase the accuracy and precision of the derived abundance and timing estimates, and enhance the likelihood of separating Chinook salmon runs, as opposed to low sampling frequency surveys (*e.g.*, surveys performed every month within the year). On the other hand, high sampling frequency surveys require larger field crews than low sampling frequency surveys, resulting in higher cost.

The objective of this study is to evaluate the potential effects that redd surveys performed every week, two weeks, three weeks and four weeks (*i.e.*, monthly surveys) within a sampling season extending from August 1 through May 1 have in the estimates of Chinook salmon spawning abundance (*i.e.*, total number of redds built within the sampling season) and timing of spawning (*i.e.*, dates at which particular percentages of the cumulative distribution of all newly-built redds are achieved), as well as the likelihood of evaluating the correct number of spawning groups or runs present.

A simulation approach was chosen to achieve the objective of this study because no direct comparison of the data obtained by the high sampling frequency surveys (*i.e.*, Index-Area redd surveys) and low sampling frequency surveys (*i.e.*, monthly extensive-area survey) performed during the 2008-2009 Pilot Survey was possible. Although the Index-Area surveys provided rich data to allow for reasonable Chinook salmon spawning abundance and timing estimates, they were performed in a very restricted area. On the other hand, the monthly surveys extended over the three Yuba River study reaches, but provided a limited amount of data.

1. Method

1.1 General Approach

The simulation approach chosen to address the objective of this study consists of several steps. First, the rich data collected in the Index-Area redd surveys of the 2008-2009 Pilot Redd Survey were used to fit a statistical model that provided the population and sampling parameters of the assumed “true” redd distribution for the August 1 - May 1 sampling season (Section 1.2). Second, 100 schedules of sampling dates per sampling frequency category (*i.e.*, weekly, bi-weekly, tri-weekly and monthly) were randomly selected within the sampling season (Section 1.3). Third, the number of counted redds per sampling date for each of the 100 randomly selected schedules was simulated from the fitted statistical model (Section 1.4). Next, the model population parameters were estimated again from each set of the 100 sets of weekly, bi-weekly, tri-weekly and monthly simulated redd counts (Section 1.5), and the new model population parameter estimates were used to evaluate redd abundance and spawning timing for the four sets of 100 simulated redd data.

1.2 Statistical Model and Assumptions

The statistical model predicts the number of Chinook salmon redds counted at any given sampled date *j* ($\hat{C}_j$) of the Index-Area redd survey. The sampling date *j* is an integer number running from 1 (August 1) to 274 (May 1). There were a total of N = 34 sampling dates *j* actually sampled during the Index-Area redd survey, and they were spaced every other 2 or 3 days from September 15 through December 1, every week until December 15, and every two weeks afterwards.

The predicted number of redds counted at any given sampled date is defined by the following equation:

$$\hat{C}_j = \hat{q} \times \left\{ \sum_{j=i}^{i-12} \hat{\pi}_{j-i} \times \left[\sum_{R=1}^{3} \left(\hat{Y}_{R,j+1} - \hat{Y}_{R,j} \right) - \hat{C}_{j-1} \right] \right\} \qquad \textbf{(1)}$$

where $\hat{q}$ is a constant with value between 0 and 1 that indicates the counting efficiency. The subscript *i* is an integer number running from 1 (August 1) to 274 (May 1), and the subscript *R* indicates the run or spawning group to which the redd count belongs. Initial inspection of the temporal distribution of the redd counts during the 2008-2009 Index-Area redd survey suggested the presence of at least 3 runs or spawning groups, one centered around October 15 (probably mostly associated with spring-run Chinook salmon mixed with some fall-run Chinook salmon), a second group centered around mid November (probably mostly fall-run Chinook salmon), and a third group dispersed from late December through March (initially identified as late fall-run Chinook salmon). The values $\hat{Y}_{R,j}$ and $\hat{Y}_{R,j+1}$ are the cumulative number of redds belonging to run or spawning group R built through days j and j+1 as described by the following logistic equation:

$$\hat{Y}_{R,j} = \frac{\hat{K} \times \hat{\theta}_R}{\left(1 + \exp\left(\hat{\alpha}_R + \hat{\beta}_R \times j\right)\right)} \qquad \textbf{(2)}$$

where $\hat{K}$ is the asymptotic total number of redds (a measure of redd abundance), $\hat{\alpha}_R$ and $\hat{\beta}_R$ are the logistic intercept and slope associated to the logistic curve of the run or spawning group R. Finally, $\hat{\theta}_R$ is the proportion of the asymptotic total number of redds that corresponds to the run or spawning group R, subject to the constraint $\sum_{R=1}^{3} \hat{\theta}_R = 1$.

The model assumes that a certain fraction of redds built in days prior to sampling day j will still remain distinguishable for counting as a fresh redd during sampling day j. In equation **(1)** this fraction, hereinafter called "distinguishability", is indicated by $\hat{\pi}_i$ and was modeled as:

$$\hat{\pi}_i = \frac{\left(1 + \exp\left(-\hat{\alpha}_\pi\right)\right)}{\left(1 + \exp\left(-\hat{\alpha}_\pi + i\right)\right)} \qquad \textbf{(3)}$$

for $i = \{0, 1, 2 \ldots 12\}$.

The model described in equations **(1)** through **(3)** has a total of 11 parameters to be estimated for a sample size N = 34. Of these 11 parameters, 9 are population parameters (*i.e.*, $\hat{K}$, $\hat{\alpha}_R$ and $\hat{\beta}_R$ for R =1, 2 and 3, and $\hat{\theta}_R$ for R =1 and 2) and 2 are sampling parameters (*i.e.*, $\hat{q}$ and $\hat{\alpha}_\pi$).

The 11 parameters of the model were estimated by minimizing the residual sum of squares *RSS* for the N = 34 days sampled during the 2008-2009 Index-Area redd survey:

$$\sum_{d=1}^{34} \left(\hat{C}_d - C_d\right)^2,$$

where $\hat{C}_d$ are the redd counts predicted by the model and C_d are the redds counted in any of the 34 sampled days (d). The minimization of *RSS* was achieved using Excel® function add-in Solver.

In fitting the statistical model, described above, the following assumptions were made:

- Chinook salmon redds were identified without error.

- Individual newly built redds were counted only once during the whole extent of the survey season (August 1 –May 1).

- The timing of redd construction is described by a logistic distribution of time.

- There were three spawning groups or runs present during the survey season, each with distinct timings described as logistic functions.

- For a given sampling day a certain fraction of the redds built in days prior to the sampling day still remain distinguishable to be counted as newly built during the particular sampling day.

- The "distinguishability" of newly built redds follows an exponential decay from 1 during the day of construction to 0, 12 days after redd construction.

1.3 Selection of Sampling Dates

A set of 100 schedules of sampling dates was randomly chosen per sampling frequency category (*i.e.*, weekly, bi-weekly, tri-weekly and monthly). A total of 100 initial sampling dates was chosen by randomly selecting an integer number between 1 (corresponding to August 1) and 46 (corresponding to September 15) to guarantee that the initial portion of the spawning distribution will be sampled.

Once the 100 initial sampling dates were selected, the remaining dates of the sampling schedules corresponding to the weekly, bi-weekly, tri-weekly and monthly sampling frequency categories were determined by selecting every 7th, 14th, 21st and 28th day from the initial sampling date.

The resulting 100 schedules consisted of 33 to 44 sampling dates for the weekly sampling frequency category, 17 to 20 sampling dates for the bi-weekly sampling frequency category, 11 to 14 sampling dates for the tri-weekly sampling frequency category, and only 9 to 10 sampling dates for the monthly sampling frequency category.

1.4 Redd Counts Simulation

Once the four 100 sampling schedules have been determined, the number of redd counts for each selected date j in the schedules was randomly selected assuming Binomial distributions with number of trials N equal to the rounded value $\hat{C}_j / \hat{q}$ predicted by the fitted model (Section 1.2) and probability p equal to $\hat{q}$.

1.5 Fitting of Simulated Data

Once four 100 simulated data sets of redd counts have been generated, the statistical model (Section 1.2) was fitted to each simulated data set to estimate new population parameters (*i.e.*, $\hat{K}$, $\hat{\alpha}_R$ and $\hat{\beta}_R$ for R =1, 2 and 3, and $\hat{\theta}_R$ for R =1 and 2) and leaving the sampling parameters (*i.e.*, $\hat{q}$ and $\hat{\alpha}_\pi$) fixed at the values estimated with the Index-Area redd survey data. The new sets of population parameter estimates were saved to evaluate the effects of the survey sampling frequency on the abundance and timing estimates and on the likelihood of evaluating the correct number of spawning groups or runs present.

1.6 Summarizing of Results

The 400 sets of 9 newly estimated population parameters were used to calculate cumulative distributions of newly built Chinook salmon redds relative to all Chinook salmon redds (those belonging to all the runs or spawning groups) built from August 1 through May 1. These cumulative distributions are used to evaluate timing of redd construction and compare with the "true" cumulative distribution (*i.e.*, the cumulative distribution that resulted from the fit of the statistical model to the Index-Area redd survey data and was used to originate the 400 sets of simulated redd data).

Effects on redd abundance estimates will be obtained by comparing the 400 new estimates of K with the original value $\hat{K}$.

The timing and abundance estimates from each of the 100 sets of 9 newly estimated population parameters were summarized per sampling frequency category in terms of the averages and 95% confidence intervals of the 100 estimated abundances, and the 100 estimated times (dates) associated with the 1%, 10%, 25%, 50%, 75%, 90% and 99% of each estimated cumulative distribution of newly built redds. Additionally, the bias (*i.e.*, B = (Average – True Value)/True Value) in the estimates of timing and abundance per sampling frequency category also was calculated.

2. Results

2.1. Model Fit

Figure 1 displays the model fitted to the 2008-2009 Index-Area redd survey data by comparing the redd counts predicted by the fitted model and the redds actually counted in the 34 sampled days of the 2008-2009 Index-Area redd survey. The fitted model explained 83% of the data variability (*i.e.*, R^2 = 0.83). *MSE*, the mean square error of the fit was 3.2 (*i.e.*, $MSE = \sqrt{RSS/(N-p)} = \sqrt{241.2/(34-11)}$).

The fitted model predicted the daily distribution of newly built redds for 3 runs or spawning groups (**Figure 2**). The predicted peak for run 1 (probably mostly associated with spring-run Chinook salmon mixed with some fall-run Chinook salmon) was October 10, and that for run 2 (probably mostly fall-run Chinook salmon) was November 10. The predicted peak for the third run (assumed to be associated to the spawning of late fall-run Chinook salmon) was January 15.

The three curves depicted in Figure 2 arise from the following fitted logistic equations:

$$\hat{Y}_{1,j} = \frac{599 \times 0.63}{\left(1+\exp\left(12.066 - 0.168 \times j\right)\right)} \text{ for run 1} \qquad \textbf{(4)}$$

$$\hat{Y}_{2,j} = \frac{599 \times 0.13}{\left(1 + \exp\left(22.491 - 0.220 \times j\right)\right)} \text{ for run 2} \quad \textbf{(5)}$$

$$\hat{Y}_{3,j} = \frac{599 \times 0.24}{\left(1 + \exp\left(13.090 - 0.076 \times j\right)\right)} \text{ for run 3} \quad \textbf{(6)}$$

where $\hat{K} = 599$ is the asymptotic total number of redds (i.e., measure of total redd abundance).

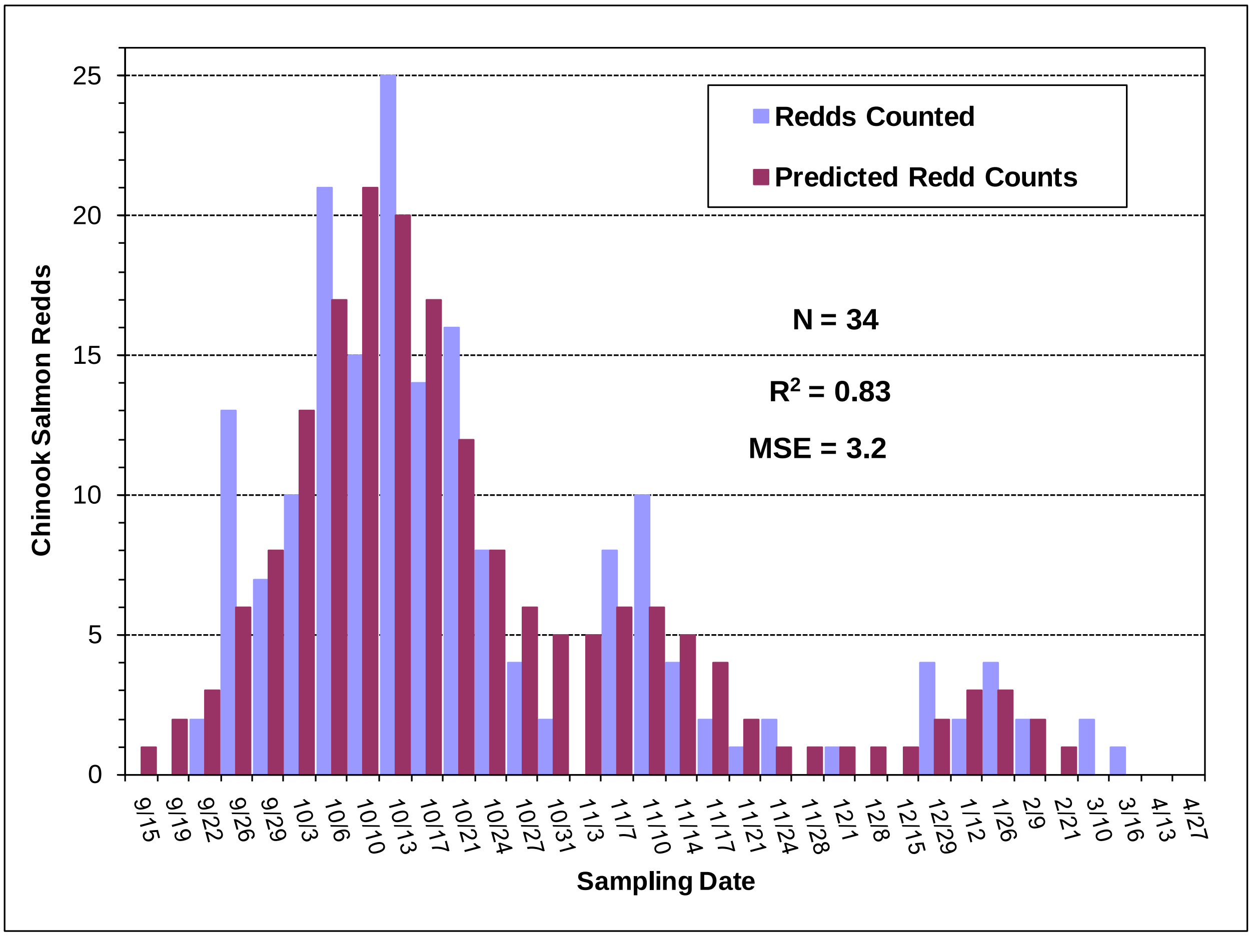

Figure 1. Comparison of the number of Chinook salmon redds counted during the Index-Area survey performed as part of the 2008-2009 Yuba River Pilot Redd Survey and the number of redds and number of redd counts predicted by the fitted statistical model for the 34 sampling days of the survey. R^2 indicates the coefficient of determination, and MSE is the mean square error of the fit.

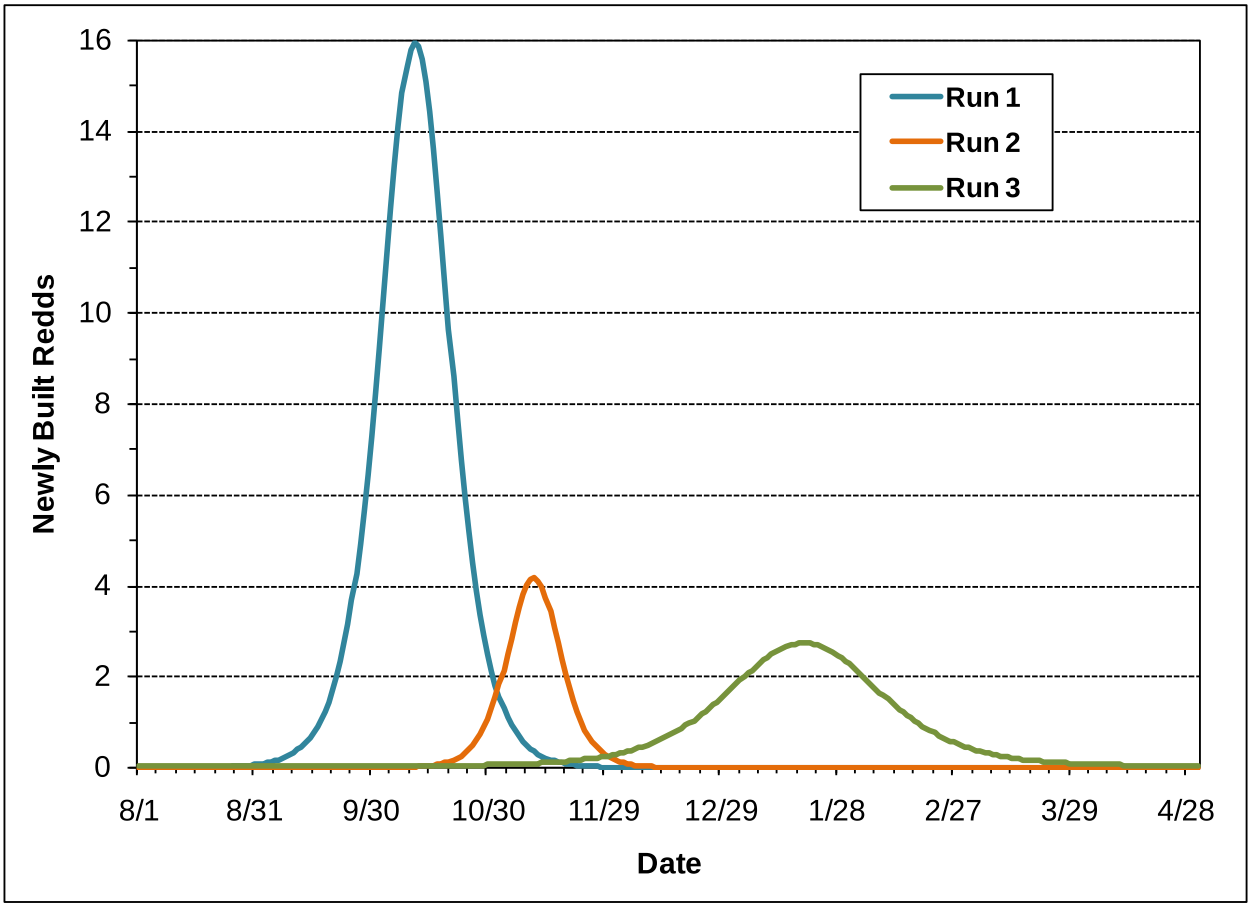

Figure 2. Predicted temporal distribution of newly built Chinook salmon redds during the season extending from August 1 through May 1, obtained from redds observed during the 2008-2009 Index-Area Pilot Redd Survey. The colored lines display the temporal distributions for the three runs assumed in the model.

The sum of the three logistic relationships expressed by equations **(4)**, **(5)** and **(6)** divided by $\hat{K} = 599$ generates the relative cumulative distribution of newly built Chinook salmon redds over the entire survey season (August 1 through May 1). This relative cumulative distribution, depicted by the bold black line in **Figure 3**, was used to compute the true timing of redd construction that was contrasted with the timings originated from the fit of the model to the simulated data.

Figure 3 indicates that 25% of all Chinook salmon redds were constructed by October 8, 50% by October 18 and 75% by November 20. Moreover, Figure 3 indicates that by November 20 most of the redds built by runs 1 and 2 had been built.

In addition to values for the 9 population parameters that define equations **(4)**, **(5)** and **(6)**, the fitted model provided values for two sampling parameters (*i.e.*, the counting efficiency $\hat{q}$ and the parameter $\hat{\alpha}_{\pi}$ that defines the shape of the "redd-distinguishability" function). The estimated counting efficiency was $\hat{q} = 0.566$.

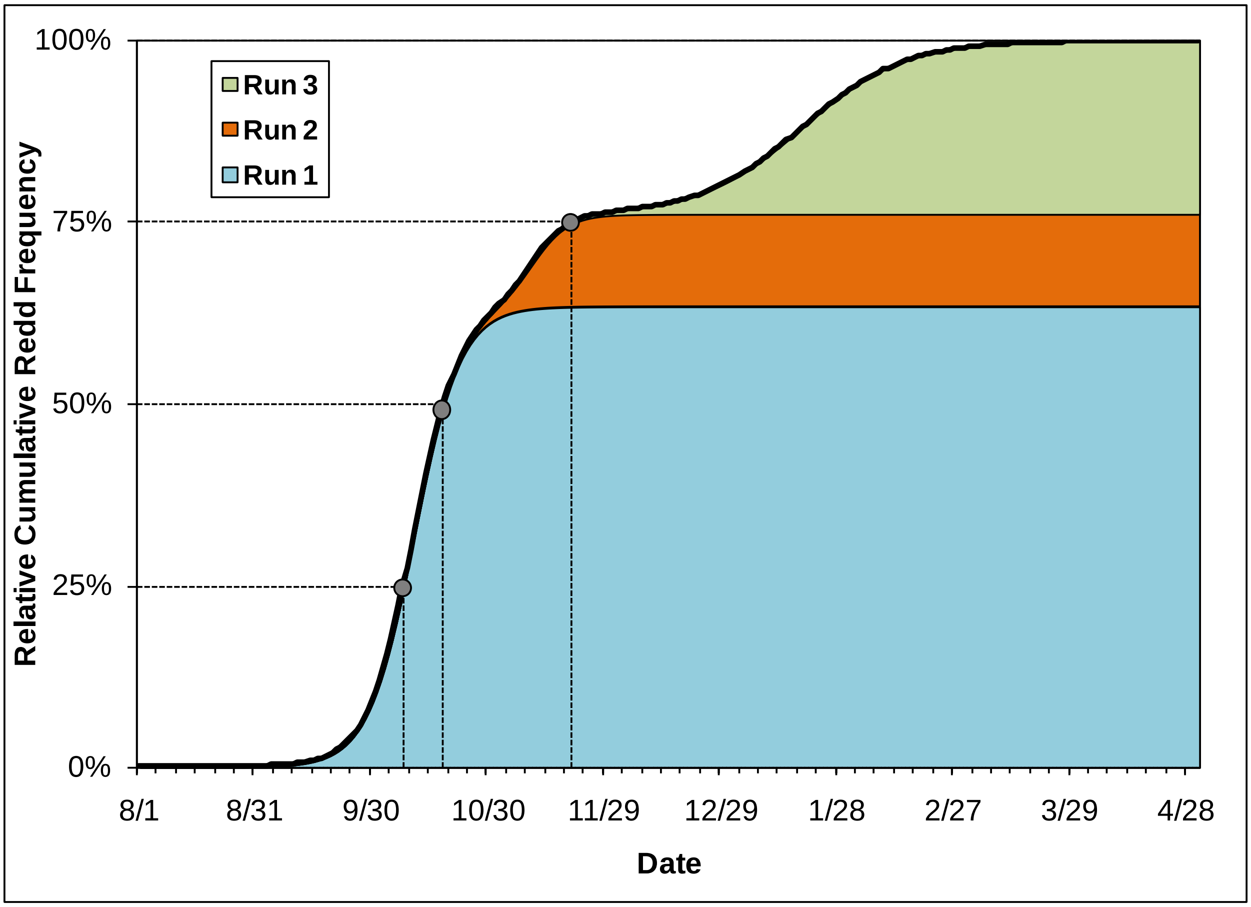

Figure 3. Predicted cumulative distribution of newly built Chinook salmon redds relative to all Chinook salmon redds built from August 1 through May 1, based on redds observed during the 2008-2009 Index-Area Pilot Redd Survey. The colored areas display the relative cumulative proportions of redds belonging to any of the three runs assumed in the model in any given date.

Finally, the predicted function describing “redd-distinguishability” depicted in **Figure 4** was:

$$\hat{\pi}_i = \frac{\left(1+\exp\left(-1\right)\right)}{\left(1+\exp\left(-1+i\right)\right)} \quad \textbf{(7)}$$

The predicted function depicts a rather sharp decrease in “redd-distinguishability” with only 16% of newly-built redds distinguishable by the third day after redd construction, and with nearly 0% distinguishable 9 days after construction.

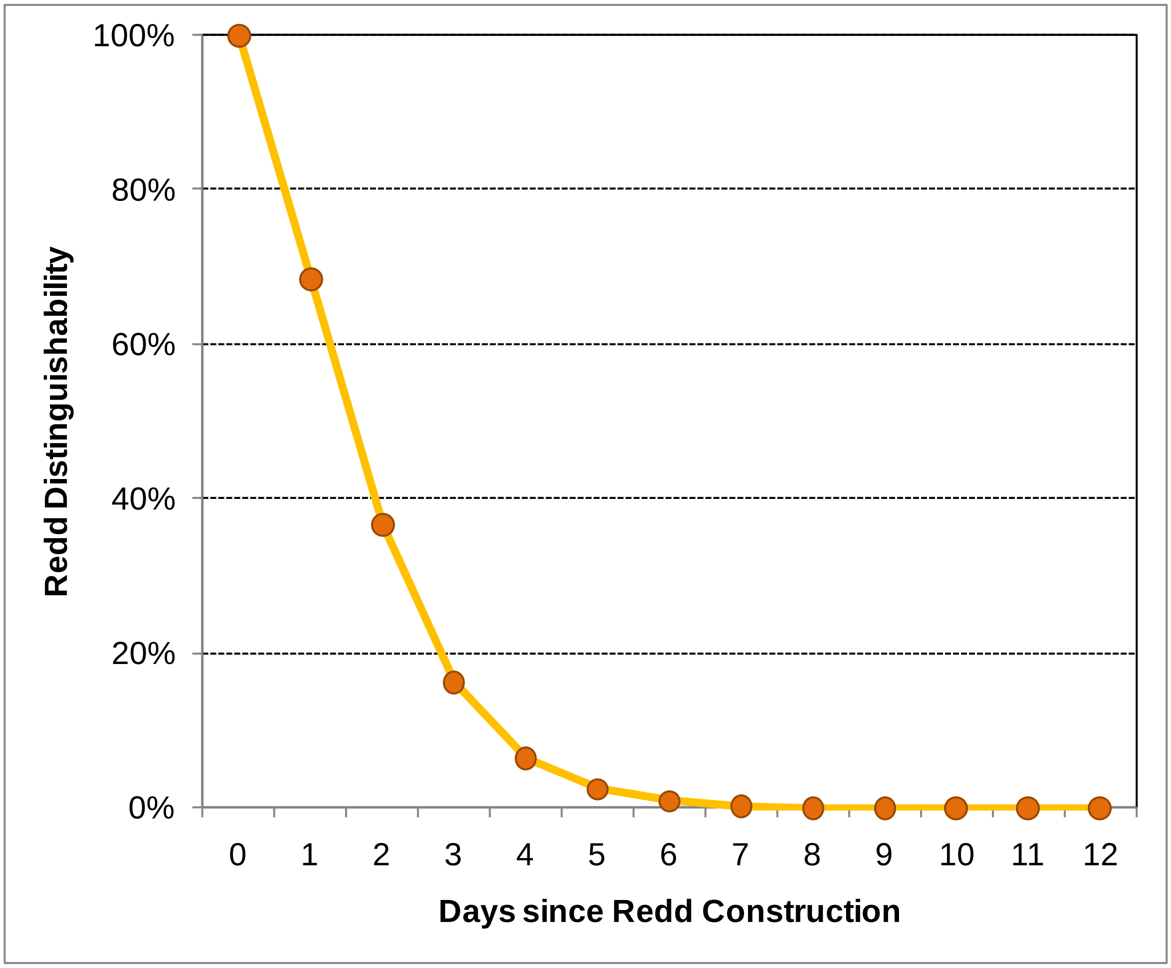

Figure 4. Predicted distinguishability of newly-built redds as function of days after redd construction.

2.2. *Effect of Sampling Frequency on Redd Abundance*

Table 1 compares the redd abundance estimates (*i.e.*, $\hat{K}$) resulting from fitting the statistical model of Section 1.2 to the four sets of 100 simulated redd survey data with $\hat{K} = 599$, the value obtained from fitting the model to the 2008-2009 Index-Area redd survey data that is considered the "true" abundance.

The averages of the 100 redd abundance estimates from weekly and bi-weekly redd survey sampling frequencies were somewhat smaller than the true value $\hat{K} = 599$. On average, both sampling strategies produced negatively biased abundance estimates, with the abundance estimates for the bi-weekly redd survey sampling frequencies being slightly more biased. The averages of the 100 redd abundance estimates from tri-weekly and monthly redd survey sampling frequencies were larger than the true value $\hat{K} = 599$. On average, the abundance estimates were positively biased with the relative bias increasing from 4% to almost 15% with the decrease of the survey sampling frequency from tri-weekly to monthly. Additionally, the width of the 95% confidence intervals of the 100 abundance estimates increased as the redd survey sampling decreases from weekly to monthly.

Table 1. Comparison of total Chinook salmon redd abundances for the true redd distribution and those estimated from simulated redd observations of 100 simulated annual redd surveys with weekly, bi-weekly, tri-weekly and monthly sampling frequencies.

True Redd Abundance (Redds)	Redd Survey Sampling Frequency	Redd Abundance Estimated from 100 simulations		
		Average Redd Abundance (Redds)	95% Confidence Interval (Redds)	Relative Bias (%)
599	Weekly	596	(517 - 679)	-0.42%
	Bi-Weekly	591	(494 - 682)	-1.24%
	Tri-Weekly	624	(488 - 781)	4.19%
	Monthly	686	(498 - 1021)	14.58%

2.3. *Effect of Sampling Frequency on Redd Timing*

Figure 5 through **Figure 8** display the average (red line) and 95% confidence intervals (orange areas) of the 100 relative cumulative distributions generated from the simulated redd survey data collected under the four sampling frequency strategies, together with the true relative cumulative distribution (blue line). These figures help evaluate redd timing under each sampling frequency strategy. For example, the date at which 75% of the true cumulative distribution of redds has been built is found by reading the x-coordinate associated to the intersection of the blue line with the 75% dotted line.

Similarly, for any of the 4 sampling frequency strategies, the average date associated with the 75% of the simulated cumulative distributions is the x-coordinate (date) that corresponds with the intersection of the red line (the average of the 100 relative cumulative distributions generated from the simulated redd survey data) and the 75% dotted line. Moreover, the 95% confidence interval of the date associated with the 75% of the simulated cumulative distributions is determined by the x-coordinates of the points at the intersection of the 75% dotted line and the upper and lower boundary of the orange area.

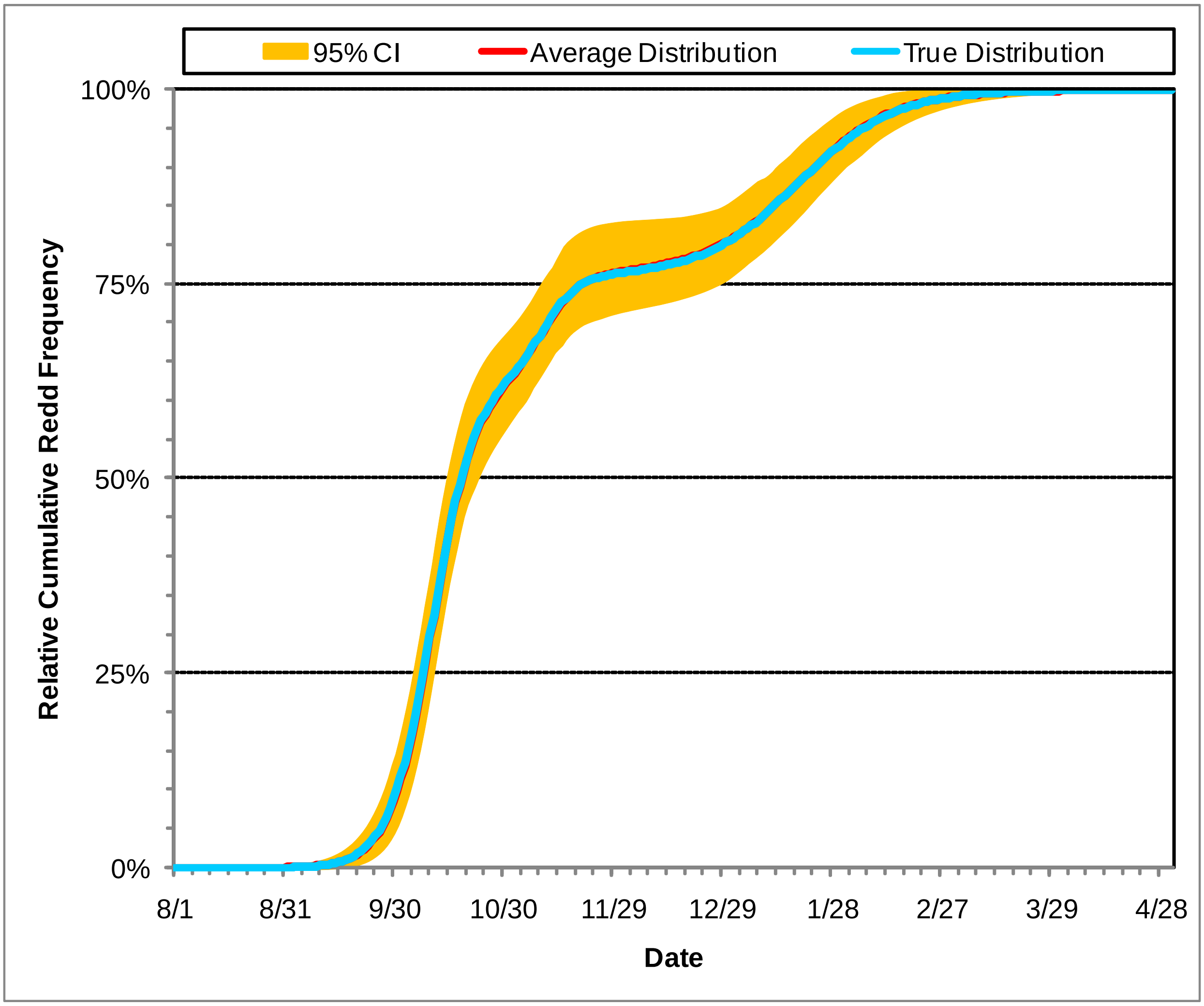

Figure 5. True cumulative distribution of newly built Chinook salmon redds relative to all Chinook salmon redds built from August 1 through May 1 (blue line) compared to distributions estimated from simulated redd observations of 100 simulated annual redd surveys with weekly sampling frequencies. The red line indicates the average distribution over the 100 simulations and the orange area demarks the 95% confidence intervals.

The comparison of Figures 5 through 8 shows that within any given sampling frequency strategy, the width of the 95% confidence intervals of estimated timing for particular percentages of the cumulative distributions generally increases as the percentage increases. Moreover, for the four sampling frequency strategies, the width of the 95% confidence intervals of estimated timing are larger for 65% through 90% of the respective cumulative distributions. These wider 95% confidence intervals may be associated with the difficulties in estimating the right combination of population parameters to define run 2. Additionally, the width of the 95% confidence intervals of estimated timings increases as the survey sampling frequency decreases from weekly to monthly.

In Figures 5 through 8, the distances separating the blue line of the "true" cumulative distribution and the red line of the average distribution gives a measure of the average bias in the redd timings calculated with the simulated cumulative distributions, when read on the x-axis.

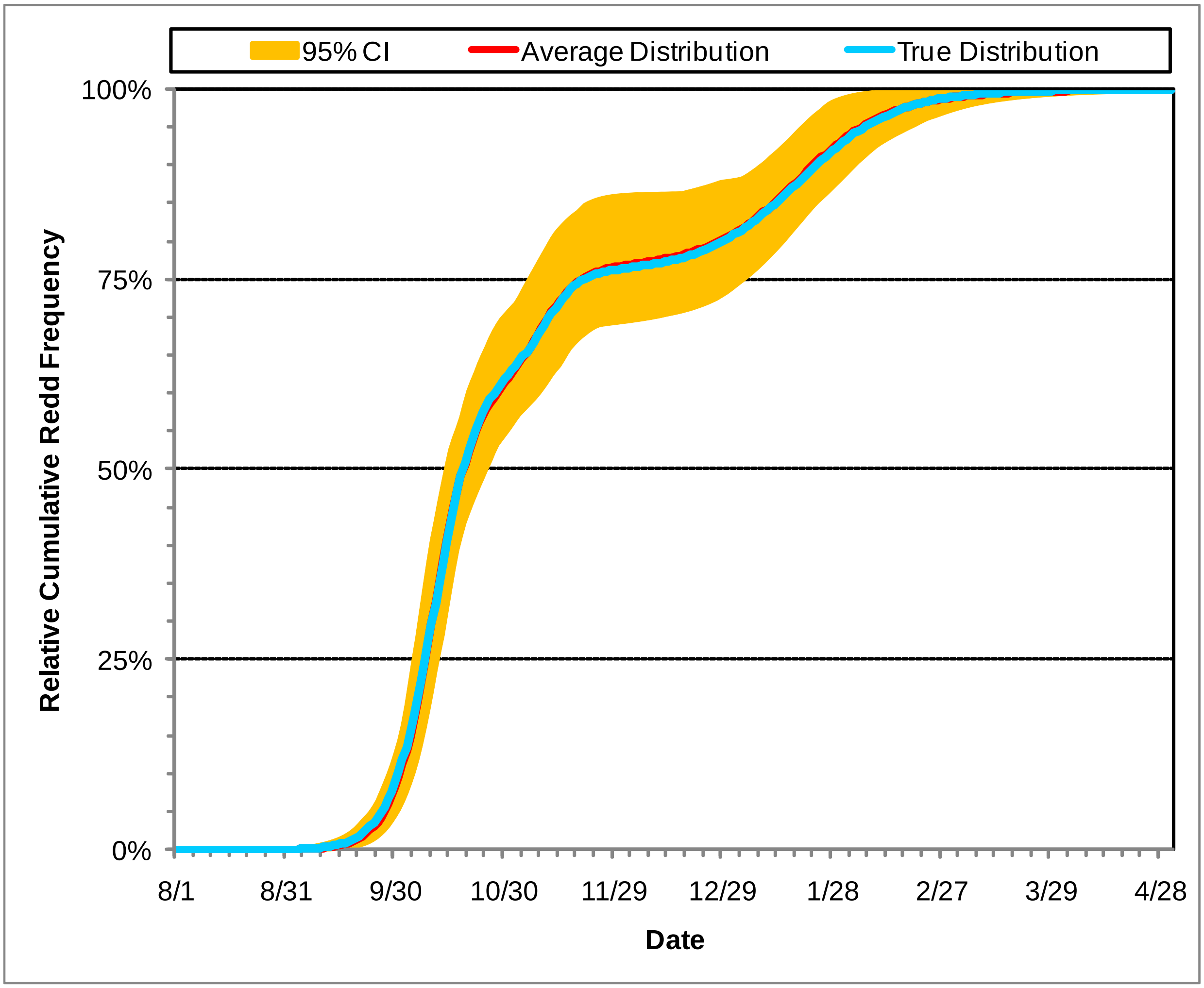

Figure 6. True cumulative distribution of newly built Chinook salmon redds relative to all Chinook salmon redds built from August 1 through May 1 (blue line) compared to distributions estimated from simulated redd observations of 100 simulated annual redd surveys with bi-weekly sampling frequencies. The red line indicates the average distribution over the 100 simulations and the orange area demarks the 95% confidence intervals.

The distances separating the blue and red lines (i.e., the timing bias) were almost undetectable for the simulated distributions of the weekly and bi-weekly sampling frequency categories (Figures 5 and 6, respectively). They became detectable for the tri-weekly sampling frequency category (Figure 7) and very noticeable for the monthly sampling frequency category (Figure 8), particularly for the redd timing associated with 60% to 75% of the simulated cumulative distributions.

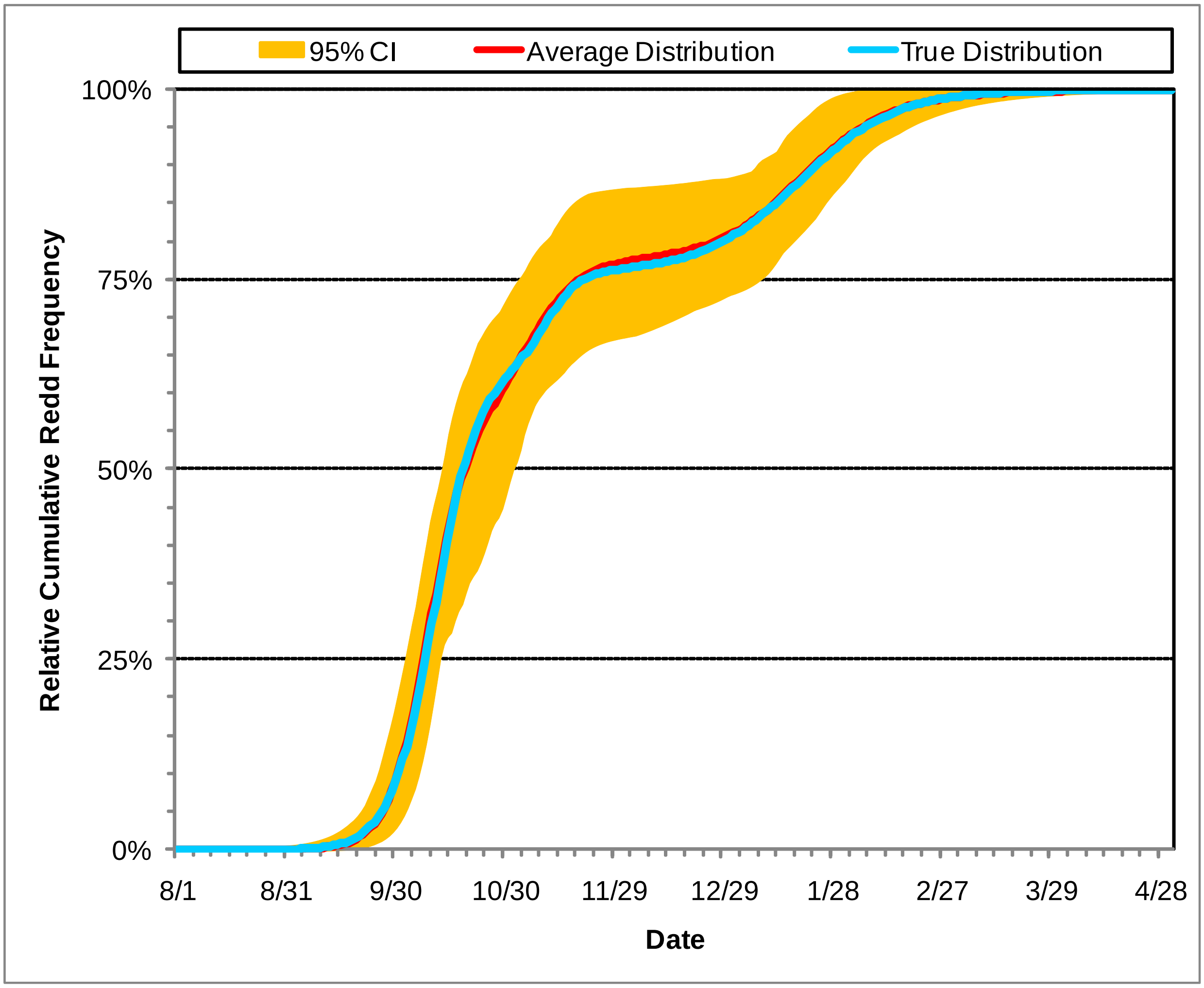

Figure 7. True cumulative distribution of newly built Chinook salmon redds relative to all Chinook salmon redds built from August 1 through May 1 (blue line) compared to distributions estimated from simulated redd observations of 100 simulated annual redd surveys with <u>tri-weekly</u> sampling frequencies. The red line indicates the average distribution over the 100 simulations and the orange area demarks the 95% confidence intervals.

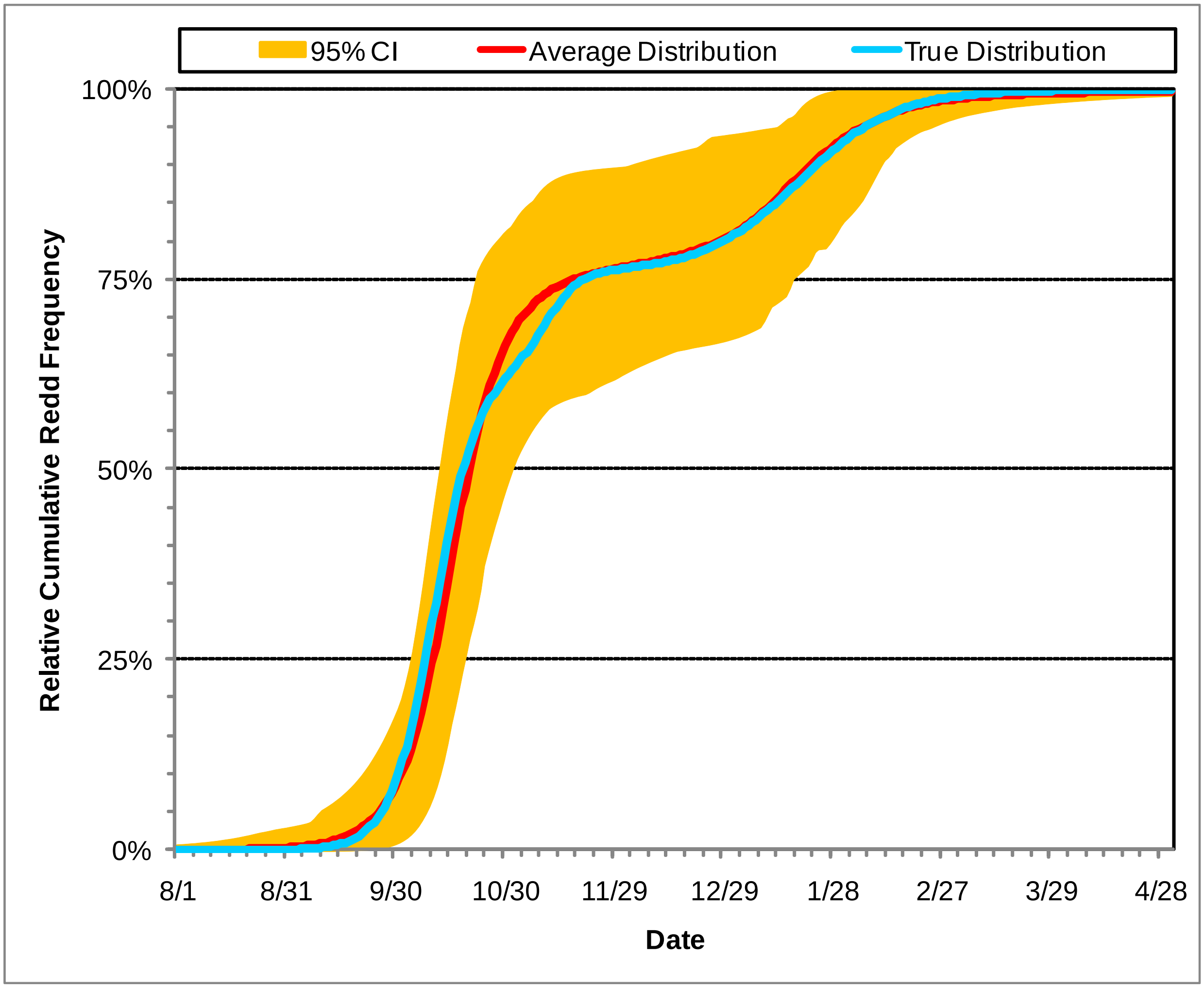

Figure 8. True cumulative distribution of newly built Chinook salmon redds relative to all Chinook salmon redds built from August 1 through May 1 (blue line) compared to distributions estimated from simulated redd observations of 100 simulated annual redd surveys with monthly sampling frequencies. The red line indicates the average distribution over the 100 simulations and the orange area demarks the 95% confidence intervals.

Finally, **Table 2** summarizes the comparison of the timings of Chinook salmon redd construction associated with the 1%, 10%, 25%, 50%, 75%, 90% and 99% of the estimated cumulative distributions under the four sampling frequency strategies. Relative bias exceeding 1% is highlighted in Table 2.

Table 2. Comparison of the timing of Chinook salmon redd construction (expressed as the date at which a particular proportion of the cumulative redd distribution is observed) for the true redd distribution and those estimated from simulated redd observations of 100 simulated annual redd surveys with weekly, bi-weekly, tri-weekly and monthly sampling frequencies.

Redd Cumulative Proportion	True Date	Weekly Redd Survey Sampling Frequency			Bi-weekly Redd Survey Sampling Frequency		
		Average Date	95% Confidence Interval	Relative Bias (%)	Average Date	95% Confidence Interval	Relative Bias (%)
1%	9 / 16	9 / 16	9 / 11 - 9 / 22	0.8%	9 / 17	9 / 11 - 9 / 22	2.3%
10%	9 / 30	9 / 30	9 / 27 - 10 / 4	0.8%	9 / 30	9 / 28 - 10 / 4	1.3%
25%	10 / 8	10 / 7	10 / 5 - 10 / 10	-0.4%	10 / 7	10 / 4 - 10 / 11	-0.3%
50%	10 / 18	10 / 18	10 / 14 - 10 / 22	0.2%	10 / 18	10 / 13 - 10 / 24	0.2%
75%	11 / 20	11 / 26	11 / 9 - 12 / 27	5.5%	11 / 28	11 / 5 - 1 / 2	7.5%
90%	1 / 23	1 / 22	1 / 13 - 1 / 31	-0.3%	1 / 21	1 / 8 - 2 / 2	-0.8%
99%	3 / 1	2 / 27	2 / 11 - 3 / 13	-0.7%	2 / 26	1 / 30 - 3 / 20	-1.0%

Redd Cumulative Proportion	True Date	Tri-weekly Redd Survey Sampling Frequency			Monthly Redd Survey Sampling Frequency		
		Average Date	95% Confidence Interval	Relative Bias (%)	Average Date	95% Confidence Interval	Relative Bias (%)
1%	9 / 16	9 / 17	9 / 8 - 9 / 24	2.8%	9 / 14	8 / 24 - 9 / 29	-4.1%
10%	9 / 30	9 / 30	9 / 25 - 10 / 6	0.6%	10 / 1	9 / 20 - 10 / 11	2.6%
25%	10 / 8	10 / 7	10 / 2 - 10 / 11	-1.1%	10 / 10	10 / 4 - 10 / 18	3.0%
50%	10 / 18	10 / 18	10 / 13 - 10 / 31	1.2%	10 / 20	10 / 12 - 10 / 31	2.8%
75%	11 / 20	11 / 26	11 / 2 - 1 / 7	5.8%	11 / 26	10 / 22 - 1 / 17	5.6%
90%	1 / 23	1 / 22	1 / 7 - 2 / 3	-0.5%	1 / 19	11 / 29 - 2 / 9	-2.2%
99%	3 / 1	2 / 25	1 / 28 - 3 / 19	-1.5%	2 / 26	1 / 23 - 4 / 15	-1.0%

2.4. *Effect of Sampling Frequency on Run Identification*

Although, even under the weekly sampling frequency strategy it was normally harder to estimate the right combination of population parameters to define run 2, the three runs were estimated for the 100 redd survey data simulated under the weekly and bi-weekly sampling frequency strategies. The parameters defining run 2 could not be estimated 5 out of the 100 redd survey data sets simulated under the tri-weekly sampling frequency strategy. In other words, under the tri-weekly sampling strategy, the parameters that define the daily redd distributions of the three runs were estimated 95% of the time.

Only the population parameters defining two out of the three runs were estimated with the 100 redd survey data simulated under the monthly sampling frequency strategy. This is not surprising, because defining the three runs assumed by the statistical model requires the estimation of 9 population parameters, and the sample size of the survey N (the number of sampling days during the survey season) must be greater than 10. As mentioned in Section 1.3, the 100 schedules obtained for the monthly sampling frequency category consisted of only 9 to 10 sampling dates. Consequently, the population parameters for only two runs (run 1 and run 3) were estimated with the 100 redd survey simulated data, based on the monthly sampling strategy.

3. Conclusions

This evaluation results in the following conclusions:

- The sampling frequency of the redd surveys affects the estimated total number of redds built within the sampling season (i.e., a measure of spawning abundance)
- The sampling frequency of the redd surveys affects the estimates of timing of spawning (i.e., dates at which particular percentages of the cumulative distribution of all newly-built redds are achieved)
- The sampling frequency of the redd surveys affects the likelihood of evaluating the correct number of spawning groups or runs present during the survey season
- Redd surveys performed with a weekly sampling frequency provides the most precise and accurate (least biased) estimates of total redd abundance and timing of redd construction, as well as the likelihood of detecting modalities in the temporal distribution of redd counts that could lead to the identification of distinct spawning groups or runs present during the sampling season
- Redd surveys performed with a bi-weekly sampling frequency provides the second most precise and accurate estimates of total redd abundance and timing of redd construction, but also provides relatively wide confidence intervals compared to the weekly sampling frequency. The bi-weekly sampling frequency also allows for the detection of modalities in the temporal distribution of redd counts that could lead to the identification of distinct spawning groups or runs present during the sampling season
- Redd surveys performed with a tri-weekly sampling frequency provides estimates of total redd abundance and timing of redd construction that are less precise and accurate than those produced by redd surveys with a weekly or bi-weekly sampling frequency, and may result in difficulties in detecting modalities in the temporal distribution of redd counts that could be used in the identification of distinct spawning groups or runs present during the sampling season
- Redd surveys performed with a monthly sampling frequency provides the least precise and accurate (most biased) estimates of total redd abundance and timing of redd construction, much wider confidence intervals, and a reduced likelihood of detecting modalities in the temporal distribution of redd counts that could lead to the identification of distinct spawning groups or runs present during the sampling season

4. Recommendations

The following recommendations are based on the results and conclusions of this evaluation and the need to identify an adequate sampling frequency for the long-term extensive-area redd survey to be performed in the lower Yuba River.

- The long-term extensive-area redd survey should be performed with a weekly sampling frequency, at least from the start of the sampling season through December 31 (which represents the majority of spawning activity), to provide enough sampling events during the season of most intense Chinook salmon spawning activity to facilitate the gathering of unbiased estimates of total redd abundance and timing of redd construction, and to enhance the probability of differentiating spring-run and fall-run spawning activity

- The start date of the long-term extensive-area redd surveys should occur some time between August 1 and early September to guarantee that the start of the spawning activity is adequately sampled

- A bi-weekly sampling frequency, if used at all (as a cost-efficiency measure) during the long-term extensive-area redd survey, should be employed during the last portion of the survey season (*i.e.*, January 1 through May 1) when Chinook salmon spawning activity has declined and most of the spawning still occurring is probably associated with late fall-run Chinook salmon

- Tri-weekly and monthly sampling frequency strategies are not recommended for Yuba River long-term extensive-area redd surveys

ATTACHMENT 2

Establishing Sample Size for Redd Area Measurements in Order to Address Redd Superimposition

Redd area measurements are needed to examine redd superimposition throughout the lower Yuba River for Chinook salmon and steelhead. Evaluation of Chinook salmon redd areas (m^2) calculated for the 2008-2009 index area indicated that redd area significantly differed ($r^2 = 0.24$, $P < 0.01$) during the majority of the spawning activity (mid-September through December). Therefore, a sampling design specifically addressing redd area estimation is necessary for the extensive area redd surveys.

A systematic sampling design will be used to collect redd area measurement data during the extensive area redd survey, where every 17^{th} sampling unit (redd) will be included in the sample for redd area measurements. Systematic sampling is often used for ease of execution and convenience (Hansen *et al.* 2006). In addition, systematic samples are usually spread more evenly over the population, so population attributes can be estimated more precisely than simple random sampling (Hansen *et al.* 2006).

During the 2008-2009 pilot extensive area redd survey, a total of 1257 Chinook salmon redds were observed in the lower Yuba River. However, it is recognized that this is a minimum number of redds due to the relatively infrequent sampling (i.e., monthly) and duration of fresh redd visibility. Therefore, for sample size considerations, it is assumed that up to 2000 Chinook salmon redds could be potentially observed during each annual redd survey season. Given the variance of redd area measured at 169 Chinook salmon redds in the index area during the 2008-2009 pilot survey season, as estimated 111 redds would need to be measured in order to estimate redd size within 10% of the calculated average redd area. Therefore, assuming a similar variance structure in the future and further assuming a potential total of 2000 Chinook salmon redds constructed annually, an estimated 5.6% of the total number of redds would need to be measured to obtain an estimate of the average redd area with a precision of 10%, resulting k^{th} sampling unit of 17.8. Consequently, rounding downwards in order to avoid establishing a sample size resulting in an anticipated less precise estimate, the k^{th} sampling unit will be 17. In other words, 1 out of every 17 redds observed in the lower Yuba River during the extensive area redd survey will be measured to estimate redd area.

ATTACHMENT 3: Extensive Area Redd Survey Data Sheet – Document all newly constructed redds

Survey Date:	Surveyor Initials:	Survey Section:	Number of Crews:	Crew (A or B):
Weather (Clear, Cloudy, Rain, Wind):		Secchi Reading (ft):	Average flow (cfs):	

	Redd GPS I.D. (Date + plus redd number) example 082908-001	GPS waypoints collected (Yes/No)	Species Constructing Redd	# of Fish observed on Redd	Substrate (dominant/sub-dominant)	Area measurments	Comments (location, side channel, potential imposition etc.):
1		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
2		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
3		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
4		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
5		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
6		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
7		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
8		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
9		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
10		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
11		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
12		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
13		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
14		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
15		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
16		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
17		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
18		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
19		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
20		Y N			/	PL____, PW____, TL____, TW1____, TW2____	
21		Y N			/	PL____, PW____, TL____, TW1____, TW2____	

Comments:

Note: If multiple crews are out per day, **Crew A will use I.D. redd number 001- 499** and **Crew B will use 500- 999**. Collect area measurements on every 17th Chinook salmon redd encountered and on every Steelhead redd. For every redd encountered, in the data dictionary of the GPS record: species constructing the redd, number of fish observed, potential for superimposition, and habitat type (i.e. pool, riffle, run, or glide) for every redd. Redds greater than 1.56m long and or 1.37m wide are CHN, smaller are considered Steelhead.

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