PROTOCOL
FOR
MONITORING EFFECTIVENESS
OF
SPAWNING GRAVEL PROJECTS

MC-7

Washington Salmon Recovery Funding Board

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ORGANIZATION

Instream habitat improvements are popular habitat restoration projects. They have accounted for 35% of all SRFB restoration projects and 39% of the funding. They have the potential to create improvements in fish habitat by creating cover and improving stream morphology in a short time (1-5 years). This document details the monitoring design, procedures necessary to document and report effectiveness at the reach scale of projects involving the **placement of spawning gravel.**

This document is in compliance with the Washington Comprehensive Monitoring Strategy (Crawford et al. 2002).

Spawning salmon require clean gravel of the proper size in order to spawn successfully. The female seeks out areas of percolation where oxygenated water is circulating freely through the interstices of the gravel. A redd (egg nest) is dug in these areas and then covered loosely with gravel. Where the stream is subjected to high sediment loading, gravel that is normally the proper size and location may become embedded into a matrix of silt and clay sediments that do not provide aeration of the redd. Although lack of adequate spawning gravel is seldom the limiting factor for salmon productivity in a watershed, there are some exceptions where the stream is "gravel starved" due to dams, culverts, and other blockages to normal downstream transport of gravel. Another exception is where major siltation problems affect the entire spawning area of a stream. Examples include the effect of the eruption of Mt. St. Helens on the Toutle River, and the effects of major landslides that have occurred in the Stillaguamish River.

The goal of gravel placement projects is to improve spawning capabilities within the impacted area by artificially placing gravel in the stream. The assumption is that spawning areas are a limiting factor in producing juvenile salmon, and placing gravel in the stream should result in an increase in successful spawning and local juvenile and adult fish abundance.

MONITORING GOAL

Determine if projects that place spawning gravel into streams are effective in improving salmon spawning and increasing local adult fish abundance in the impacted area at the stream reach level.

QUESTIONS TO BE ANSWERED

Has gravel placed in the stream remained in the stream for up to ten years for the sampled gravel replacement projects?

Has gravel remained usable for spawning over time or has it become embedded with fines?

Have more adult salmon utilized the new spawning gravel?

NULL HYPOTHESIS

Placement of spawning gravel in the stream has had no effect upon:

- Increasing the quantity of spawning gravel.
- Improving the quality of spawning gravel in terms of percent fines and embedded substrate.
- Increasing adult spawner abundance in the impacted area.

OBJECTIVES

BEFORE PROJECT OBJECTIVES (YEAR 0)

Determine the total area of spawning gravel in the impact and control reaches for each of the gravel placement projects sampled.

Determine how embedded the spawning gravel is in the control and impact reaches for the sampled gravel placement projects.

Determine the percentage of fines in the gravel in the control and impact reaches for the sampled gravel placement projects.

Determine the number of adult spawners of the targeted salmon species in the control and impact reaches for each of the gravel placement projects sampled.

AFTER PROJECT OBJECTIVES (YEARS 1, 3, 5, AND 10)

Determine the total area of spawning gravel in the impact reaches for each of the gravel placement projects sampled.

Determine how embedded the spawning gravel is in the control and impact reaches for the sampled gravel placement projects.

Determine the percentage of fines in the gravel in the control and impact reaches for the sampled gravel placement projects.

Determine the number of adult spawners of the targeted salmon species in the control and impact reaches for each of the gravel placement projects sampled.

RESPONSE INDICATORS

Level 1 Design Criteria- Area of gravel remaining in the sampled reach. Spawning gravel placed in the stream must be identified using GPS coordinates and other techniques such as streambank markers in order to track the life of the gravel placement over time.

Spawning gravel placement indicator

Indicator Abbreviation	Description
GRAVAREA	Measure of gravel present after placement

Level 2 Habitat Characteristics- Gravel characteristics. Gravel characteristics can be quantified using the EMAP protocol for characterizing stream substrate (Peck et al. 2003). This protocol measures size of substrate. Percent of fines is commonly used as a measure of siltation. Embeddedness is also determined.

Stream morphology response variables

Indicator Abbreviation	Description
PCT_FN	Mean percent of the study substrate in fines
XEMBED	Mean percentage of the substrate that is embedded within the study reach

Level 3 Fish Abundance - number of adult salmon in the reach. Abundance of salmon can be determined using adult spawner counts. Adults will be monitored using protocols developed by Washington Department of Fish and Wildlife. Adult estimating procedures are found on pages 19-20. The least intrusive monitoring protocol will be used whenever possible. Impact areas will be compared to the controls. Only one target species will be measured for spawner abundance or redd abundance.

Adult fish abundance response variables

Indicator Abbreviation	Description
BULLADULT	Measure of bulltrout spawner abundance within the study reach
BULLREDD	Measure of bulltrout redd counts within the study reach
CHINADULT	Measure of chinook spawner abundance within the study reach
CHINREDD	Measure of chinook redd counts within the study reach
CHUMADULT	Measure of chum spawner abundance within the study reach
CHUMREDD	Measure of chum redd counts within the study reach
COHOADULT	Measure of coho spawner counts within the study reach
COHOREDD	Measure of coho redd counts within the study reach
PINKADULT	Measure of pink spawner counts within the study reach
PINKREDD	Measure of pinks redds within the study reach
SHADULT	Measure of steelhead spawner abundance with the study reach
SHREDD	Measure of steelhead redds within the study reach
SOCKADULT	Measure of sockeye spawner abundance within the study reach
SOCKREDD	Measure of sockeye redds within the study reach

MONITORING DESIGN

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with placing spawning gravel (Stewart-Oaten et al. 1986). A BACI design samples the control and impact simultaneously at both locations at designated times before and after the impact has occurred. For this type of restoration, placing spawning gravel would be the impact, which would determine the location impacted by the restoration action, and a location upstream of the gravel placement would represent the control.

The BACI design tests for changes at the project impact reach *relative to* the changes in spawning gravel stream morphology and fish abundance observed at a control site upstream. This type of design is required when external factors (e.g., ocean conditions and harvesting) affect the population abundances at the control sites. The object is to see whether the difference between upstream (control) and downstream (impact) spawning salmon abundances, stream morphology, and acres of gravel has changed as a result of the spawning gravel placement projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplication. It is also not considered cost effective to employ multiple control locations for each passage project as recommended by Underwood. Although the ideal BACI would have multiple years of before data as well as after data, this is not possible with locally sponsored projects where there is a need and desire to complete their project as soon as possible.

The plan is to compare the most recent time period of sampling with Year 0 conditions, or the conditions before the project is implemented. A paired *t*-test will be used to test for differences between control (upstream) and impact (downstream) sites during the most recent impact year and Year 0. In other words, we first compute the difference between the control and impact and use those values in a paired *t*-test. This test assumes that differences between the control and impact sites are only affected by the placing of spawning gravel and that external influences affect population abundance and stream morphology in the same way at both the control and impact sites. The paired sample *t*-test does not have the same assumptions for normality and equality of variances of the two-sample *t*-test but only requires that the differences are approximately normally distributed. In fact, the paired-sample test is really equivalent to a one-sample *t*-test for a difference from a specified mean value.

To implement the design, we will monitor spawning gravel projects funded beginning in Round 4 in 2004 and thereafter as needed. This will provide ten total projects to test for effectiveness. The number of projects is based upon the calculated sample size needed to obtain statistically significant information in the shortest amount of time. If there are insufficient projects funded in any one year to obtain a proper sample size, then multiple years will be used until the critical sample size is reached.

The variance associated with impact and control areas will not be known until sampling has occurred in Year 0 of both impact and control reaches. After Year 0, a better estimate of the true sample size needed to detect change will be available. Cost estimates and sampling replicates may need to be adjusted at that time.

At the end of the effectiveness monitoring testing, there will be one year of “Before” impact information for all projects for both control and impact reaches, and four years of “After” impact information for the same control and impact areas for each of the projects. Depending upon circumstances, the results may also be tested for significance, using a linear regression model of the data points for each of the years sampled and for each of the indicators tested.

Testing for significant trends can begin as early as Year 1. Final sampling may be completed in 2014.

DECISION CRITERIA

Table 1 details the decision criteria used in evaluating whether there has been a statistically significant change in the response indicators when testing the null hypothesis.

Table 1. Decision criteria and statistical test type

Habitat	Indicators	Metric	Test Type	Decision Criteria
Gravel Placement	Measure of gravel present after placement (GRAVAREA)	m^2	Count of acres of gravel remaining	≥ 50% of gravel area is remaining by Year 10
Instream habitat	Mean percent of the study substrate in fines (PCT_FN)	%	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year10
	Mean percentage of the substrate that is embedded within the study reach (XEMBED)	%	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
Adult Fish Abundance (Note: Only one target species will be monitored for abundance)	Chinook redds (CHINREDD) or Chinook Spawner abundance (CHINADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Coho redds (COHOREDD) or coho spawner abundance (COHOADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Steelhead redds (SHREDD) or coho spawner abundance (SHADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Bulltrout redds (BULLREDD) or bulltrout spawner abundance (BULLADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Pink salmon redds (PINKREDD) or pink salmon spawner abundance (PINKADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Chum redds (CHUMREDD) or chum spawner abundance (CHUMADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10
	Sockeye redds (SOCKREDD) or sockeye spawner abundance (SOCKADULT)	#/km	BACI Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Treatment and control by Year 10

SAMPLING PROCEDURE

SELECTING SAMPLING REACHES

IMPACT REACH

Gravel placement areas are not very large and can be measured in their entirety. The gravel placement project should be measured to determine overall area, and the linear distance in the stream affected.

CONTROL REACH

An equal number of control reaches distributed upstream of each project site should be selected and designed in the same manner as the impact reaches. If there is only one impact reach, then the control should consist of a distance of equal size immediately upstream of the project site in habitat of similar quality and description.

BEFORE PROJECT SAMPLING

All gravel placement projects identified for long-term monitoring by the SRFB must have completed pre-project Year 0 monitoring before placing the gravel.

Year 0 monitoring will consist of:

- Determining the linear distance in meters to the nearest tenth of the impact stream reach and the gravel area in square meters to be impacted with gravel placement (impact area).
- Determining the linear distance in meters to the nearest tenth of the control reach and the gravel area in square meters for the control areas.
- Determine the percent fines and percent embedded substrate characteristics within the project impact and control areas.
- Determine the abundance of adult spawning salmon in the impact and control areas prior tog ravel placement.

AFTER PROJECT SAMPLING

Upon placement of the gravel, Years 1, 3, 5, and 10 monitoring will consist of:

- Determining the changes for impact and control, if any, in linear distance in miles to the nearest tenth and the area in square feet impacted with gravel placement and the controls.
- Determine the percent fines and percent embedded substrate characteristics within the project impact and control areas.
- Determine the abundance of adult spawning salmon in the impact and control areas.

METHOD FOR LAYING OUT CONTROL AND IMPACT STREAM REACHES FOR WADEABLE STREAMS

Protocol taken from: ***Peck et al. (2003), pp. 63-65, Table 4-4; Mebane et al. (2003)***

EQUIPMENT

Metric tape measure, surveyor stadia rod, handheld GPS device, 3 - 2 ft. pieces of rebar, orange and blue spray paint or plastic rebar caps, engineer flagging tape, waterproof markers

SAMPLING CONCEPT

The concept of EMAP sampling is that randomly selected reaches located on a stream can be used to measure changes in the status and trends of habitat, water quality, and biota over time if taken in a scientifically rigorous manner per specific protocols. We have applied the EMAP field sampling protocols for measuring effectiveness of restoration and acquisition projects. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These "impact" reaches have been matched with "control" reaches of the same length and size on the same stream whenever possible.

Within each sampled project reach a series of Transects A-K are taken across the stream and riparian zone as points of reference for measuring characteristics of the stream and riparian areas (see Figure 1). The Transects are then averaged to obtain an average representation of the stream reach.

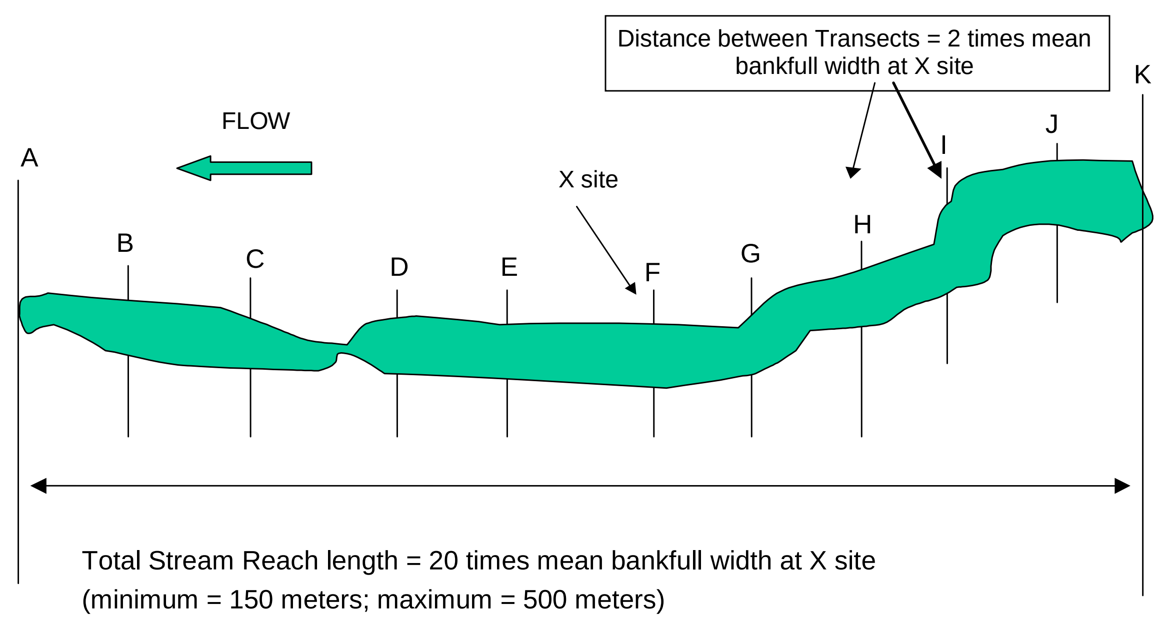

Figure 1. Sampled project reach

LAYING OUT THE TREATMENT AND CONTROL STREAM REACHES

Step 1: Using a handheld GPS device, determine the location of the X site and record latitude and longitude on the stream verification form. The X site should be considered the center of the impact or control study reach. The impact reach X site must fall within the project affected area. The location of the control X site should be determined based upon the length of the impact reach. It will be located in the center of the control reach, which will measure the same as the length of the impact reach whenever possible. Mark the X site on the bank above the high water mark with one of the rebar stakes and a colored plastic cap so that the X site can be found in future years. Use a surveyor's rod or tape measure to determine the bankfull width of the channel at five places considered to be of "typical" width within approximately five channel widths distance upstream and downstream of the X site location. Average those five bankfull widths, then multiply that average bankfull width by 20 to determine the reach length. For streams less than 7.5 m in average bankfull width, the reach length should be at minimum 150 m, and for streams greater than 25 m in width, the maximum reach length shall be 500 m. If the impact reach is less than 150 m, measure and include the entire impact area in the sampling reach. Determine the impact reach length based upon the above, and set the control site reach length equal to the impact reach length.

Step 2: Check the condition of the stream upstream and downstream of the X site by having one team member go upstream and one downstream. Each person proceeds until they can see the stream to a distance of 10 times the bankfull width (equal to one half the sampling reach length) determined in Step 1.

For example, if the reach length is determined to be 150 meters, each person would proceed 75 m from the X site to lay out the reach boundaries.

NOTE: *For restoration projects less than 20 times bankfull width, the entire project's length should be sampled and a control reach of similar size should likewise be developed within the treatment stream either upstream or downstream as appropriate.*

Step 3: Determine if the reach needs to be adjusted around the X site due to confluences with lower order streams, lakes, reservoirs, waterfalls, or ponds. Also adjust the boundaries to end and begin with the beginning of a pool or riffle, but not in the center of the pool or riffle. Hankin and Reeves (1988) have shown that measures of the variance of juvenile fish populations is decreased by using whole pool/riffles in the sample area. To adjust the stream reach, simply add or subtract additional length to Transects A or K, as appropriate (i.e. do not shift the entire reach upstream or downstream to encompass an entire pool). In the case where the treatment site is dry in Year 0, reach lengths should still be based upon 20 times the bankfull width.

Step 4: Starting back at the X site, measure a distance of 10 average bankfull widths down one side of the stream using a tape measure. Be careful not to cut corners. Enter the channel to make measurements only when necessary to avoid disturbing the stream channel prior to sampling activities. This endpoint is the downstream end of the reach and is flagged as Transect "A".

Step 5: Using the tape, measure 1/10th (2 average bankfull widths in big streams or 15 m in small streams) of the reach length upstream from the start point (Transect A). Flag this spot as the next cross section or Transect (Transect B).

For example, if the reach length is determined to be 200 meters, a Transect will be located every 20 meters, which is equivalent to 1/10th the total reach length.

Step 6: Proceed upstream with the tape measure and flag the positions of nine additional Transects (labeled “C” through “K” as you move upstream) at intervals equal to 1/10th of the reach length. At the reach end points (Transects A and K) and the middle of the reach (X site or Transect F), install a rebar stake as described in Step 1.

METHOD FOR QUANTIFYING GRAVEL PLACEMENT AREAS

PURPOSE

The intent of this method is to document whether the gravel remains in the area where it was placed, flooding or other actions wash away the newly placed gravel, or siltation has rendered the new gravel useless for spawning activities by salmon and trout.

EQUIPMENT

50m measuring tape, surveyor's stadia rod, hand-held GPS device (surveyor's transit optional)

PROCEDURE

Step 1: In Year 0, prior to placing gravel in the stream, lay out the boundaries of the control and impact areas and record the location of the X site using **GPS** technology and latitude longitude coordinates as described on pages 12-14.

Step 2: Measure the areas of gravel in acres within the impact and control areas using a **measuring tape** or surveyor's transit and obtain the sum of the areas for a total available within each reach.

Step 3: During Year 1, and immediately after the gravel has been placed in the stream, determine the overall area in acres of the newly placed gravel. Visually estimate the percentage of the stream channel containing substrate of a size suitable to support spawning of the target species. Do this for each Transect (A-B, B-C, etc.) and record on the gravel form (Figure 2).

Step 4: During Year 3, 5, and 10 repeat the measurements described in Step 3.

Note: For additional information consult the Mokelumne River Spawning Habitat Improvement Project Monitoring conducted by California Department of Fish and Game at http://www.delta.dfg.ca.gov/afrp/documents/GravelEvaluation.pdf.

GRAVEL FORM				
Site:	Station:		Team:	
Visit #:	Date:			
Location	**Length**	**Width**	**%**	**Coverage**
A Main				
A Supplemental				
B Main				
B Supplemental				
C Main				
C Supplemental				
D Main				
D Supplemental				
E Main				
E Supplemental				
F Main				
F Supplemental				
G Main				
G Supplemental				
H Main				
H Supplemental				
I Main				
I Supplemental				
J Main				
J Supplemental				
K Main				
K Supplemental				

Figure 2. Gravel form

METHOD FOR MEASURING SUBSTRATE

Protocol taken from: ***Peck et al. (2003), Table 7-7 modified Wolman pebble count***

PURPOSE

Determining the changes in the percentage of fines and embeddedness within the impact and control areas pre- and post-project in order to determine any significant changes.

EQUIPMENT

Meter stick, surveyor's rod, metric tape

SITE SELECTION

The sample reaches should be laid out according to page 12-14.

SAMPLING DURATION

Counts should be taken during summer low flow period when turbidity and visibility is normally at its best. This may not be true for glacial streams.

PROCEDURE

Step 1: Substrate size class is estimated for a total of 105 particles taken at 5 equally-spaced points along each of 21 cross sections, located at 11 regular transects (A through K) and 10 intermediate transects. Depth is measured and embeddedness estimated for the 55 particles located along the 11 regular transects also. Cross sections are defined by laying the surveyor's rod or tape to span the wetted channel.

Step 2: Fill in the header information on the Substrate Form. Indicate the cross-section Transect. At the Transect, extend the surveyor's rod across the channel perpendicular to the flow, with the zero end at the left bank (facing downstream). If the channel is too wide for the rod, stretch the metric tape in the same manner. For dry and intermittent streams, where no water is in the channel, use the bankfull width to determine where to collect substrate information (record the wetted width depths as zeros).

Step 3: Divide the wetted channel by 4 to locate substrate measurement points on the cross section to get locations corresponding to 0% (LFT), 25% (LCTR), 50% (CTR), 75% (RCTR), and 100% (RGT) of the measured wetted width.

Step 4: Place your sharp-ended meter stick or calibrated pole at the LFT location (0 m). Measure the depth and record it on the field data form. Cross section depths are measured only at regular Transects A through K, not at the 10 mid-way cross sections (A-B, B-C, etc.).

Step 5: Pick up the substrate particle that is at the base of the meter stick (unless it is bedrock or boulder), and visually estimate its particle size, according to the following table (Table 2). Classify the particle according to its median diameter (the middle dimension of its length, width, and depth). Record the size class code on the Substrate Form (Figure 3). (Cross section side of form for Transects A-K; special entry boxes on Thalweg Profile side of form for mid-way cross-sections.)

Table 2. Substrate particle classification

Code	Size class	Size range (mm)	Description
RS	Bedrock (smooth)	>4000	Smooth surface rock bigger than a car
RR	Bedrock (rough)	>4000	Rough surface rock bigger than a car
HP	Hardpan		Firm, consolidated fine substrate
BL	Boulders	>250 to 4000	Basketball to car size
CB	Cobbles	>64 to 250	Tennis ball to basketball size
GC	Gravel (coarse)	>16 to 64	Marble to tennis ball size
GF	Gravel (fine)	>2 to 16	Ladybug to marble size
SA	Sand	>0.06 to 2	Smaller than ladybug size, but visible as particles – gritty between fingers
FN	Fines	<0.06	Silt, Clay, Muck, (not gritty between fingers)
WD	Wood	Regardless of size	Wood and other organic particles
OT	Other	Regardless of size	Concrete, metal, tires, car bodies, etc.

Step 6: Evaluate substrate embeddedness as follows at 11 Transects A-K. For particles larger than sand, examine the surface for stains, markings, and algae. Estimate the average percentage embeddedness of particles in the 10 cm circle around the measuring rod. Record this value on the field data form. By definition, sand and fines are embedded 100 percent, bedrock and hardpan are embedded 0 percent.

Step 7: Move successively to the next location along the cross section. Repeat steps 4 through 6 at each location. Repeat steps 1 through 6 at each new cross section Transect.

SUBSTRATE FORM

Site: ________________ Date: _________________ Reach: __________________ Surveyors: ________________________

Main Transect Substrate

Transect	Substrate Size Code					FLAG
	LFT	LCTR	CTR	RCTR	RGT	
A						
B						
C						
D						
E						
F						
G						
H						
I						
J						
K						

Intermediate Transect Substrate

Intermediate Transect	LFT			LCTR			CTR			RCTR			RGT		
	Depth (cm)	Substrate	Embed. (%)	Depth (cm)	Substrate	Embed. (%)	Depth (cm)	Substrate	Embed. (%)	Depth (cm)	Substrate	Embed. (%)	Depth (cm)	Substrate	Embed. (%)
A^1															
B^1															
C^1															
D^1															
E^1															
F^1															
G^1															
H^1															
I^1															
J^1															

Figure 3. Gravel form

METHOD FOR ESTIMATING ADULT SPAWNER ABUNDANCE

Protocol adopted from: ***Nickelson (1998); Hahn et al. (2001); Jacobs and Nickelson (1999)***

PURPOSE

The estimates of adult spawner abundance and/or redd counts pre- and post-project will allow the investigator to determine whether there has been an increase in the abundance of spawners post treatment and to ascertain whether the project was effective in allowing more adult fish to spawn. Instead of a randomly selected stream reach, the stream reach impacted by the project is sampled. These impact reaches have been matched with control reaches of the same length and size on the same stream whenever possible in order to produce a BACI experimental design.

EQUIPMENT

Waders, engineering flagging tape, Polaroid glasses, knife, appropriate waterproof notebook or forms.

SITE SELECTION

The sample reaches are those laid out according to Identified methods on page 12-14.

Be sure that all collectors' permits and ESA clearances have been obtained before proceeding.

SAMPLING DURATION

Sampling should occur in both the impact and control stream reaches beginning with the earliest anticipated spawning for the target species and should continue until the end of the normal spawning period.

PROCEDURES

FOOT SURVEYS

For most SRFB fish passage restoration projects, foot surveys are the most appropriate method for detecting adult spawning salmon. Foot surveys are conducted on designated stream reaches to obtain counts of all live and/or dead salmon and to record the number of redds observed in control and impact stream reaches.

Step 1: Walk along the entire reach length on the banks whenever possible, entering the stream only as needed to confirm redds and/or species of fish on the redds. The observer should wear Polaroid sunglasses and carry a "write-in-the-rain" notebook to record data.

Step 2: Record the number of live and/or dead salmon that are observed, as well as any redds that are observed in both the impact and control reaches. Use surveyor's plastic flagging to mark the location of any redds observed.

Step 3: Conduct surveys at intervals of less than ten days during the spawning season for the target species. Weather conditions, water clarity and number of redds are also recorded.

CARCASS SURVEYS

Carcass sampling should be conducted as part of any adult spawner survey in order to obtain an accurate estimate of the total abundance of males and females in the treatment and control reaches.

Step 1: Walk along the entire reach length on the banks whenever possible, entering the stream only as needed to confirm carcasses. The observer should wear Polaroid sunglasses and carry a “write-in-the-rain” notebook to record data.

Step 2: Count all dead salmon encountered within the reach. Remove the caudal fin, flag the jaw, or use some other method to mark those carcasses that have been counted to avoid double counting.

Step 3: Conduct carcass counts on a weekly basis throughout the sampling period along with the ground counts of redds. For steelhead, bull trout, and cutthroat, these methods will not be applicable.

MARKED REDD CENSUS METHOD

Counting redds is the preferred method for enumerating chinook and steelhead. This method sums the number of new redds counted during the spawning season. By marking redds, old but still visible redds are not counted twice.

Step 1: Mark redds by either tying plastic flagging around an oblong rock that is subsequently placed in the redd, or by flagging tied to bushes or trees adjacent to the redd on the stream bank. The color of the flagging should be changed for each survey, or some method should be used to track redd visibility.

Incomplete redds should not be flagged and not counted until the next survey.

On subsequent surveys, the absence of a flagged rock on a redd means that it is a new redd not previously marked, or that another redd has been superimposed on a previous redd.

Step 2: Some bias of results can occur from removal of flagging by people. Mapping of redds on a weekly basis onto an aerial photograph or sketch of the stream can help reduce bias from this source.

Step 3: All carcasses of spawned-out target species are examined for fin clips and tags.

Step 4: All carcasses are marked for future identification during future surveys.

Step 5: Number of redds, carcasses, and live spawners should be recorded for each Transect (A-B, B-C, etc.).

The investigator should be familiar with the size of the redds produced by the various species of salmonids and the species of fish that may be spawning at the time the surveys are conducted. Surveys will focus on one target species; however, if other species are observed during the surveys, the information should also be recorded.

Estimating Total Redds

Because all redds are marked in the sampled control and impact reaches, they represent a total count and not an estimate.

Redd Visibility

Redd visibility estimates should not normally be needed because foot surveys allow each redd to be identified and marked.

SUMMARY STATISTICS

After field data collection, the data are uploaded into an MS Access® database which then computes summary statistics to reflect habitat conditions at the reach scale. These summary statistics were generally developed as part of the EPA EMAP and were selected for this program based on their high signal to noise ratios as compared to other potential summary variables. The following variables are reported for Spawning Gravel Placement Projects.

GPS Coordinates
The GPS coordinates taken at Transect A and Transect K in each reach. These response variables are the GPS coordinates in Degrees, Minutes, Seconds, which are entered into the stream verification form onsite.

Sample Date
This is the date that the reach was surveyed, which is entered into the stream verification form onsite.

Reach Length
Reach length is measured onsite as the distance between the start and end of a reach, or calculated as forty times the average wetted width of the stream. The reach length is determined for both the impact and control reaches, as described in the Method For Laying Out Control And Impact Stream Reaches For Wadeable Streams. The Reach Length variable is simply reported as this measurement or calculated distance.

Reach Width
Reach width is calculated as the average wetted width of the reach. A measurement of wetted with is taken at each Transect in meters and entered into the Physical Habitat form. Wetted width and bar width are measured at station 5, between each Transect, in meters during the physical habitat survey. Each of the 11 wetted width measurements from the physical habitat form and the 10 measurements of wetted width from the thalweg profile (the width used from the thalweg profile is defined as the wetted width minus the bar width) are summed and divided by the number of measurements to come up with the average wetted width, which is Reach Width, in meters.

Gravel Present After Placement
The area of gravel present after placement is calculated by first measuring the length and the width of any new patches of gravel in the impact reach. The area for each placed patch is calculated by multiplying the length of the patch by the width. The cumulative sum of all the areas of all placed patches is reported. This area is reported in acres. This parameter is only measured in the impact reach after project completion.

Percent Fines
Percent fines is calculated using the 105 measurements of substrate class that are collected at each main transect and intermediate transect through the reach. The total number of classes for with the code FN (fine sediment) is selected is divided by the total number of sediment class measurements made. The proportion is converted to a percentage and is reported as percent fines.

Percent Embeddedness
Percent embeddedness is calculated as the average of all the embeddedness estimates for the entire reach.

Spawner Density
Spawner density is calculated primarily for the target species identified for each project. However, if additional spawners are observed, the densities for these fish will also be presented. The density is calculated by

dividing the cumulative number of spawners (by species) by the linear distance (in meters) of the sample reach. This number is then converted into spawners per km.

Redd Density

Redd density is calculated primarily for the target species identified for each project. However, if additional redds are observed, the densities for these redds will also be presented. The density is calculated by dividing the cumulative number of redds (by species) by the linear distance (in meters) of the sample reach. This number is then converted into redds per km.

TESTING FOR SIGNIFICANCE

We can create a table resembling Table 3 from the data collected for each of the indicators for area of gravel, percent fines, embedded gravel, and adult abundance.

Table 3. Example table for testing BACI differences.

	Year 0			Year 1			Year 3			Year 5		
	Treat	**Cntrl**	**Diff**	**Treat**	**Cntrl**	**Diff**	**Treat**	**Cntrl**	**Diff**	**Treat**	**Cntrl**	**Diff**
Proj. 1												
Proj. 2												
Proj. 3												
Proj. 4												
Proj. 5												
Proj 6												
Proj 7												
Proj 8												
Proj 9												
Proj 10												
Mean												
Var.												

TESTING FOR CHANGES IN GRAVEL CHARACTERISTICS

We wish to test whether the gravel placed in the stream actually stayed where it was placed or whether it was washed away during high flows. We also want to test whether the gravel that was placed in the stream remained useful for spawning or whether it became loaded with fines and embedded. Two measures, mean percent fines (silt, clay, and muck) and mean percent substrate (embeddedness) demonstrate high precision and signal to noise ratio (see Table 4). We wish to test whether the average percentage of the area embedded with fines in the new gravel placed in the project has increased significantly post impact and whether the percent substrate embedded mid-channel and margin has increased significantly post project.

The data will be tested using a paired *t*-test. The paired *t*-test is a very powerful test for detecting change because it eliminates the variability associated with individual sites by comparing each stream to itself, that is, at upstream and downstream locations within the same stream. The impact reach and control reach for each stream are affected by the same local environmental factors and local characteristics in the fish population in contrast with other stream systems with their own unique environmental conditions. In other words, the two observations of the pair are related to each other.

Because the paired *t*-test is such a powerful test for detecting differences, very small differences may be statistically significant but not biologically meaningful. For this reason, biological significance will be defined as a 20% increase in percent fines and embeddedness and a 50% decrease in overall gravel area at the impact sites. The statistical test will be one-sided for an Alpha=0.10. We use a one-sided test because a significant decrease in salmon abundance after the impact would not be considered significant, that is, the project would not be considered effective. In other words, we are not interested in testing for that outcome. The test will be conducted in Years 1, 3, 5, and 10. If the results are significant in any of those years, the gravel placement projects will be considered ineffective.

Our conclusions are, therefore, based upon the differences of the paired scores for the sampled spawning gravel projects. Though somewhat confusing, it may be helpful to think of the statistic as the "difference of the differences". A one-tailed paired-sample *t*-test would test the hypothesis:

H_0 : The mean difference is less than or equal to zero.
H_A : The mean difference is greater than zero.

The test statistic is calculated as:

$$t_{n-1} = \frac{\underline{đ} - 0}{S_{đ}}$$

where
$\underline{đ}$ = mean of the differences for Year 0 and a subsequent year

$S_{đ}$ = variance of the differences

$S_{đ} = S_d / n^{1/2}$ = variance mean

n = number of sites (or site pairs).

Table 4. Composite variable exhibiting the best all around precision and signal to noise ratios. RMSE = σ rep is the root mean square error. The lower the value, the more precise the measurement. CV σ rep / "(%) is the coefficient of variation. The lower the number, the more precise the measurement. S/N = σ2st(yr) / σ2rep is the signal to noise ratio. The higher the number, the more that metric is able to discern trends or changes in habitat in a single or multiple sites (Kauffmann et al. 1999). This table is provided for information purposes only.

Variable	Description	RMSE = σ_{rep}	CV = σ_{rep} / "(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
PCT_FN	Mean % substrate fines (silt, clay, muck)	7.4	32	15
XEMBED	Mean % substrate embedded – mid-channel + margin	9.5	18	7.7

STATISTICAL TESTING FOR CHANGES IN ADULT ABUNDANCE

The number of spawning adults per kilometer or the number of redds per kilometer has been shown to be more descriptive than other measures in detecting abundance of spawning fish. Whether redds/kilometer or spawners/kilometer is used is dependent upon the species. Applying the *t*-statistic from above we can demonstrate how the statistic is calculated. Using hypothetical steelhead redd data from Table 5, the test statistic would be calculated as:

$$t = \frac{3.4}{3.2 / 10^{1/2}} = \frac{3.4}{1.29} = 2.63 \qquad \underline{t}_{0,10,9} = 1.83$$

For this example, 2.63 was much greater than the *t*-value required for significant change (*t* = 1.83). In other words, the amount of change observed for these data from Year 0 to Year 1 was significantly different from 0.

The data may also be tested for significance using a linear regression model of the data points for each of the years sampled. This approach requires all sites to be sampled every year. If data for a site is incomplete, it must be excluded from the regression. This approach also requires an approximately normal distribution for the error term.

Table 5. Example table of hypothetical data for adult abundance (# redds/mile) for steelhead.

mmmm	Year 0 2003	Year 0 2003	Year 0 2003	Year 1 2005	Year 1 2005	Year 1 2005	Test yr 0 vs. yr 1
	Impact	**Cntrl**	**Diff yr 0**	**Impact**	**Cntrl**	**Diff yr 1**	**Diff yr 0 vs. yr 1**
1	**0**	**9**	**9**	**7**	**10**	**3**	**-6**
2	**4**	**20**	**16**	**8**	**19**	**11**	**-5**
3	**5**	**15**	**10**	**5**	**15**	**10**	**0**
4	**0**	**12**	**12**	**10**	**16**	**6**	**-6**
5	**7**	**16**	**9**	**8**	**14**	**6**	**-3**
6	**4**	**7**	**3**	**5**	**9**	**4**	**1**
7	**2**	**4**	**2**	**4**	**3**	**-1**	**-3**
8	**0**	**0**	**0**	**1**	**1**	**0**	**0**
9	**5**	**15**	**10**	**10**	**17**	**7**	**-3**
10	**0**	**11**	**11**	**12**	**14**	**2**	**-9**
Total							
Mean			**8.2**			**4.8**	**3.4**
Variance							**10.1**
SD							**3.2**

DATA MANAGEMENT PROCEDURES

Data will be collected in the field using various hand-held data entry devices. Raw data will be kept on file by the project monitoring entity. A copy of all raw data will be provided to the SRFB at the end of the project. Summarized data from the project will be entered into the PRISM database after each sampling season. The PRISM database contains data fields for the following parameters associated with these objectives.

Table 6. PRISM data requirements for Instream Spawning Gravel Projects

Indicator	Metric	Pre impact Year 0	Post impact Year 1	Post impact Year 3	Post impact Year 5	Post impact Year 10
Stream Distance affected by gravel placement	kilometer	√				
Area of gravel placement	m^2	√	√	√	√	√
Gravel remaining	%		√	√	√	√
Level 1 Effective	Yes/No		√	√	√	√
Stream substrate and embeddedness impact	% fines	√	√	√	√	√
Stream substrate and embeddedness control	% fines	√	√	√	√	√
Level 2 Effective	Yes/No		√	√	√	√
Adult salmon spawner abundance impact	#/km	√	√	√	√	√
Adult salmon spawner abundance control	#/km	√	√	√	√	√
Level 3 Effective	Yes/No		√	√	√	√

REPORTS

PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season for Years 1, 3, and 5.

FINAL REPORT

A final report will be presented to the SRFB in writing after the sampling season for Year 10. It shall include:

- Estimates of precision and variance
- Confidence limits for data
- Summarized data required for PRISM database
- Determination whether project met decision criteria for effectiveness
- Analysis of completeness of data, sources of bias

Results will be reported to the SRFB during a regular meeting after 1, 3, 5, and 10 years post project. Results will be entered in the PRISM database and will be reported and available over the Interagency Committee for Outdoor Recreation web site and the Natural Resources Data Portal.

ESTIMATED COST

It is estimated that approximately 220 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of $13,000 per project.

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APPENDIX A

Stream Measurement and Densiometer Reading Locations

TRANSECT MEASUREMENTS AND DENSIOMETER READING LOCATIONS

Figure 1

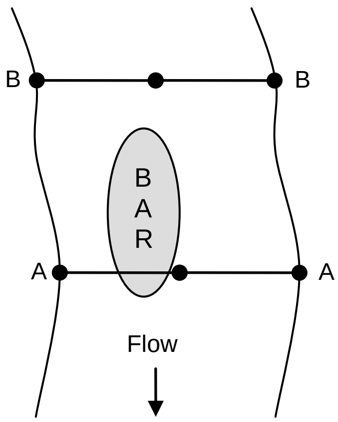


Figure 2

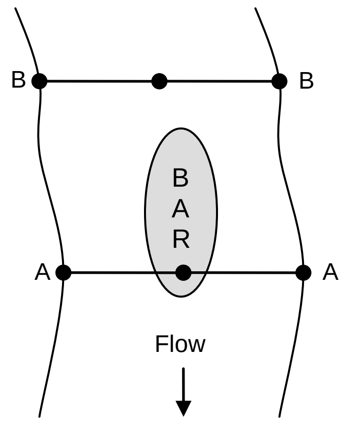


Figure 3

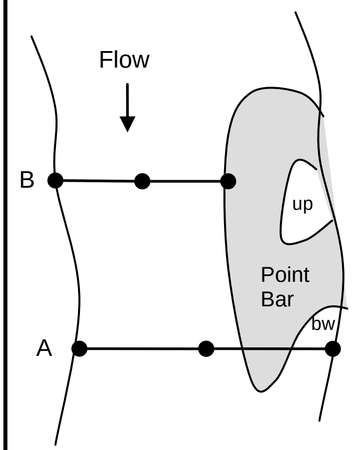


Figure 4

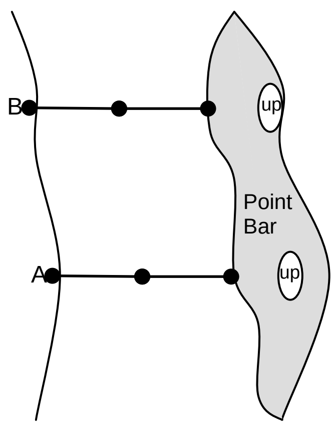


Figure 5

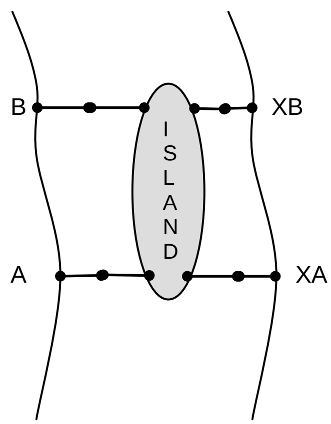


Figure 6

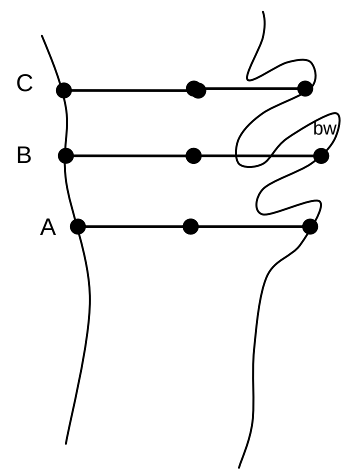


Figure 7

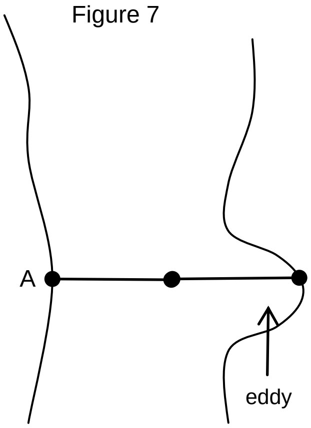


Figure 8

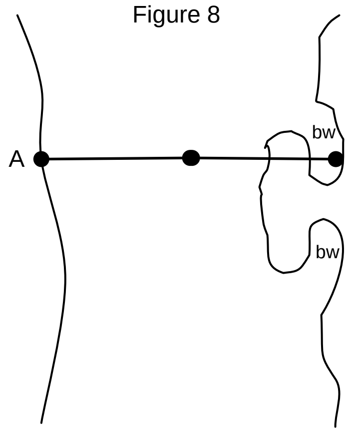
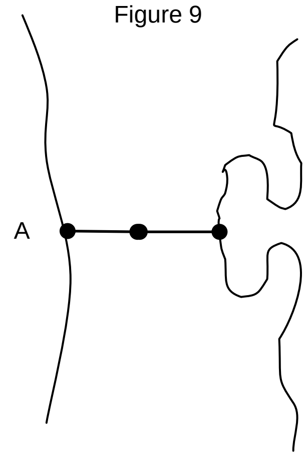


Figure 9



Notes:

- up = unconnected puddle; bw = backwater
- In all figures, flow is from the top of the figure to the bottom of the figure.
- In all figures, each line across the channel represents a Transect and the dots represent the locations of densiometer measurements.
- Measurement locations within the reach are determined based on the conditions present at the time of the survey.
- Substrate measurements (not illustrated in the figures) are made at five equal distance locations across each Transect and each secondary/mid-Transect (e.g., between Transect A and B).
- Right bank is on the right side of the stream when facing downstream; left bank is on the left side of the stream when facing downstream.
- Regardless if a bar is present, densiometer readings occur at the right bank, in the center of the channel, and at the left bank (Figures 1 and 2).
- Wetted width is measured across bars from the right edge of water to the left edge of water (Figures 1 and 2). The bar width is also measured and is independent of the wetted width measurement.
- If a point bar is present (e.g., gray areas in Figures 3 and 4), the edge of water is where the point bar and water meet (i.e., the bank). In Figures 3 and 4, the left bank measurements occur where the point bar and water meet (i.e., the left edge of the water). However, in the case of Transect A, in Figure 3, backwater is present and, therefore, the left edge of water (i.e., the left bank) would be on the left bank of the backwater. Unconnected puddles are never included in any measurements.
- Bars are mid-channel features below the bankfull flow mark that are dry during baseflow conditions. Islands are mid-channel features that are dry even when the stream is experiencing a bankfull flow. Both bars and islands cause the stream to split into side channels. When a mid-channel bar is encountered along the thalweg profile, it is noted on the field form and the active channel is considered to include the bar. Therefore, the wetted width is measured as the distance between the wetted left and right banks. It is measured across and over mid-channel bars and boulders. If mid-channel bars are present, record the bar width in the space provided in the form.
- If a mid-channel feature is as high as the surrounding flood plain, it is considered an island (Figure 5). Treat side channels resulting from islands different from mid-channel bars. Manage the ensuing side channel based on visual estimates of the percent of total flow within the side channel as follows:

    Flow less than 15% - Indicate the presence of a side channel on the thalweg field data form.

    Flow 16 to 49% - Indicate the presence of a side channel on the thalweg field data form.

  Establish a secondary Transect across the side channel (Figure 5) designated as “X” plus the primary Transect letter; (e.g., XA), by creating a new record in the physical habitat form and selecting “X” and the appropriate Transect letter (e.g., A through K) in the new record on the field data form. Complete the physical habitat and riparian cross-section measurements for the side channel on this form. No thalweg measurements are made in the side channel. When doing width measurements within a side channel separated by an island, include only the width measurements of the main channel in main channel form, and then measure the side channel width separately, recording these width measurements in the physical habitat side channel form. Refer to Peck et al. (2003) for detailed instructions on side channel measurements.

- When multiple backwaters and eddies are encountered (Figure 6), measurements are made across the entire channel, over depositional areas (e.g., Figure 6, Transect B) to the edge of water.
- When eddies are encountered (Figure 7), measurements are still made from the right bank to the left bank.
- In instances where a depositional area has become a peninsula and the Transect falls in a location where backwater is present (Figure 8), measure from the right bank across the depositional area to the left bank (e.g., Figure 8, Transect A). When the Transect falls in a location where backwater is not present (e.g., Figure 9, Transect A), only measure to where the water meets the edge of the depositional area/peninsula.