PROTOCOL FOR MONITORING EFFECTIVENESS OF RIPARIAN LIVESTOCK EXCLUSION PROJECTS

MC-4

Washington Salmon Recovery Funding Board

June 2011

Prepared by
Bruce A. Crawford
Project Manager

Revised by Tetra Tech EC, Inc.

Kaleen Cottingham, Director

Recreation and Conservation Office
1111 Washington Street
PO Box 40917
Olympia, Washington
98504-0917

www.rco.wa.gov

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The Salmon Recovery Funding Board would like to thank the Independent Science Panel and Steve Leider of the Governor's Salmon Recovery Office for their review and helpful suggestions for the experimental design.

We would like to acknowledge the assistance of Leska Fore of "Statistical Designs," who provided consultation for structuring statistical tests and in estimating sample size.

We would also like to acknowledge the assistance of Phil Larsen and Phil Kauffman of the U.S Environmental Protection Agency for providing assistance in developing protocols and in providing estimates of variances associated with EMAP response variables.

Thanks are also extended to George Pess of NOAA Fisheries, and Bill Ehinger, Washington Department of Ecology, for their assistance and critique of the procedure.

We would also like to acknowledge the assistance and review of various lead entity staff for their input and concerns.

ORGANIZATION

This document details the monitoring design, procedures, and quality assurance steps necessary to document and report the effectiveness of:

- **Livestock exclusion fencing**

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

Livestock exclusions have the potential to create improvements in bank stabilization, streamside shading, erosion control, and other benefits in a moderate time (5-20 years).

The goal of livestock exclusion fencing is to exclude cattle from the riparian area of the stream where they can cause severe damage to the stream by breaking down stream banks and increasing erosion, destroying shade producing trees and shrubs, and increasing sedimentation. By excluding cattle with fencing, these adverse impacts can be avoided and restoration of the shoreline can occur.

MONITORING GOAL

Determine whether livestock exclusion projects are effective in excluding livestock, restoring riparian vegetation, and restoring stream bank stability.

QUESTIONS TO BE ANSWERED

Are livestock excluded from the riparian area?

Has riparian vegetation been restored in the impact reach?

Has bank erosion been reduced in the impact reach?

NULL HYPOTHESIS

Exclusion of livestock from the riparian corridor has had no significant effect upon:

- Increasing the amount of shading.
- Increasing the complexity of canopy layers of streamside riparian cover.
- Reducing the proportion of actively eroding streambanks.

OBJECTIVES

BEFORE PROJECT OBJECTIVES (YEAR 0)

Determine overall use by livestock of the riparian area to be excluded.

Determine the total acreage to be fenced.

Determine the total kilometers of stream protected.

Determine the overall riparian vegetation cover layers and percent shading within the project area.

Determine the overall proportion of stream bank actively eroding.

POST-PROJECT OBJECTIVES (YEARS 1, 3, 5, AND 10)

Determine the overall use by livestock of the riparian area excluded.

Determine the overall riparian vegetation cover layers and percent shading within the project area.

Determine the overall percentage of pool tail fines.

Determine the overall proportion of stream bank actively eroding.

RESPONSE INDICATORS

Level 1--Exclusion Effectiveness. The presence or absence of livestock inside the exclusion can be used as a measure of the effectiveness of the fencing design in excluding livestock from the riparian area.

Indicator Abbreviation	Description
EXCLDESIGN	The number of livestock exclusions meeting the design criteria for excluding livestock from the stream
LVSTOCKAREA	The area excluded with fencing

Level 2-- Riparian Indicators. Using EMAP protocols (Peck et al. Unpubl.), the percent shading (using a densitometer) is a metric that can be determined in a consistent manner. This metric was chosen because it has been shown to have one of the highest signal to noise ratios (17) of 18 different parameters measured involving riparian vegetation. Using EMAP protocols, the percent of riparian area containing all three layers of vegetation, canopy layer (.5m high), understory (0.5 to 5m high), and ground cover (,0.5m high). This metric was chosen because it has been shown to have one of the highest signal to noise ratios (8) of 18 different parameters measured involving riparian vegetation. Using ODFW methods outlined on page 23, the proportion of actively eroding streambanks can be determined within the sampled stream reaches.

Riparian vegetation variables

Indicator Abbreviation	Description
XCDENBK	Mean percent shading at the bank (using a densitometer)
XPCMG	Proportion of the reach containing all 3 layers of riparian vegetation, canopy cover, under-story, and ground cover
BANK	Proportion of the reach containing actively eroding stream banks
PTFINES	Percentage of pool tail fines within the reach
STRMLGTH	Affected stream length includes meander length affected by the project
CREACHLGTH	The length of the stream control reach actually sampled
IREACHLGTH	The length of the stream Impact reach actually sampled

MONITORING DESIGN

The Board will employ a Before and After Control Impact (BACI) experimental design to test for changes associated with livestock exclusions (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 livestock exclusions would be the impact, that is, the location impacted by the restoration action, and a location upstream of the livestock exclusion would represent the control.

For riparian vegetation and actively eroding streambanks, the BACI design tests for changes at the livestock exclusion impact reach *relative to* the changes in riparian vegetation and actively eroding streambanks observed at a control site upstream. This type of design is required when external factors (e.g., soils, rainfall) affect the riparian vegetation and actively eroding streambanks at the control site. The object is to see whether the difference between upstream (control) and downstream (impact) riparian vegetation and actively eroding streambanks has changed as a result of the livestock exclusion projects. The presence of multiple projects with control and impact locations will address the concerns detailed by Underwood (1994) regarding pseudoreplications. 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 was 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, before the projects. 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 reaches are only affected by the placing of a livestock exclusion and that external influences affect riparian vegetation and actively eroding streambanks 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 be 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 livestock exclusion projects funded in Round 4, 5, and 6 beginning in 2004 until 10 total projects can be tested for effectiveness. If there are insufficient projects funded in any one year to obtain a proper sample size, then replicates of the design will be used in multiple years 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 areas. 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 areas, and multiple 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 2016.

DECISION CRITERIA

Effective if design criteria are met for 80% or more of the structures by Year 10.

Effective if a change of 20% or more is detected in the calculated difference of the mean percent canopy density, the proportion of actively eroding stream banks, and the proportion of the three layers of riparian vegetation between the paired impact and control areas by Year 10 or earlier at the Alpha = 0.10 level.

Table 1. Decision criteria for livestock exclusions

Habitat	Indicators	Metric	Test Type	Decision Criteria
Livestock exclusion fencing	The number of livestock exclusions meeting the design criteria for excluding livestock from the stream (EXCLDESIGN)	#	None. Count of functional exclusions	≥ 80% of exclusions are functional by Year 10. “Functional” means there are no holes in the fencing and no recent signs of livestock inside the exclusion.
Riparian Condition	Mean percent canopy density at the bank Densitometer Reading (XCDENBK)	1-17 score	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Impact and control by Year 10
	3-layer riparian vegetation presence (proportion of reach) (XPCMG)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Impact and control by Year 10
	Percentage of pool tail fines (PTFINES)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Impact and control by Year 10
	Actively eroding banks (BANK)	%	Linear Regression or Paired *t*-test	Alpha =0.10 for one-sided test. Detect a minimum 20% change between Impact and control by Year 10

SAMPLING

We wish to determine whether the fencing exclusion has been effective in excluding cattle and in restoring riparian vegetation. The entire impact area should be surveyed, if sufficiently small.

SELECTING SAMPLING REACHES

IMPACT REACH

Livestock exclusions are often not very large and may be measured in its entirety, or may require one stream reach identified and laid out according to the methods described on pages 11-13.

CONTROL REACH

A paired control reach immediately upstream of each project site should be selected and designed in the same manner as the impact reach for each of the projects. Care should be taken that the control area is not subjected to more cattle use due to the exclusion downstream.

PRE-PROJECT SAMPLING

All livestock exclusion projects identified for long term monitoring by the SRFB must have completed pre-project Year 0 monitoring prior to beginning the project. Year 0 monitoring will consist of:

- Determining the extent of use by livestock (high, medium, low).
- Determining the linear distance in kilometers to the nearest tenth of the stream protected by fencing.
- Measuring riparian vegetation structure for the project area, including canopy cover and density measurements. The riparian vegetation is divided into three layers, canopy layer (0.5m high), understory (0.5 to 5m high), and ground cover (0.5m high).
- Measuring percentage of pool tail fines within the reach.
- Measuring the proportion of stream bank that is actively eroding.

POST PROJECT SAMPLING

Upon completion of the project, Years 1, 3, 5, and 10 monitoring will consist of:

- Determining whether the area inside the exclusion has been used by livestock.
- Measuring riparian vegetation structure for the project area, including canopy cover and density measurements. The riparian vegetation is divided into three layers, canopy layer (0.5m high), understory (0.5 to 5m high), and ground cover (0.5m high).
- Measuring percentage of pool tail fines within the reach.
- Measuring proportion of stream bank at Transect locations actively eroding.

METHOD FOR DETECTING PRESENCE/ABSENCE OF LIVESTOCK

PURPOSE

This protocol is used to determine whether the design criteria are met over a ten-year period. The restoration project excludes livestock from the riparian zone in order for the riparian vegetation and stream morphology to recover from the effects of livestock. Therefore, the fence design and strength should continue to exclude livestock for at least ten years.

EQUIPMENT

Prepare for the survey by bringing a quality pair of binoculars, a digital camera, and a "write-in-the-rain" notebook for recording results.

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 12-14.

SAMPLING DURATION

Sampling should occur during summer low flow conditions, or when feasible at each project site.

SAMPLING PROCEDURE

Step 1: Walk the length of the fence looking for breaks in the fence and/or evidence of livestock passing through, under, or over the fencing. Photograph any breaks or evidence of livestock activity and note them on the appropriate form.

Step 2: Proceed inside the exclusion area and walk the length of the exclusion looking for the presence of livestock tracks, hair or other signs of recent use being careful to distinguish between deer, elk hair, or other wildlife signs and domestic livestock. Report the same in the notebook and take photographs for reference.

Note this in some cases it may be necessary to conduct the Year 1 survey shortly after the completion of the fence. In such cases, fresh signs of livestock may be present within the exclusion area due to recent livestock activity prior to exclusion. To avoid erroneously concluding that the fencing has failed, in Year 1 the fence should be inspected for breaks and the exclusion area inspected for the presence of livestock. Other fresh signs of livestock activity within the exclusion area do not need to be documented in Year 1 unless they can be positively determined to have occurred after the completion of the fence. In all other survey years following Year 1, the presence of livestock signs should be documented as previously described above.

Step 3: If livestock have been using the area, determine the cause, if possible. Does evidence show that the fence is damaged or inadequate under Step 1? Is there evidence that livestock have been purposely or accidentally allowed inside the exclusion through a gate, etc.?

Project Number	Date	Fencing Intact Y/N	Livestock present Y/N	If present what is the cause?

Figure 1. Sample livestock exclusion field sampling form

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 2). The Transects are then averaged to obtain an average representation of the stream reach.

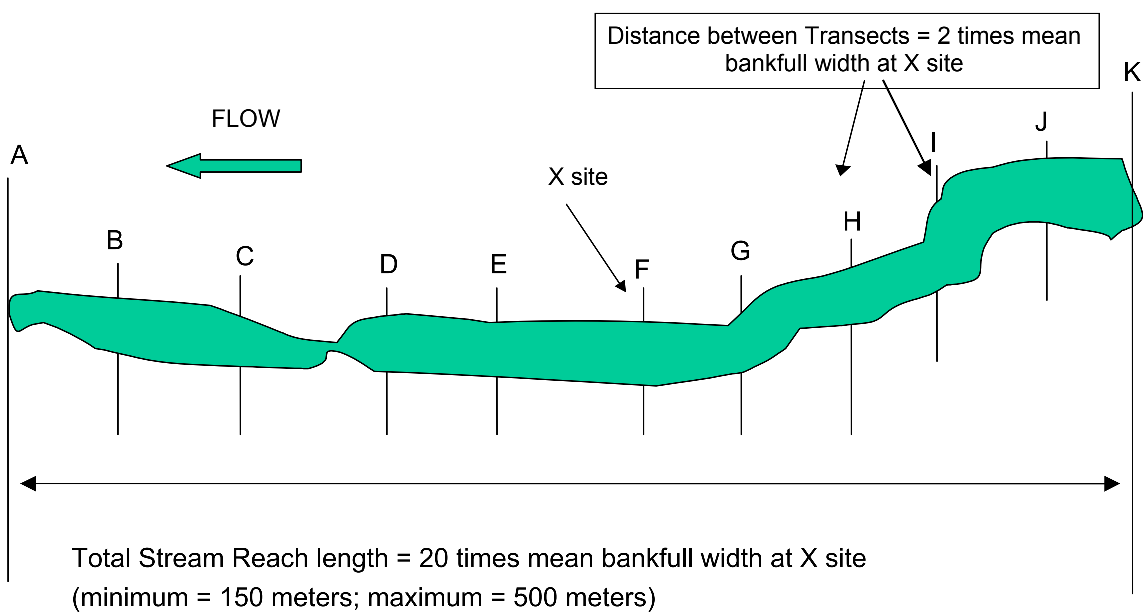


Figure 2. Sampled project reach

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 CHARACTERIZING RIPARIAN VEGETATION STRUCTURE

Protocol taken from: ***Peck et al. (2003), Table 7-10; Kauffman et al. (1999)***

PURPOSE

This protocol is designed to determine the changes in riparian vegetation due to a restoration project where riparian vegetation has been planted.

EQUIPMENT

Convex spherical densiometer, field waterproof forms, hip boots or waders

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 12-14.

SAMPLING DURATION

Sampling should occur during June - August when vegetation is at its maximum growth, or when feasible at each project site.

PROCEDURES FOR MEASURING RIPARIAN VEGETATION AND STRUCTURE

Following are taken from Table 7-10 of EMAP protocols:

Step 1: Standing in mid-channel at a Transect (A-K), estimate a 5m distance upstream and downstream (10m length total).

Step 2: Facing the left bank (left as you face downstream), estimate a distance of 10m back into the riparian vegetation or until an exclosure is encountered. On steeply sloping channel margins, estimate the distance into the riparian zone as if it were projected down from an aerial view.

Step 3: Within this 10 m X 10 m area, conceptually divide the riparian vegetation into three layers: a canopy layer (>5 m [16ft] high), an understory (0.5 to 5 m [20 inches to 16ft.] high), and a ground cover layer (<0.5 m high).

Step 4: Within this 10 m X 10 m area, determine the dominant vegetation type for the canopy layer as Deciduous, Coniferous, Broadleaf Evergreen, Mixed, or None. Consider the layer mixed if more than 10% of the aerial coverage is made up of the alternate vegetation type. Indicate the appropriate vegetation type in the "Visual Riparian Estimates" section of the Channel/Riparian Cross Section Form (Figure 3).

Step 5: Determine separately the aerial cover class of large trees (>0.3 m [1ft] diameter breast height [DBH]) and small trees (<0.3m DBH) within the canopy layer. Estimate aerial cover as the amount of shadow that would be cast by a particular layer alone if the sun were directly overhead. Record the appropriate cover class on the field data form ("0"= absent: zero cover, "1"= sparse: <10%, "2"= moderate: 10-40%, "3"=heavy: 40-75%, or "4"= very heavy: >75%).

Step 6: Look at the understory layer. Determine the dominant vegetation type for the understory layer as described in Step 4.

Step 7: Determine the aerial cover class for woody shrubs and saplings separately from non-woody vegetation within the understory, as described in Step 5 for large trees.

Step 8: Look at the ground cover layer. Determine the aerial cover class for woody shrubs and seedlings, non-woody vegetation as described in Step 5 for large canopy trees, and the amount of bare ground present. Note that Reed's canary grass often meets the height requirements for the understory layer, but should always be counted as ground cover.

Step 9: Repeat steps 1 through 8 for the right bank.

Step 10: Repeat steps 1 through 9 for all Transects, using a separate field data form for each Transect. Once vegetation has been accounted for in a layer, it should not be included in subsequent layers as they are evaluated.

Riparian Vegetation Cover	Left Bank					Right bank					Flag
	Canopy (> 5m high)										
Vegetation type	**D**	**C**	**E**	**M**	**N**	**D**	**C**	**E**	**M**	**N**	
Big trees (trunk > 0.3m DBH) XCL	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Small trees (trunk ,0.3m DBH) XCS	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
	Understory (0.5 to 5m high)										
Vegetation type	**D**	**C**	**E**	**M**	**N**	**D**	**C**	**E**	**M**	**N**	
Woody shrubs and saplings XMW	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Non-woody herbs grasses and forbs XMH	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
	Ground Cover (0.5m high)										
Woody shrubs & saplings XGW	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Non-woody herbs grasses and forbs XGH	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	
Barren dirt or duff XGB	**0**	**1**	**2**	**3**	**4**	**0**	**1**	**2**	**3**	**4**	

Figure 3. Form for recording visual riparian estimates

Note: Use one form for each Transect (A – K)

The following table taken from Kauffman et al. (1999) details the parameter codes and precision metrics of EMAP procedures conducted in Oregon (Table 2). Parameters in bold type are the most precise. This table is provided for information purposes only.

Table 2. Parameter codes and precision metrics of EMAP procedures conducted in Oregon.

Code	Variable name and description	RMSE = σ_{rep}	CV = σ_{rep} / ”(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
XCL	Large diameter tree canopy cover (proportion of riparian)	0.057	38	4.6
XCS	Small diameter tree canopy cover (proportion of riparian)	0.12	55	1.4
XC	**Tree canopy cover (proportion of riparian)**	**0.12**	**33**	**2.4**
XPCAN	**Tree canopy presence (proportion of riparian)**	**0.08**	**8.7**	**10**
XMW	Mid-layer woody vegetation cover (proportion of riparian)	0.12	41	0.9
XMH	Mid-layer herbaceous vegetation cover (proportion of riparian)	0.13	100	0.9
XM	**Mid-layer vegetation cover (proportion of riparian)**	**0.19**	**44**	**0.6**
XPMID	**Mid-layer vegetation presence (proportion of riparian)**	**0.03**	**3.5**	**2.1**
XGW	Ground layer woody vegetation cover (proportion of riparian)	0.17	77	0.1
XGH	Ground layer herbaceous vegetation cover (proportion of riparian)	0.16	40	1.1
XGB	Ground layer barren or duff cover (proportion of riparian)	0.07	47	2.0
XG	Ground layer vegetation cover (proportion of riparian)	0.22	36	0
PCAN_C	Conifer riparian canopy (proportion of riparian)	0.11	58	8.5
PCAN_D	Broadleaf deciduous riparian canopy (proportion of riparian)	0.13	31	7.4
PCAN_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.16	65	2.9
PMID_C	Conifer riparian mid-layer (proportion of riparian)	0.02	55	37
PMID_D	Broadleaf deciduous riparian mid-layer (proportion of riparian)	0.33	58	0.7
PMID_M	Mixed conifer-broadleaf canopy (proportion of riparian)	0.32	87	0.6

PROCEDURES FOR MEASURING CANOPY COVER

Canopy cover is determined for the stream reach in the treatment and control areas at each of the 11 cross-section Transects. A convex spherical densiometer (Model B) is used. Six measurements are obtained at each cross section Transect at mid-channel

Step 1: At each cross-section Transect, stand in the stream at mid-channel and face upstream.

Step 2: Hold the densiometer 0.3 m (1 ft.) above the stream. Hold the densiometer level using the bubble level. Move the densiometer in front of you so that your face is just below the apex of the taped "V".

Step 3: Count the number of grid intersection points within the "V" that are covered by either a tree, a leaf, a high branch, or other shade providing feature (Reed's canary grass, bridge or other fixed structure, stream bank, etc.). Record the value (0-17) in the CENUP field of the canopy cover measurement section of the form.

Step 4: Face toward the left bank (left as you face downstream). Repeat steps 2 and 3, recording the value in CENL field of the data form.

Step 5: Repeat steps 2 and 3 facing downstream, and again while facing the right bank (right as you look downstream). Record the values in the CENDWN and CENR fields of the field data form.

Step 6: Repeat steps 2 and 3 again, this time facing the bank while standing first at the left bank, then the right bank, while holding the densiometer approximately 0.3 m (1 ft.) above the water surface and at the wetted edge. Record the value in the LFT and RGT fields of the data form.

Step 7: Repeat steps 1-6 for each cross-section Transect (A-K). Record data for each Transect on a separate data form.

Step 8: If for some reason a measure cannot be taken, indicate in the "Flag" column. This situation would occur if there is no access to one side of the channel, or if the channel is too wide or deep to cross, so middle measurements cannot be taken. If measurements cannot be taken they will not be estimated.

Location	1-17	Flag
CENUP		
CENL		
CENDWN		
CENR		
LFT		
RGT		

Figure 4. Form for tallying canopy density

Each of the measures taken at the center of the stream are summed for all 11 Transects and converted to a percentage based upon a maximum score of 17 per Transect. The results are then averaged to produce a mean % canopy density at mid-stream (XCDENMID).

Each of the measures taken at the banks of the stream are summed for all 11 Transects and converted to a percentage based upon a maximum score of 17 per Transect. The results are then averaged to produce a mean % canopy density at the stream bank (XCDENBK).

Each of the measures are totaled and averaged to produce the following table of riparian vegetative cover.

Table 3. The shaded composite variables are considered the most important in terms of their precision and are the ones that will be used to determine effectiveness of riparian plantings. 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 = $\sigma^2_{st(yr)}$ / σ^2_{rep} 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. This table is provided to demonstrate the best indicators for testing significance.

Variable	Description	RMSE = σ_{rep}	CV = σ_{rep} / ”(%)	S/N = $\sigma^2_{st(yr)}$ / σ^2_{rep}
XCDENBK	Mean % canopy density at bank (Densiometer reading)	3.9	4.4	17
XC DENMID	**Mean % canopy density mid-stream (densiometer reading)**	**5.8**	**8.1**	**15**
XCM	Mean riparian canopy + mean mid-layer cover	0.22	33	1.4
XPCM	Riparian canopy and mid-layer presence (proportion of reach)	0.08	9.8	7.9
XPCMG	**3-layer riparian vegetation presence (proportion of reach)**	**0.08**	**9.8**	**8.0**

METHOD FOR MEASURING POOL TAIL FINES

Protocol taken from: ***Heitke et al (2010), pp. 49-50.***

PURPOSE

This protocol is designed to determine the percentage of fine sediments on the pool tail surface of plunge pools and scour pools.

EQUIPMENT

Grid (14”x14”, with 49 evenly distributed intersections), measuring stick, electrical tape, field forms, waders

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 12-14.

SAMPLING DURATION

Sampling should occur during June - August at low flow levels, or when feasible at each project site.

PROCEDURES FOR MEASURING POOL TAIL FINES

For the purposes of this method, the following criteria must be met for a feature to be considered a pool:

- Pools are depressions in the streambed that are concave in profile, laterally and longitudinally.
- Pools are bound by a ‘head’ crest (upstream break in streambed slope) and a ‘tail’ crest (downstream break in streambed slope).
- Only consider main channel pools where the thalweg runs through the pool, and not backwater pools.
- Pools span at least 50% of the wetted channel width at any location within the pool. So a pool that spans 50% of the wetted channel width at one point, but spans <50% elsewhere is a qualifying pool.
- When islands are present only consider pools in the main channel; don’t measure pools in side channels.
- If a side channel is present, the pool must span at least 50% of the main channel’s wetted width; disregard side channels width when making this determination.
- Maximum pool depth is at least 1.5 times the pool tail depth.

Step 1: Collect measurements in the first ten scour and plunge pools of each reach beginning at the downstream end (Transect A). Exclude dam pools (and beaver pools). If there are fewer than 10 pools within the reach, sample all pools that meet the criteria listed above.

- Sample within the wetted area of the channel.
- Take measurements at 25, 50, and 75% of the distance across the wetted channel, following the shape of the pool tail.

- Take measurements upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less.

For example, if the pool length is 7 meters, measurements would be taken 0.7 meters upstream of the pool tail crest, which is 10% of the pool length.

If the pool length is 12 meters, measurements would be taken at 1 meter upstream from the pool tail crest because it is less than 10% of the pool's length, which would be 1.2 meters.

- Locations are estimated visually.

Step 2: Assess surface fines using a 14 x 14 inch grid with 49 evenly distributed intersections. Include the top right corner of the grid and there are a total of 50 intersections.

Step 3: Using the grid, take measurements in each pool by completing the following steps:

1. Place the bottom edge of the grid upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less (Figure 5).

2. Place the center of the grid at 25% of the distance across the wetted channel, making sure the grid is parallel to and following the shape of the pool tail crest.

3. If a portion of the fines grid lands on substrate 512 mm (approx. 20 inches) or larger in size (b-axis), record the intersections affected as non-measurable intersections (Figure 6).

Step 4: Record the number of intersections that are underlain with fine sediment < 2 mm in diameter at the b-axis in the Pool Tail Fines Form (Figure 7). Place a 2 mm wide piece of electrical tape on the grid and use this to assess the particle size at each intersection.

Step 5: Record the number of intersections that are underlain with fine sediment < 6 mm in diameter at the b-axis in the Pool Tail Fines Form (Figure 7). Place a 6 mm wide piece of electrical tape on the grid and use this to assess the particle size at each intersection.

Step 6: Aquatic vegetation, organic debris, roots, or wood may be covering the substrate. First attempt to identify the particle size under each intersection. If this is not possible due to debris, then record the number of non-measurable intersections. Do not attempt to move the obstructing debris

Notes:

- Your number of fines < 2mm cannot exceed the number of fines < 6mm.
- In small streams you can have grid placements overlap.

Step 7: Repeat steps 2 – 6 at 50% and 75% of the distance across the wetted channel, for a total of three measurements per pool

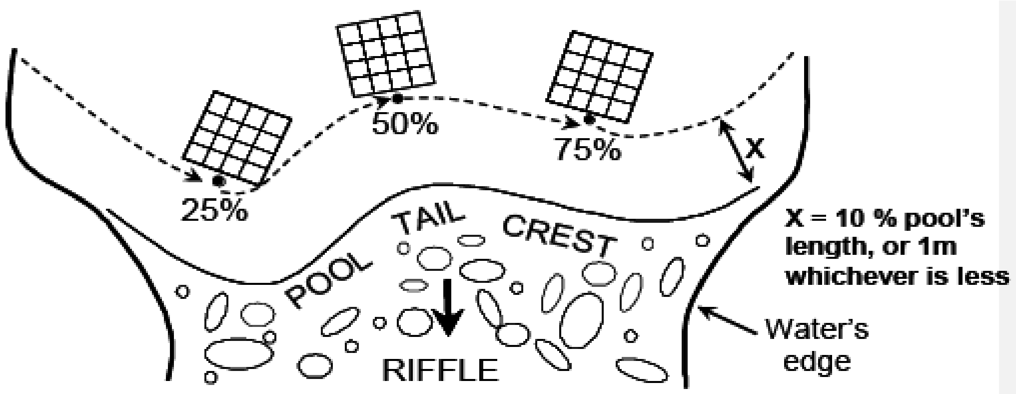


Figure 5. Orientation and location of grid placement (from Heitke et al (2010)).

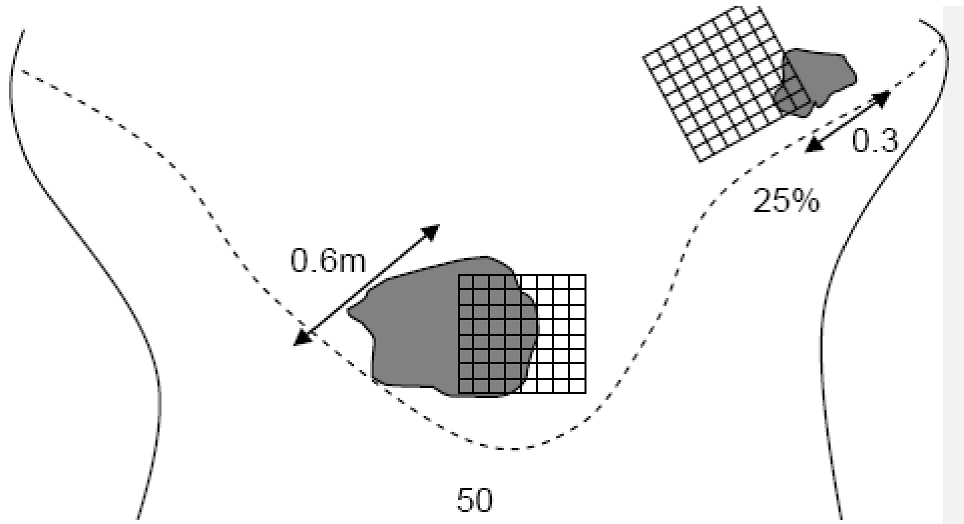


Figure 6. This figure illustrates non-measureable substrate at the 50% placement (from Heitke et al (2010)).

Pool Tail Fines Data Sheet

Site: ___________ Reach: Control Impact Surveyors: ___________

Date: ___________ Visit #: ___________

Transect (A-B, B-C, etc.)	**Pool #** (1-10)*	**# Intersections with Fine Sediment** (out of 50 at each location)								
		25%			***50%***			***75%***		
		<2mm	***<6mm***	***Non-measurable***	***<2mm***	***<6mm***	***Non-measurable***	***<2mm***	***<6mm***	***Non-measurable***

Comments:

*Pools should be numbered from 1-10 sequentially beginning at downstream end of reach.

Note: The number of intersections listed as < 2 mm can not exceed the number that is listed as < 6 mm

Figure 7. Pool Tail Fines Form

METHOD FOR MEASURING ACTIVELY ERODING STREAMBANKS

Protocol taken from: ***Moore et al. (1998)***

PURPOSE

This protocol will allow us to determine if the stream banks within the habitat restoration area have improved and thereby reduced siltation and erosion by reducing the percentage of the streambank that is actively eroding.

EQUIPMENT

Appropriate waterproof sampling form, waders or hip boots

SITE SELECTION

The sample reaches are those laid out according to the methods on pages 12-14.

SAMPLING DURATION

Sampling should occur during summer low flow conditions, or when feasible at each project site.

PROCEDURE

Step 1: Estimate the percent of the lineal distance between each Transect (A – B, B – C, etc.) that is actively eroding at the active channel height. Active erosion is defined as recently actively eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability.

Step 2: Record estimated percent on the bank erosion form (Figure 8)

Transect	Left Bank	Right Bank
A-B		
B-C		
C-D		
D-E		
E-F		
F-G		
G-H		
H-I		
I-J		
J-K		
Total (sum left & right bank)		
Mean Percent erosion (total/20)		
Variance		

Figure 8. Bank erosion form (percent erosion)

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 Livestock Exclusion Projects.

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

Project Site Verification Measurements

GPS Coordinates
The GPS coordinates are taken at Transect A, Transect F (also known as the X-site), and Transect K in each reach, impact and control. These response variables are the GPS coordinates in Degrees, Minutes, Seconds, which are entered into the stream verification form on-site.

Reach Length
Reach length is measured on-site as the distance between the start and end of a reach, or calculated as twenty times the average bankfull 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 (pages 12-14). In general, the impact reach length is scaled to the reach width and the control reach length is set to match the impact reach length unless that is not feasible. The Reach Length variable is simply reported as this measurement or calculated distance in meters.

Reach Width
Reach width is calculated as the average wetted width of the reach. A measurement of wetted with (in meters) is taken at each Transect, and wetted width and bar width are measured at station 5 or 7, the midpoint between each Transect. Each of the 11 wetted width measurements from the major transects and the 10 measurements of wetted width from midpoints, or intertransects, (the width used from the intermediate transects 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 the Reach Width, in meters.

In- Channel Data Collection

Canopy Cover
This is the mean percent canopy density at the bank, based on densiometer readings at the left and right banks. We collect a measurement from a densiometer at locations near the right and left banks of each transect in the reach. The reading is a value between 0 and 17, with 0 indicating no canopy density whatsoever and 17 reading 100 percent canopy density. The final variable takes the measurements read from each transect, both left and right, and calculates the mean.

Riparian Vegetation Structure
Riparian Vegetation Structure is the proportion of the reach containing all 3 layers of riparian vegetation: canopy cover, understory and ground cover. Each of the three layers of riparian vegetation is defined by two constituent layers, and we count a layer as containing riparian vegetation if either of its two constituents are present. The constituents for canopy cover are small trees and big trees. Understory is broken into woody understory and non-woody understory, and ground cover is broken into woody ground cover and non-woody ground cover. At each transect a value is recorded for all six constituents at each bank. For instance a value is recorded for big trees on the left bank and big trees on the right bank at each transect. The values are integers from 0 to 4, representing percentage ranges. A 0 means no presence whatsoever, 1 means less than 10 percent, 2 means 10-40 percent, 3 is 40-75 percent, and 4 is greater than 75 percent.

The calculation is the percentage of the 22 possible locations in the reach that have each of the three layers of riparian vegetation present. We treat the right and left banks separately to come up with the 22 possible locations (the right and left banks for each of the 11 transects.) Since presence of a layer is shown if either of its constituents are present, we start the calculation by looking at the canopy cover, and if the value for big trees OR the value for small trees is 1 or greater, then we count that location to have canopy cover present. In a similar way we judge understory and ground cover and if the location has all 3 layers present we contribute that location to the percentage of the full 22 locations in the reach.

Bank Erosion
Bank erosion is a measure of the proportion of the reach containing actively eroding stream banks. At each transect we collect an estimation in percent (0-100) along the left and right banks. The variable Bank Erosion is the mean of all the measurements, right and left banks combined.

Average Pool Tail Fines
This is an average of all pool tail fines collected in each transect and across entire reach.

Livestock Exclusion Data Collection

Exclusion Design
Following implementation of the project, the exclusion structure is evaluated to determine if it was constructed per the design. This variable is reported as a “Yes” or “No” in response to whether or not the project meets the design specifications.

Area of Exclusion
This is reported as the area excluded from livestock use as part of the project as measured in acres.

TESTING FOR SIGNIFICANCE

We can create a table resembling the following from the data collected for each of the indicators for livestock exclusions (Table 4), canopy cover (Table 5), 3 layer riparian cover (Table 6), and bank erosion.

Table 4. Example of a data table for presence of intact livestock exclusions

	Year 0 2003	Year 1 2005	Year 3 2006	Year 5 2008	Year 10 2014
	Impact	**Impact**	**Impact**	**Impact**	**Impact**
Proj. 1	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj. 2	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj. 3	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj. 4	**No**	**Yes**	**No**	**No**	**No**
Proj. 5	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj. 6	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj. 7	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj 8	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj 9	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Proj 10	**No**	**Yes**	**Yes**	**Yes**	**Yes**
% Change	**0**	**100**	**90**	**90**	**90**

Table 5. Mean % canopy density at bank (densitometer reading)

	Year 0 2003		Year 1 2005		Year 3 2006		Year 5 2008		Year 10 2014	
	Impact	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**
Proj. 1										
Proj. 2										
Proj. 3										
Proj. 4										
Proj. 5										
Proj. 6										
Proj. 7										
Proj 8										
Proj 9										
Proj 10										
Sum										
Mean										
Var.										
% Change										

Table 6. 3-layer riparian vegetation presence (proportion of reach)

	Year 0 2003		Year 1 2005		Year 3 2006		Year 5 2008		Year 10 2014	
	Impact	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**
Proj. 1										
Proj. 2										
Proj. 3										
Proj. 4										
Proj. 5										
Proj. 6										
Proj. 7										
Proj 8										
Proj 9										

	Year 0 2003		Year 1 2005		Year 3 2006		Year 5 2008		Year 10 2014	
	Impact	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**	**Impact**	**Cntrl**
Proj 10										
Sum										
Mean										
Var.										
% Change										

Among all of the measures taken, two measures (mean percent canopy density at the bank and the three-layer riparian vegetation presence) demonstrate the greatest precision and signal to noise ratio. We wish to test whether these parameters have increased significantly post impact. We also wish to test whether the proportion of the stream bank actively eroding has changed over time.

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 species composition and density of vegetation 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 mean percent canopy density at the bank and the three layer riparian vegetation presence 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 mean percent canopy density at the bank, the three layer riparian vegetation presence, and bank erosion after the impact would not be considered significant, that is, the project would not be considered effective. Therefore, 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 livestock exclusion projects will be considered effective.

Our conclusions are, therefore, based upon the differences of the paired scores for the ten sampled livestock exclusion 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:

$$t_{n-1} = \frac{\bar{d} - 0}{s_{\bar{d}}}$$

where
$\bar{d}$ = mean of the differences for Year 0 and a subsequent year
s_d = variance of the differences
$s_{\bar{d}} = {s_d}/{\sqrt{n}}$ = variance mean
n = number of sites (or site pairs).

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 7. Category 1 Livestock Exclusion 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 exclusion	Miles	√				
Total area affected	Acres	√				
Livestock present	Yes/No	√	√	√	√	√
Level 1 effective	Yes/No		√	√	√	√
Riparian shade impact	Mean % canopy density at the bank	√	√	√	√	√
Riparian shade control	Mean % canopy density at the bank	√	√	√	√	√
Statistically significant	Yes/No			√	√	√
Riparian cover impact	Proportion of impact reaches where 3 vegetation layers are present	√	√	√	√	√
Riparian cover control	Proportion of control reaches where 3 vegetation layers are present	√	√	√	√	√
Eroding banks Impact	Proportion of banks actively eroding					
Eroding banks control	Proportion of banks actively eroding					
Level 2 effectiveness	Yes/No		√	√	√	√

REPORTS

PROGRESS REPORT

A progress report will be presented to the SRFB in writing after the sampling season for Year 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.
- Determine 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 37 hours per project would be required to conduct all field activities under the protocol. This results in a relative 2004 cost of $2,300-$3,800 per project.

REFERENCES CITED

Crawford, B.A., C. Drivdahl, S. Leider, C. Richmond, and S. Butkus (2002). The Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery. Vol. 2. Olympia, WA. 377p.

Hankins, D.G. and G.H. Reeves (1988). Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.

Heitke, Jeremiah D.; Archer, Eric K.; and Roper, Brett B. 2010. Effectiveness monitoring for streams and riparian areas: sampling protocol for stream channel attributes. Unpublished paper on file at: http://www.fs.fed.us/biology/fishecology/emp.

Kauffman, P.R., P. Levine, E.G. Robinson, C. Seeliger, and D.V. Peck (1999). Quantifying physical habitat in wadeable streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Mebane, C., T.R. Maret, R.M. Hughes (2003). An index of biological integrity (IBI) for Pacific Northwest rivers. Trans. Amer. Fish. Soc. 132:239-261.

Moore, K., K. Jones and J. Dambacher (1998). Methods for stream habitat surveys aquatic inventory project. Oregon Department of Fish and Wildlife. Corvallis, OR. 36p.

Peck, D.V., J.M. Lazorchak, and D.J. Klemm (editors). Unpublished draft (2003). Environmental Monitoring and Assessment Program -Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. EPA/XXX/X-XX/XXXX. U.S. Environmental Protection Agency, Washington, D.C.

Salmon Recovery Funding Board (2003). Sampling protocols; Effectiveness monitoring requirements. Interagency Committee for Outdoor Recreation. Olympia, WA. 41p.

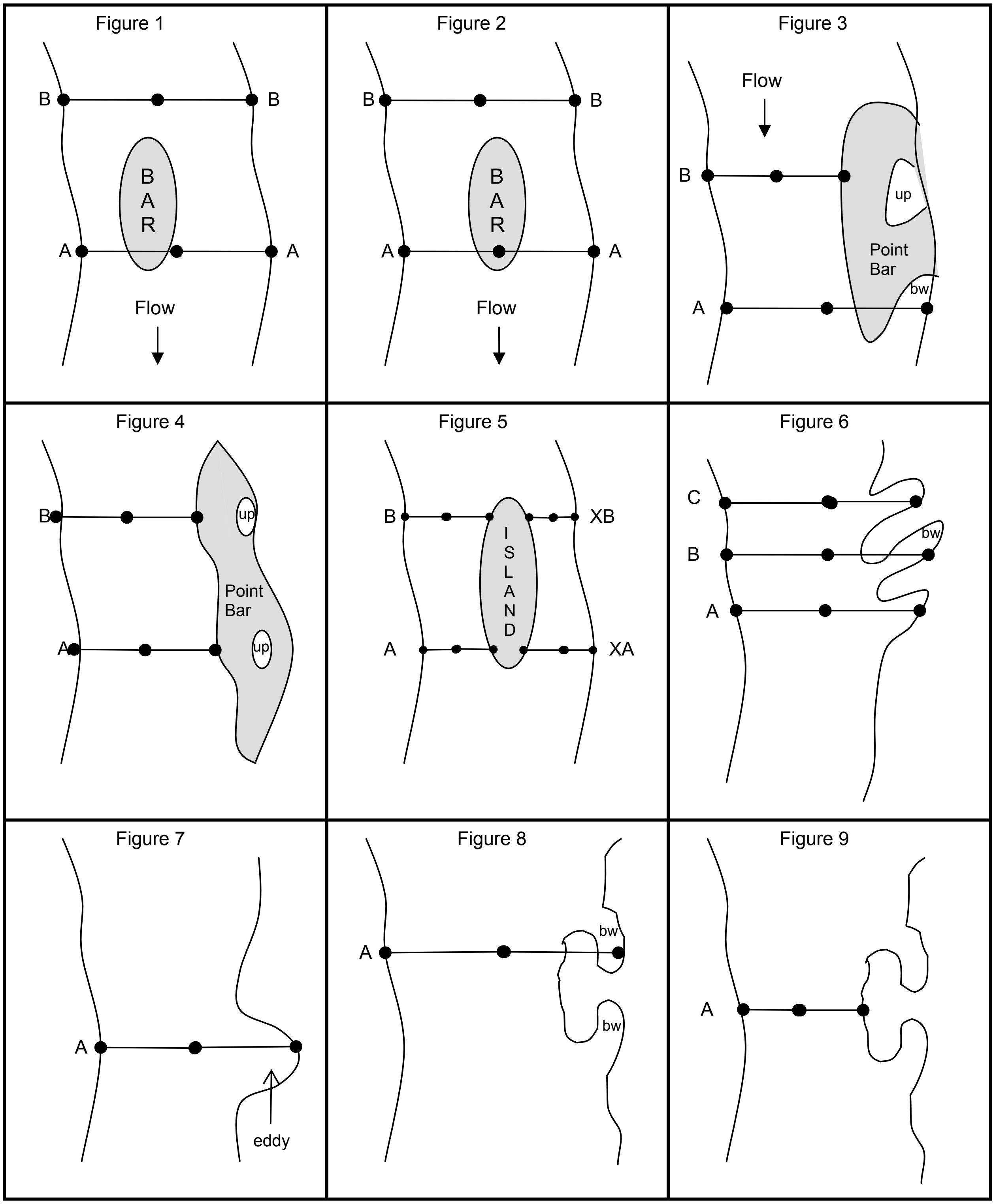
Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker (1986). Ecology. Vol. 67(4) pp. 929-940.

Underwood, A.J. (1994). On beyond BACI: Sampling designs that might reliably detect environmental disturbances. Ecological Applications. 4(1):pp 3-15.

APPENDIX A

Stream Measurement and Densiometer Reading Locations

TRANSECT MEASUREMENTS AND DENSIOMETER READING LOCATIONS



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.