Report for 2004MT30B: Evaluation of various methods to assess condition of perennial stream ecosystems

- Articles in Refereed Scientific Journals:
  - Miller, T.J. and C.B. Marlow. Submitted 2005. Evaluating riparian health assessment methods for perennial streams in Montana. Journal of Range Ecology and Management.

Report Follows

Abstract

The purpose of this project is to determine the relationship between several riparian inventory methodologies and in-stream biological conditions. Many state and Federal land management agencies infer water quality and fish habitat conditions from land-based evaluation of riparian vegetation and channel morphology. However, there is minimal documentation that the metrics used in the riparian condition inventories are correlated with water quality or in-stream habitat conditions. We are requesting support to sample additional streams in central and eastern Montana to expand the data base already developed for the western part of the state.

Introduction

The evaluation of streamside or riparian health has become a major focus of government agencies, private land owners, and the general public when formulating land management decisions (Fleming et al. 2001). These interests coincide with the broad societal desire to maintain or restore stream ecosystem stability and biotic integrity (Magurran 1987; Resh et al. 1995). Throughout the past decade numerous stream and riparian health assessment protocols have been developed by different federal agencies interested in characterizing the health of these systems. Federal agencies that currently use riparian assessment protocols include the Natural Resource Conservation Service (NRCS), Bureau of Land Management (BLM), U.S. Forest Service (FS), and Environmental Protection Agency (EPA). Similar assessment protocols are also being used by more than 85% of state water quality programs (Southerland and Stribling 1995). All these protocols were developed to provide a qualitative rating of a riparian system's condition in relation to its site potential (Prichard 1998; NRCS 2004a).

Because these assessment protocols are ocular (indirect) estimates or subjective classification of physical parameters of stream systems (Poole et al. 1997), their use may lead to inaccurate assessments of riparian health and biotic integrity. Not only may different assessment protocols differ in stream health ratings, but it has also been found that different observers using the same protocol differ in their evaluation of stream health within the same stream reach (Roper et al. 2002). Furthermore, assessment protocols are applied statewide, regionally and nationally, which may not take into consideration the potential differences in riparian ecosystems due to climate and physiographic province (Ward et al. 2003; Resh et al. 1995). The question then arises: do current assessment protocols reflect ecosystem function and/or water quality across these large spatial scales and are the results congruent with the assessment of in-stream or habitat conditions?

In an effort to address this question we focused on the on the application of different riparian assessment protocols on the same perennial stream systems, and then to evaluate their ability to reflect both ecosystem function and aquatic macroinvertebrate distribution across different climatic and physiographic provinces. To accomplish this goal we identified potential stream sites on private lands in western and eastern Montana during spring 2004; negotiated cooperative agreements with landowners in April and May 2004 and began collecting field data in July 2004.

Background

Because riparian health or status is weighed heavily in management plans for Federal lands and on private property when landowners are involved in Federal conservation assistance projects we chose two of the most commonly used riparian assessment protocols in Idaho, Montana and Wyoming. Two other assessment methods that used a similar approach and appeared to have promise were included in the project evaluation. The two riparian assessment protocols most often used by Federal land management agencies in Montana and neighboring states are a modified version of the assessment protocol first described by Prichard (1998) in *Lotic Wetland Health Assessment for Streams and Small Rivers* (Bureau of Land Management 2003) and *Riparian Assessment for Lotic Systems* (Montana Natural Resource Conservation Service, 2004). Similar assessment methods added to this study were the *Stream Visual Assessment Protocol* developed by the National Aquatic Assessment Workgroup, Natural Resource Conservation Service, in 1998 and the riparian vegetation based, *Monitoring Vegetation Resources in Riparian Areas* (Winward 2000). Testing four similar methodologies reduced the likelihood of bias for or against a specific assessment method.

Objectives

A. Assess riparian health/status on the same stream reaches in western and eastern Montana using protocols described in *Lotic Wetland Health Assessment for Streams and Small Rivers* (Bureau of Land Management 2003), *Riparian Assessment for Lotic Systems* (Montana Natural Resource Conservation Service, 2004), *Stream Visual Assessment Protocol* (Natural Resource Conservation Service (1998) and *Monitoring Vegetation Resources in Riparian Areas* (Winward 2000).

B. Measure and describe stream habitat conditions, i.e. pool-riffle ratios, streambed embeddedness, stream velocity, and macroinvertebrate populations in reaches were riparian assessments were conducted.

C. Compare and contrast riparian health/status scores from each of the assessment protocols with the presence/absence of pollution intolerant macro-invertebrate taxa and taxa diversity for the same stream reaches. The null hypothesis assumes that measures of stream physical conditions, stream health assessments, and aquatic macroinvertebrate assemblages will not differ across the state of Montana.

Methods and Materials

Site Descriptions:

Streams were selected based on four criteria: 1) streams are located in Montana, 2) streams must be low gradient (< 0.02%) and perennial, 3) streams located in western Montana must derive their source from the Rocky Mts., and 4) streams located in the east must derive their source from the prairie. A total of ten streams were selected for this study.

Western stream sections were chosen on the basis of Rosgen C type morphologies that are typical of open meadows (Rosgen 1996). The five western streams selected were located on private property and subject to annual livestock use and hay production. The names of these streams are Cottonwood Cr., Lower and Upper Nevada Cr., South Boulder Cr., and South Willow Cr. South Boulder and South Willow streams have similar average annual precipitation (46-cm) and elevations (1 615-m – 1 737-m) (WRCC 1999). Both of these streams have deep to very deep well drained soils with a texture that is predominantly sandy to course sandy loam. Parent material consists of granite, limestone, and igneous rock (NRCS 2004b). The other three western stream sections have similar elevations (1 250-m – 1 433-m), and deep to very deep, poor to well drained soils (NRCS 2004b). Cottonwood Cr. has the highest average annual precipitation (53-cm) of the western streams, and a soil texture that is predominately a gravelly loam (NRCS 2004b; WRCC 2004f). Cottonwood Cr. along with the 2 Nevada Cr. sections consists of parent material dominated by glacial till and drift. The two stream sections of Nevada Cr. have an average annual precipitation of 47-cm, and a loam to a silty clay loam soil texture (NRCS 2004b; WRCC 2004c). The two Nevada Cr. sections are divided by the Nevada Cr. Reservoir. Upper Nevada Cr. is located three miles above the reservoir, while Lower Nevada Cr. is located four miles below the reservoir.

Eastern streams were more difficult to locate due to lack of abundance and the intermittent nature found in prairie environments. The five stream sections selected were located on private property, and the Rosgen stream classification ranged from E type to G type morphologies (Rosgen 1996). The five eastern streams were subject to both annual livestock use and hay production. The names of these streams are Little Spring Cr., Louse Cr., Mission Spring Cr., Rosebud Cr., and Otter Cr. Louse Cr. the northern most eastern stream has an elevation of 1 192-m and an average annual precipitation of 39-cm (WRCC 2004e). Soils are very deep well drained loam to silty clay loams with parent materials that consist of limestone and marly shale (NRCS 2004b). Little Spring Cr. is located at an elevation of 1 341-m and an average annual precipitation of 39-cm (WRCC 2004a). Soils are moderate to deep well drained loam and clay loams, and parent materials consist of mudstone, siltstone, and sedimentary beds (NRCS 2004b). Mission Spring Cr. derives its source from the Yellowstone R. through hyporeic flow and resurfaces in hay meadows at an elevation of 1 323-m, and receives an average annual precipitation of 42-cm (WRCC 2004d). Soils are very deep, poor to well drained loam and silty clay loams, and parent material is predominantly derived from alluvium deposition (Soil Data Mart 2004). Otter and Rosebud streams are located in the south eastern corner of Montana with elevations at 884-m – 975-m, and an average annual precipitation of 33-cm – 36-cm (WRCC 2001, 2004b). Rosebud Cr. soils are very deep, well to moderately drained loams, and parent material predominantly composed of sedimentary rock (NRCS 2004b). Otter Cr. soils are very deep, well drained loams, and parent materials consist of scoria and sandstone (NRCS 2004b).

Stream and Riparian Assessment Protocols and Bank Stability ratings:

1. Proper Functioning Condition (PFC)**.** This assessment protocol is a modified version of the original PFC (Prichard 1998), and was developed by the USDI Bureau of Land Management (BLM) in the state of Montana and Idaho. The protocol is described in the US Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*) (BLM 2003). It is a first approximation designed to provide a visual rapid assessment of overall health and condition of lotic sites and systems. PFC assessment is based primarily on physical, hydrologic, and vegetative factors. These factors address a reach's ability to perform certain functions such as: sediment trapping, bank building and maintenance, water storage, aquifer recharge, flow energy

dissipation, maintenance of biotic diversity, and primary production. The condition of a reach is ranked by scores totaled for all factors (11) evaluated and that total divided by the possible perfect score and multiplied by 100. The resulting score is used to arrive at a rating category; proper functioning (80% – 100%), functioning at risk (60% – 79%), or nonfunctioning (< 60%).

2. Riparian Assessment for Lotic Systems (NRCS). This assessment protocol was developed by the Natural Resource Conservation Service in 2004, to provide a rapid assessment of sustainability and function of lotic riparian systems (NRCS 2004a). The NRCS protocol is similar to PFC protocol, and is designed as a "first cut" visual evaluation of a lotic riparian system health and condition. Scores are based on reach similarity to the highest ecological status or potential natural community of that system. This assessment protocol is based primarily on the evaluation of factors that support critical riparian functions such as: sediment trapping, bank building and maintenance, water storage, aquifer recharge, flow energy dissipation, maintenance of biotic diversity, and primary production. The NRCS protocol rates sites or reaches by dividing the summed scores of all factors (10) by the potential score and multiplying it by 100. The rating is then categorized as sustainable (80% – 100%), at risk (50% – 80%), or not sustainable (< 50%).

3. Stream Visual Assessment Protocol (SVAP). This assessment protocol was developed by the Aquatic Assessment Workgroup (NRCS), to evaluate condition of aquatic ecosystems associated with lotic systems (NRCS 1998). The SVAP is based primarily on physical conditions that relate riparian and instream attributes to ecological health criteria. The SVAP assesses ecosystem complexity and diversity of habitat for organisms and related functional hydrologic properties. This protocol was designed to be an easy to use visual assessment for landowners to evaluate lotic conditions on their land and through continued monitoring. The SVAP rates sites or reaches by dividing the summed scores of all factors (15) by the number of actual factors scored. The rating is then categorized as excellent (> 9), good (7.5 – 8.9), fair (6.1 – 7.4), or poor (< 6). For the purpose of this study the PFC, SVAP, and NRCS assessment protocols will be used as riparian and stream indicators of ecological function and health of lotic systems. Identification teams consisting of local NRCS and BLM personal conducted the assessments to avoid researcher bias.

4. US Forest Service Greenline Bank Stability (GL). This measure evaluates the first vegetative community types on or near the water's edge and their ability to buffer against forces of moving water (Winward 2000). Riparian vegetative communities measured adjacent to the stream channel were based on this methodology developed by Winward (2000). Vegetative community types adjacent to the stream are indicators of channel and bank stability. Assessment of individual reaches were then categorized by a stability rating excellent (9 – 10), good (7 – 8), moderate (5 – 6), poor (3 – 4), and very poor (0 – 2) (Winward 2000).

*Study Design***:**

Once stream sections were selected by the researcher they were divided into 4 individual reaches, each approximately 110-m in thalweg length. Individual reaches were separated by a distance of 6 times bank full width or if a reach could not fit within management boundaries such (i.e. fences) it was placed on the other side of the boundary so that it would not be divided. On some streams all reaches were exposed to the same management practice, while others were separated by fenced boundaries and exposed to different management livestock and irrigation practices. Streams where reaches differed in management were Cottonwood Cr., South Willow

Cr., Louse Cr., Little Spring Cr., and Mission Spring Cr. Each reach was assigned as the sampling unit.

1. Riparian and Instream measures: Riparian and instream ecological parameter measurements consisted of channel and floodplain cross-section morphologic characteristics, substrate composition, discharge, instream habitat, riparian vegetative composition, and aquatic macroinvertebrate assemblages. All measures were taken during base flow to reduce variability.

Permanent cross-sections were established as the starting point for each reach. Methods used to measure channel and floodplain cross-section morphology are based on Rosgen (1996). Parameters measured were entrenchment ratio, gradient, Wolman pebble count, and discharge measured in cubic ft per second (CFS). Entrenchment ratio measures the streams ability to access the floodplain during high flow events, which enables the stream to dissipate energy and trap sediment. Gradient was measured using a survey transit by taking stream water surface elevation measures 30-m upstream and 30-m downstream from the permanent reach cross-section and dividing the difference in elevation by 60-m. The Wolman pebble count was developed to characterize substrate composition of percent fines and course material (Wolman 1954). A grid was also used to calculate percent fines, which counted particle sizes less than 2-mm in size (Overton et al. 1997). Grid measurements were measured in the tail-outs of 3 different pools within a reach to calculate a mean for percent fines.

Instream habitat measures were based on Overton et al. (1997). Habitats were identified and measured as pools, riffles, and glides. Width depth ratios, surface area and volume were measured for each habitat within the entire length of each reach. Habitat measures for cover were based on undercut banks, vegetative overhang, and large wood and boulders along and within the stream channel throughout the length of the reach. Bank stability (GL) measurements were made on each side of the stream for the length of each reach (110-m).

Aquatic macroinvertebrate assemblages have become a common tool used as indicators of stream health and water quality (Wiggins 1996; Barbour et al. 1999; Bollman 2002). Federal agencies such as the EPA use aquatic macroinvertebrates as key assessment methods to characterize stream condition and water quality. Aquatic macros were sampled in 3 different riffle habitat types or glides when riffle habitats were not available in each reach. This produced 12 samples per stream. Samples were collected during the month of September in 2003 and 2004. Insects were collected using a D-frame dip net, and kicking the streambed material for one minute per sample per habitat. Samples were then stored in whirl packs with 2 x Kahles solution, and were taken to a lab for sorting and identification. Samples were picked and sorted to approximately 500 organisms. Taxa were then identified to family except for Ephemeroptera-Plecoptera-Trichoptera (EPT), which were identified to genus using Merritt and Cummins 3rd edition (1996).

Once the aquatic macros were identified they were then placed into functional feeding groups and regional tolerance values (T) to organic pollutants (Barbour et al. 1999). Regional tolerance values were used to calculate the field biotic index (FBI) to distinguish water quality for each reach (Hilsenhoff 1988). The aquatic macro assessment was also used to determine diversity measures. Family and EPT diversity were measured by Shannon's H', which is an index of equitability among rare and common taxa (Peet 1974; Gurevitch et al. 2002).

Data Analysis**:**

Individual reaches were set as the sample unit (sample size *n* = 40 units), and a significance level ≤ 0.05. The program Minitab was used to conduct a two sample *t*-test of population means between western (*n* = 20) and eastern (*n* = 20) stream reach assessment scores. Assessment protocols and GL were left in their numerical scores for this analysis. A simple kappa coefficient was used to measure interrator agreement between assessment protocols and GL. Assessment protocols and GL were placed into their functional rating categories of sustainability/good-excellent, at risk/fair, and non-sustainable/poor. The functional rating categories were set at 3 for good condition, 2 for fair condition, and 1 for poor condition. When kappa is positive the observed agreement exceeds chance agreement, and its magnitude reflects the strength of the agreement (SAS/STAT 1999). If kappa is negative the observed agreement is less than the chance agreement. The test of symmetry ($Pr > S$) specifies if the agreement is similar between protocols. If $Pr > S$ are greater than α 0.05 then the agreement is considered to be similar. Simple linear regression models (SLRM) were used to distinguish between assessment protocols that best reflect aquatic macroinvertebrate diversity, richness, and tolerance/intolerance measures (R program). Classification and regression tree models (CART) were used to create a visual model to explain correlations between taxonomic presence/absence with environmental parameters and assessment protocols. CART was used to characterize abiotic relationships with aquatic macroinvertebrate taxa presence/absence. Two genera of Trichoptera were characterized, *Glossosoma sp*. (T = 0) and *Helicopsyche sp*. (T = 4). One genera of Ephemeroptera was characterized, *Callibaetis sp*. (T = 9); and the other taxa was the family Grammaridae (T = 4). These aquatic macroinvertebrates represent low, moderate, high water quality conditions.

Results

The results from the two sample t-test indicate that the SVAP was the only assessment protocol that differentiated between eastern and western stream reaches in the state of Montana (Table 1). All other protocols including the GL could not significantly distinguish between western and eastern provinces. Greenline did not significantly differ ($P = 0.07$) between eastern and western stream reaches, but eastern stream reach health scores were typically higher.

The simple kappa coefficients agreements between protocol ratings of reach condition are represented in Table 2. The PFC and NRCS assessment protocols had the only significant agreement for the health of stream reaches. However, the relationship between PFC and NRCS is not strong (*kappa* = 0.52), and there were some differences between functional ratings of 1 and 2. All other kappa coefficients resulted in non-similar agreements between protocol functional ratings of stream reach conditions.

Table 1. Two sample *t* test of assessment and Greenline scores between western and eastern stream reaches (*n* = 40)

Two Sample *t* test			
Protocol	Location	Mean Score ± SE	*P*
[1]PFC	West	68.4± 1.7	0.40
	East	75.0 ± 3.9	
[2]NRCS	West	76.1 ± 15.5	0.20
	East	72.5 ± 13.6	
[3]SVAP	West	7.11 ± 0.2	< 0.01
	East	4.99 ± 0.2	
[4]GL	West	6.85 ± 0.1	0.07
	East	7.30 ± 0.2	

[1]PFC = U.S. Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*); [2]NRCS = Riparian Assessment for Lotic Systems; [3]SVAP = Stream Visual Assessment Protocol; [4]GL = Greenline

The SVAP was the best predictor of aquatic biotic integrity and water quality across stream reaches (Table 3). The simple linear regression models for SVAP had the best fit with the highest R^2 and lowest residual variance throughout the data for EPT diversity (Fig. 1), richness, and FBI scores. The PFC assessment protocol did indicate a significant linear relationship ($P \leq 0.05$) with the response variables; however, the R^2 was low indicating a higher degree of unexplained variance within the models (Fig. 2). The NRCS assessment protocol and GL did not signify significant relationships and adequate R^2 with aquatic biotic integrity and water quality across stream reaches (Figs. 3–4).

Table 2. Kappa Coefficients agreement between NRCS, PFC, SVAP and GL ratings of stream reach condition

Kappa Coefficients						
Comparisons	Kappa	[1]95% CL (L)	[2]95% CL (U)	[3]O-S Pr > Z	[4]T-S Pr > ∣ Z ∣	[5]Pr > S
NRCS x PFC	0.52	0.31	0.73	< 0.01	< 0.01	0.15
NRCS x SVAP	- 0.11	- 0.29	0.07	NS	NS	0.01
NRCS x GL	- 0.15	- 0.35	0.06	NS	NS	< 0.01
PFC x SVAP	0.21	0.002	0.41	0.02	0.03	< 0.01
PFC x GL	- 0.21	- 0.44	0.02	0.03	NS	0.03
SVAP x GL	- 0.11	- 0.3	0.05	NS	NS	< 0.01

[1] 95% CL (L) = Lower Confidence Limit; [2] 95% CL (U) = Upper Confidence Limit;
[3] O–S Pr > Z = One-Sided Probability > Z-test; [4] T–S Pr > Z = Two-Sided Probability > Z-test; [5] Pr > S = Probability > Statistic

Table 3. SLRM of assessment protocols and GL scores for all streams in correlation with EPT diversity, richness, and FBI

	Simple Linear Regression Relationships					
	[1]EPT Diversity		[2]EPT Richness		[3]FBI	
Protocol	*P*	R^2	*P*	R^2	*P*	R^2
[4]PFC	< 0.01	0.34	< 0.01	0.22	< 0.01	0.29
[5]NRCS	NS	0.02	NS	0.01	NS	0.02
[6]SVAP	< 0.01	0.75	< 0.01	0.87	< 0.01	0.80
[7]GL	NS	0.02	NS	0.04	NS	0.03

[1]EPT Diversity = Ephemeroptera–Plecoptera–Trichoptera Diversity; [2]EPT Richness = Ephemeroptera–Plecoptera–Trichoptera Richness; [3]FBI = Field Biotic Assessment; [4]PFC = U.S. Lotic Wetland Health Assessment for Streams and Small Rivers (*Survey*); [5]NRCS = Riparian Assessment for Lotic Systems; [6]SVAP = Stream Visual Assessment Protocol; [7]GL = Greenline

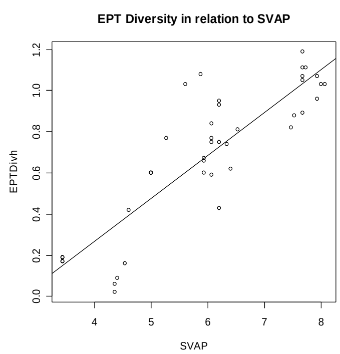


Figure 1. SLRM of EPT diversity relationship with SVAP scores.

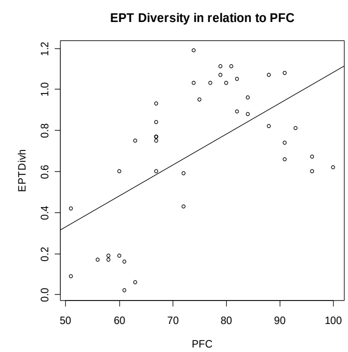


Figure 2. SLRM of EPT diversity relationship with PFC scores.

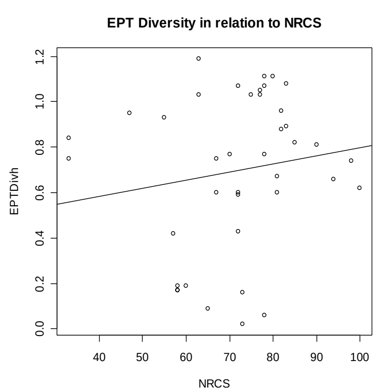


Figure 3. SLRM of EPT diversity relationship with NRCS scores.

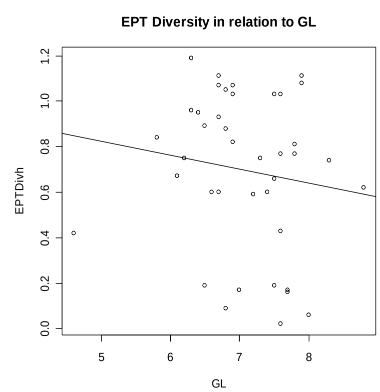
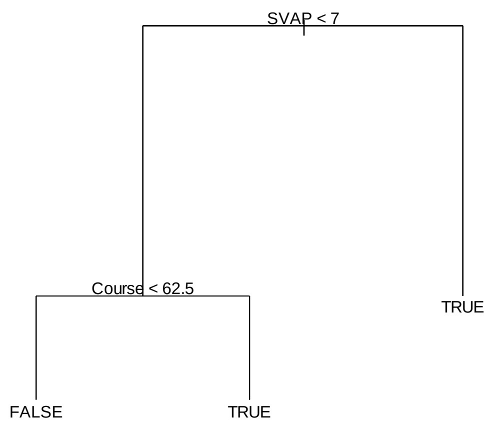


Figure 4. SLRM of EPT diversity relationship with GL scores.

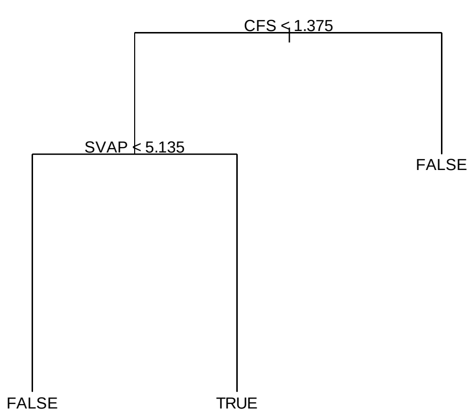
Results from the CART models suggest that substrate composition, CFS, habitat units, and SVAP reflected correlations with presence/absence of the selected taxa. The genus *Glossosoma sp*. has a strong correlation with SVAP and percent course material (Fig. 5). This genus was present in all stream reaches where SVAP was > 7. In reaches where SVAP was < 7 the proportion of course substrate material > 62.5% determined the presence of *Glossosoma sp*. This genus correlates with streams that have higher water quality, riparian health, and a high proportion of course substrate material.



Number of terminal nodes: 3
Residual mean deviance: 0.2997 = 11.09 / 37
Misclassification error rate: 0.1 = 4 / 40
1) root 40 53.84 FALSE (0.6000 0.4000)
  2) SVAP < 7 28 22.97 FALSE (0.8571 0.1429)
    4) Course < 62.5 20 0.00 FALSE (1.0000 0.0000) *
    5) Course > 62.5 8 11.09 TRUE (0.5000 0.5000) *
  3) SVAP > 7 12 0.00 TRUE (0.0000 1.0000) *

Figure 5. Richness of the genus *Glossosoma sp*. correlated with SVAP and percent course stream bed material.

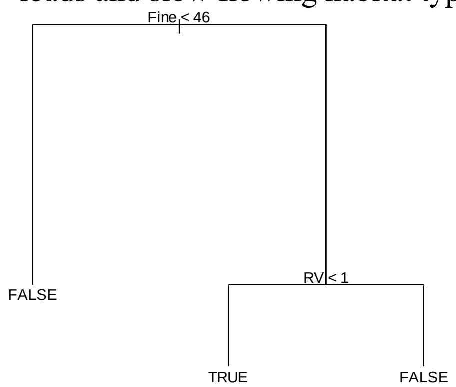
The genus *Helicopsyche sp*. has a strong correlation with CFS and SVAP in its distribution patterns (Fig 6). CFS > 1.375 *Helicopsyche sp*. was absent, which correlated with all western streams except Lower Nevada Cr. The next determining factor for presence/absence was the SVAP rating. Reach ratings < 5.135 indicated this genus's absence. Presence and absence of *Helicopsyche sp*. correlates with streams that may be considered as moderate to fair water quality and habitat conditions.



Number of terminal nodes: 3
Residual mean deviance: 0.2056 = 7.606 / 37
Misclassification error rate: 0.025 = 1 / 40
1) root 40 53.840 FALSE (0.60000 0.40000)
  2) CFS < 1.375 28 38.240 TRUE (0.42857 0.57143)
    4) SVAP < 5.135 11 0.000 FALSE (1.00000 0.00000) *
    5) SVAP > 5.135 17 7.606 TRUE (0.05882 0.94118) *
  3) CFS > 1.375 12 0.000 FALSE (1.00000 0.00000) *

Figure 6. Richness of the genus *Helicopsyche sp*. correlated with CFS and SVAP.

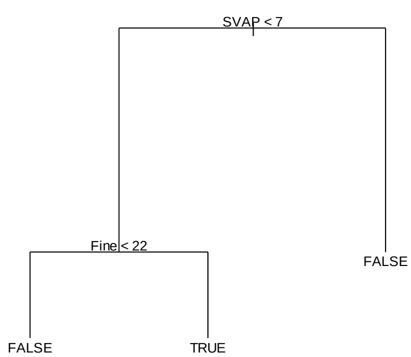
The genus *Callibaetis sp*. has a strong correlation with percent fines and riffle habitat types (Fig. 7). This genus was absent from reaches with percent fines < 46%. The next environmental parameter that best explains presence and absence of this genus was riffle volume (RV < 1 m^3 per reach). The presence of this genus indicates streams that have high sediment loads and slow flowing habitat types such as pools and glides.



Number of terminal nodes: 3
Residual mean deviance: 0.2861 = 10.59 / 37
Misclassification error rate: 0.075 = 3 / 40
1) root 40 42.65 FALSE (0.7750 0.2250)
  2) Fine < 46 26 0.00 FALSE (1.0000 0.0000) *
  3) Fine > 46 14 18.25 TRUE (0.3571 0.6429)
    6) RV < 1 6 0.00 TRUE (0.0000 1.0000) *
    7) RV > 1 8 10.59 FALSE (0.6250 0.3750) *

Figure 7. Richness of the genus *Callibaetis sp*. correlated with percent fines and riffle volume (RV)

The family Grammaridae has a strong correlation with SVAP and percent fines (Fig. 8). This family was not present on reaches with SVAP ratings < 7, which accounts for three of the western streams, South Boulder, South Willow, and Cottonwood. For reaches with SVAP < 7 this family was present only on reaches where percent fines were > 22%, which excluded all western streams except Lower Nevada Cr. and all eastern streams. Grammaridae presence correlates with fair to poor water conditions in the reaches measured across the state of Montana.



Number of terminal nodes: 3
Residual mean deviance: 0.2997 = 11.09 / 37
Misclassification error rate: 0.1 = 4 / 40
1) root 40 53.84 TRUE (0.4000 0.6000)
  2) SVAP < 7 28 22.97 TRUE (0.1429 0.8571)
  3) SVAP > 7 12 0.00 FALSE (1.0000 0.0000) *
  4) Fine < 22 8 11.09 FALSE (0.5000 0.5000) *
  5) Fine > 22 20 0.00 TRUE (0.0000 1.0000) *

Figure 8. Richness of the family Grammaridae correlated with SVAP and percent fines.

Discussion

The SVAP was the only assessment protocol that distinguished between streams in western and eastern geological provinces. SVAP reach scores were higher on western streams indicating substantial physical differences among instream characteristics between the provinces. Dissimilarities amongst protocols and GL agreement of reach ratings were evident in the results, and only PFC and NRCS protocols had a significant relationship with a moderate kappa coefficient. It would make sense that PFC and NRCS are similar because both methods emphasize and evaluate similar characteristics within a stream system. A similar relationship was also found by Ward et al. (2003). They found that the SVAP and Habitat Assessment Field Data Sheet (HAFDS), which target similar parameters resulted in a strong positive correlation ($r = 0.81$). The original version of PFC which focuses more on hydrologic functions had a weak correlation with both the SVAP and HAFDS ($r = 0.58$ and 0.54). However, Whitacre (2004) found means among protocols for 8 of the 10 physical attributes evaluated differed ($P<0.05$) across three Oregon and three Idaho streams when comparing results from three other riparian assessment methods; the Aquatic and Riparian Effectiveness Monitoring Program (AREMP), the Environmental Monitoring and Assessment Program (EMAP) and PACFISH/INFISH Effectiveness Monitoring Program (PIBO). Not only is there a weak agreement between protocols, but potential variability amongst observer evaluations of stream and riparian condition exists (Roper et al. 2004). Coles-Ritchie et al. (2004) found high variability among observers when conducting greenline (Winward 2000) surveys on different reaches with different community types and stability conditions. They found that the mean agreement for all observers was 38%, and the maximum and minimum 49% and 29%. Hannaford and Resh (1995) found that individual riparian site assessments varied considerably among college student groups. Thus is must be assumed that differences may have occurred between the different ID teams that evaluated stream reaches in this study. Observations by Miller suggest that differences in familiarity with the various assessment methods and riparian monitoring experience among the various BLM and NRCS teams could have contributed to the variation in stream reach scores across Montana.

The differences found in assessment protocols are not only reflective of the variability in stream reach condition and observer experience, but also in the various methods' ability to reflect aquatic macroinvertebrate diversity, richness, and water quality. The data collected in this study suggests that SVAP was the only assessment protocol that had a significant and strong linear relation with these three instream parameters. SVAP best exemplifies instream conditions because it takes into consideration not only vegetative and hydrologic characteristics, but also substrate composition, instream habitat types, water clarity, and aquatic macrophyte production. In other words SVAP evaluates parameters suggested by Resh et al. (1995) that capture the stream's ability to influence aquatic biotic integrity. Furthermore assessment protocols that reflect aquatic macroinvertebrate assemblages would indicate direct responses to changes in water quality, chemistry, and geological regions (Resh et al. 1995).

Environmental parameters that have been found to have some of most significant relationships to aquatic macroinvertebrate assemblages are substrate composition and annual stream flow (Allan 1995; Scarsbrook 2002). A study by Beisel et al. (1998) measured seven environmental parameters in northeastern France, and found substrate to be the dominant factor that influenced the community structure of aquatic taxa, and found that current velocity and water depth were secondary factors. Substrate composed of medium particle sizes such as gravel and cobble generally increases the abundance and richness of benthic invertebrates while excessive sediment is considered a pollutant in streams and can have negative affects on aquatic biota (Waters 1995). Nerbonne and Vondracek (2001) found that percent fines and embeddedness of the substratum were negatively correlated with aquatic macroinvertebrate assemblages. These findings related to substratum composition and aquatic macroinvertebrates are similar to the stream characteristics identified as being important in this study suggesting that western stream reaches typically had fewer fines, greater CFS, presence of taxa with a low tolerance to pollution and higher EPT diversity and richness measures. Eastern stream reaches typically had greater proportions of fines, lower CFS, presence of taxa that are moderate to highly tolerant of pollution and have lower EPT diversity and richness measures.

While PFC and NRCS may give valuable information on proper functioning condition and sustainability of flood plain communities throughout Montana they appear weak in their ability to reflect water quality and aquatic biotic integrity because they do not include information on substrate composition. The SVAP, which includes a more detailed evaluation of instream characteristics such as substrate composition, provides a stronger indirect measure of water quality and instream habitat conditions than does PFC, NRCS or GL. The components within the SVAP and the results of this study correspond with relationships reported from other studies in the United States and France.

Implications

The SVAP is an example of an assessment protocol that produces a floodplain/riparian vegetation status score that is more indicative of instream habitat conditions and water quality than the other developed protocols such as PFC and NRCS. However, our results also suggest that the PFC and NRCS protocols are robust enough to be used to assess riparian status across a broad range of physiographic conditions without introducing too much bias into the outcome. Nonetheless, it is clear that high PFC or NRCS scores do not automatically imply high water quality nor diverse macroinvertebrate populations. Management goals for high water quality and enhanced cold-water fisheries would be best supported by assessment and monitoring efforts using SVAP or other protocols that assess stream substrate characteristics. Use of the PFC, NRCS, or GL with the SVAP would provide a more in-depth evaluation of riparian function and processes than can be achieved with a single methodology. The integration of both SVAP and NRCS for example would result in little additional effort and cost when applied to a stream reach, and would provide a better understanding of the aquatic and terrestrial conditions within that stream system.

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