RESEARCH

A comparison of three visual assessments for riparian and stream health

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ABSTRACT: Visual assessments are integral components of several widely promoted efforts to assess the health of stream and riparian areas across the Nation. The U.S. Environmental Protection Agency's (EPA) Habitat Assessment Field Data Sheet (HAFDS), U.S. Department of Agriculture's Natural Resources Conservation Service's (NRCS) Stream Visual Assessment (SVA), and U.S. Department of Interior (USDI) Bureau of Land Management's (BLM) Proper Functioning Condition (PFC) assessment were applied to 234 rangeland riparian areas to determine: 1) how well the assessments correlate, and 2) how site-specific stream and riparian characteristics affect the outcome of each assessment and thus the comparison of outcomes across stream types. Habitat Assessment Field Data Sheet and Stream Visual Assessment are habitat driven assessments, which target similar parameters resulting in a strong positive correlation between these methods (r = 0.81). BLM's Proper Functioning Condition focuses on parameters related to hydrologic function, thus a weaker correlation was found when comparing Proper Functioning Condition to the Habitat Assessment Field Data Sheet and the NRCS' Stream Visual Assessment methods (r = 0.58 and 0.54, respectively). A combination of one habitat assessment and Proper Functioning Condition should be utilized to conduct a comprehensive assessment of riparian/stream health. Site characteristics, which were significantly associated with assessment outcomes included entrenchment ratio, substrate size, channel width to depth and slope. This presents a problem in that comparison of assessment outcomes across different streams and stream reaches are confounded by factors such as slope and substrate type, which may not always be indicative of riparian/stream health. The Rosgen Stream Morphology Classification system was used to successfully control for the effect of these site-specific effects on assessment outcome, allowing for comparison of riparian/stream health assessments across streams.

Keywords: Ecosystem health, Proper Functioning Condition, rapid bioassessment, Rosgen Stream Classification, Stream Visual Assessment

Visual assessments of aquatic habitat abundance and quality as well as hydrologic function are integral components of various riparian/stream health assessment efforts being promoted by natural resources management and protection agencies. While these methods are dependent upon the subjectivity and training of the individuals applying them, visual assessments provide a rapid method of evaluating various components of riparian/stream health across a large number of streams. These methods can thus facilitate the inventory of unhealthy streams across a region and allow for the prioritization of restoration efforts and resources. Numerous visual assessments have been independently developed and broadly applied. Questions often arise about the comprehensiveness of individual visual assessments in evaluating health, the level of agreement between methods, and the validity of using these methods to compare health between stream reaches with different characteristics. Outside of the documentation for the application of a given assessment method there is essentially no published data to address these questions.

The goal of this study was to apply three commonly used visual assessments across a spectrum of rangeland streams in California to develop a data set allowing for the examination of the questions raised above, providing guidance to individuals and agencies applying these methods to assess riparian and stream health. Specific study objectives were to 1) determine how well the outcomes of each assessment correlate; and 2) determine if and how site-specific riparian and stream characteristics affect assessment outcome and thus comparisons across different stream reaches.

Habitat Assessment Field Data Sheet. The Habitat Assessment Field Data Sheet (HAFDS) is included as a major component of the U.S. Environmental Protection Agency's (EPA)

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Rapid Bioassessment Protocol III (Barbour et al., 1999). Habitat Assessment Field Data Sheet was developed to provide visual assessment of instream habitat type and quality to assist in the interpretation of stream macroinvertebrate data collected during rapid bioassessments as suggested by Barbour et al., 1999; Hannaford and Resh, 1995; and Resh et al., 1995. Habitat Assessment Field Data Sheet assesses habitat features via ten questions. Each question targets the abundance and quality of a specific habitat feature. The stream reach is assigned a score of one (habitat feature not present or quality minimal) to 20 (habitat feature abundant and quality excellent). An example question from Habitat Assessment Field Data Sheet is targeted on epifaunal substrate and available cover for macroinvertabrates and fish. The overall outcome score for the reach is calculated as the average score for all 10 questions.

Stream Visual Assessment. U.S. Department of Agriculture's (USDA) Natural Resources Conservation Services' (NRCS) *Stream Visual Assessment* (SVA) was developed for use with landowners, and focuses on various physical parameters of stream health, specifically those related to instream habitat (NRCS, 1998). Stream Visual Assessment is similar to EPA's Habitat Assessment Field Data Sheet in the type of habitat features assessed. Stream Visual Assessment is composed of 15 questions targeting individual habitat related features of the stream reach. A score of 1 to 10 is assigned for each question. An example question from Stream Visual Assessment targets bank stability, where a score of 10 is assigned when banks are stable and a score of one is assigned when excessive stream bank failure is apparent. Overall SVA outcome for a reach is calculated as the mean of scores for the 15 questions.

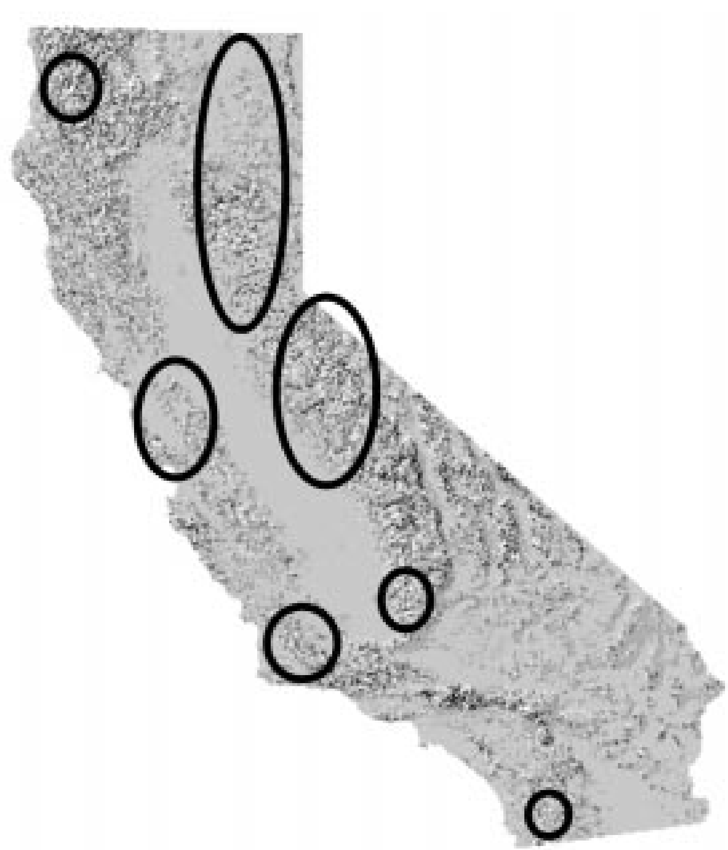
Proper Functioning Condition. A joint effort by the U.S. Department of Interior (USDI) Bureau of Land Management (BLM), USDA Fish and Wildlife Service, and NRCS lead to the development of the *Proper Functioning Condition* (PFC) visual assessment, designed to evaluate stream hydrologic function. The developmental basis was that all aspects of stream health depend upon the stream's ability to perform critical, basic hydrologic functions that can be assessed quickly and visually (Prichard et al., 1998). A total of 17 questions covering hydrology, vegetation, and erosion/deposition processes are examined. Each question can be answered as "Yes", "No", or "Not applicable" based on the site's potential. An example question from the method is, "Stream is in balance with water and sediment being supplied by the watershed?" Based upon the answers to these 17 questions, the team applying the method agrees on a final outcome rating for the stream reach out of the following: "Proper Functioning Condition," "Functioning at Risk," or "Nonfunctional."

Methods and Materials

The experimental unit in this study was a 100 m (328.08 ft) reach of stream. During 1999 and 2000, the Habitat Assessment Field Data Sheet, Stream Visual Assessment, and Proper Functioning Condition visual assessments were all applied to each of 234 rangeland stream reaches located across California (Figure 1). Stream reaches were selected to represent the many combinations of riparian vegetation, stream morphology, and hydrologic regime found across California's diverse rangeland watersheds. Stream reaches ranging from obviously "poor" to "excellent" health (from the perspective of all 3 assessments) were included in the study to provide a range of outcome scores. Stream reaches were selected so that each reach was solely contained in one combination of riparian vegetation, stream morphology, hydrologic regime and health status.

A team of two to three trained members, lead by a single team leader, visited each site and applied each assessment to the site following published guidelines for each method (NRCS, 1998; Prichard et al., 1998; Barbour et al., 1999). Each assessment was applied to the stream reach during the same visit. Entrenchment ratio, channel width to depth ratio, channel slope (%), substrate type (silt, gravel, cobble, etc.), habitat type (% of reach that is a run, riffle, and pool), stream canopy cover (%), and dominate riparian

Figure 1
Circled areas represent rangeland regions of California, which were targeted for the study. Stream reaches across these regions were sampled during 1999 and 2000.



vegetation (willow, aspen, sedge, etc.) data were also collected at each stream reach. Each stream reach was assigned a Level I Rosgen Stream Morphological Classification (A, B, C, E, F, and G) following Rosgen (1996). This classification method categorizes streams based upon basic morphological features such as entrenchment ratio, channel slope, and substrate type, providing a simple approach to grouping stream reaches with similar morphological characteristics and presumably hydrologic function. It should be noted that only Rosgen stream types A, B, C, E, F, and G were sampled.

Statistical analysis to address the first study objective of determining the correlation between EPA's Habitat Assessment Field Data Sheet, NRCS' Stream Visual Assessment, and BLM's Proper Functioning Condition was the calculation of Pearson Correlation Coefficients (r) comparing the outcomes of each assessment across all stream reaches (n = 234). Habitat Assessment Field Data Sheet and Stream Visual Assessment outcome scores are continuous variables (1 to 20 and 1 to 10, respectively), whereas Proper Functioning Condition outcome is a categorical rating (Proper Functioning Condition, Functional at Risk, and Nonfunctional). For ease of analysis, Proper Functioning Condition ratings were converted to a numeric value such that Proper Functioning Condition = 3, Functional at Risk = 2, Nonfunctional = 1. The second study objective of determining the effect of site specific riparian and stream characteristics on assessment outcome was achieved using backwards stepwise regression via General Linear Models. A decision criteria of $p<0.10$ was used for inclusion of an independent variable in the final model. Separate regressions were developed for each assessment method with overall assessment outcome as the dependent variable and entrenchment ratio, channel width to depth ratio, channel slope, substrate type, habitat type, stream canopy cover, and dominate riparian vegetation type as the independent variables offered in the initial model.

To determine if Rosgen stream class could be utilized as a simple tool to account for any effects of stream characteristics on assessment outcome, differences in the mean overall outcome for each assessment across Rosgen class was tested using ANOVA and Tukey mean separation techniques ($p<0.05$). The effect of Rosgen stream class on assessment correlation was investigated by calculating Pearson Correlation Coefficients (r) for each final assessment outcome by Rosgen Level I stream class combination.

Results and Discussion

Assessment correlations. A strong positive correlation (r = 0.81) existed between HAFDS and SVA assessment outcomes. This is not surprising given the focus of both assessments on similar aquatic habitat features such as availability and diversity of cover, streambank stability, embeddedness in riffles, and channel alteration. Moreover, the description of the condition of these features (greater than 70% cover available, less than 10% bank erosion, etc.) used to assign a score (1 to 20 or 1 to 10) is similar for questions contained in each assessment.

A relatively weaker, yet still positive, correlation existed between Proper Functioning Condition and Habitat Assessment Field Data Sheet (r = 0.58) as well as between Proper Functioning Condition and SVA (r = 0.54). As habitat assessment outcomes increased so did likelihood of a PFC outcome of Proper Functioning Condition or Functional at Risk. Recalling the focus and design of each assessment, there are basic differences between BLM's Proper Functioning Condition and both EPA's Habitat Assessment Field Data Sheet and NRCS' Stream Visual Assessment. Proper Functioning Condition targets features reflecting the hydrologic function of the system whereas the Habitat Assessment Field Data Sheet and the Stream Visual Assessment primarily target habitat features. For example, Proper Functioning Condition assesses if plant species capable of withstanding flood flows are present and if the channel is in balance with the sediment and water being supplied by the watershed. Whereas, the Habitat Assessment Field Data Sheet and the Stream Visual Assessment assess features such as embeddedness in riffles and diversity in flow regimes for habitat. It is also important to note that the Habitat Assessment Field Data Sheet and the Stream Visual Assessment outcome scores are calculated as the average of scores for each question in the assessment, giving each question equal weight for the final outcome. Since Proper Functioning Condition is not numerically driven the final outcome score must be derived in a more subjective fashion based upon the assessment team's collective decision. In such a scenario, certain questions could be given more or less weight in the derivation of the final outcome (Proper Functioning Condition, Functional at Risk, Nonfunctional) depending upon the team's opinion. It is not possible to determine which approach to developing the final assessment outcome is most appropriate from these data. It is clear that Proper Functioning Condition evaluates riparian and stream health in a different manner than the Habitat Assessment Field Data Sheet and Stream Visual Assessment.

Site characteristics and assessment outcomes. Table 1 reports the significance of several important stream characteristics in final backwards stepwise regression models predicting assessment outcome by stream characteristics. Habitat Assessment Field Data Sheet outcome was affected by entrenchment, substrate size, percent riffle, pool, and canopy. The Stream Visual Assessment outcome was affected by entrenchment, slope, substrate size, percent run, and canopy. The relationship of percent run, riffle, and pool have to the EPA's Habitat Assessment Field Data Sheet and NRCS' Stream Visual Assessment outcome is not surprising. Both assessments have several questions which target diversity in flow regime and habitat type, which are directly related to pool-riffle-run complexes. Stream Visual Assessment outcome decreased as channel slope (%) decreased. This relationship could be accounted for by the fact that lower gradient channels tend to have less diversity in habitat, particularly macroinvertebrate habitat, compared to steeper stream channels. As with the Habitat Assessment Field Data Sheet and the Stream Visual Assessment, Proper Functioning Condition was correlated to entrenchment, substrate size, and percent canopy. This indicates that these site characteristics are important determinants of assessment outcome on California's rangeland stream systems.

Substrate size. Outcome scores decrease as substrate size decreases in size from boulder (>10 in diameter) to silt, indicating that lower scores can be expected on streams dominated by fine substrates. The presence of excessive fine sediments can indeed be an indicator of lowered stream health and disturbance and thus it is appropriate that all three-assessment outcomes are sensitive to substrate size. An increase in fine sediments due to excessive erosion within the watershed can reduce habitat quality by filling in pools, embedding riffles, and covering habitat structures. However, inherent differences in stream sub-

Table 1. Results of backwards-stepwise regression model development to determine relationships between riparian / stream assessment outcome and site-specific riparian and stream characteristics. Reported values are p-values (n.s. = nonsignificant; p>0.05) for each characteristic in final models for each of the 3 visual assessment methods--Habitat Assessment Field Data Sheet (HAFDS), Stream Visual Assessment (SVA), and Proper Functioning Condition (PFC). Data are from 234, 100 m (328.08 ft) rangeland stream reaches across California rangelands.

Site characteristic	HAFDS[1]	SVA[2]	PFC[3]
Entrenchment ratio	0.002	0.004	0.090
Width to depth ratio	n.s.	n.s.	n.s.
Slope (%)	n.s.	0.026	n.s.
Substrate size	0.040	<0.001	0.040
Run (%)	n.s	<0.001	n.s.
Riffle (%)	<0.001	n.s.	n.s.
Pool (%)	<0.001	n.s.	n.s.
Stream canopy cover (%)	<0.001	<0.001	0.040
Dominant vegetation type	n.s.	n.s.	n.s.
Model adjusted R-squared	0.59	0.58	0.17

[1] **Habitat Assessment Field Data Sheet (Barbour et al., 1999).**

[2] **Stream Visual Assessment (NRCS, 1998)**

[3] **Proper Functioning Condition (Prichard, 1998)**

strate between streams must be accounted for when making comparisons across streams using these assessments. For instance, a high gradient (>5% slope) headwater stream with naturally occurring boulder or cobble substrate stream (Rosgen A or B class stream) will inherently have a higher assessment outcome score than a low gradient (<2% slope) meadow or valley stream naturally dominated by fine sediment substrates (Rosgen E stream class).

Entrenchment ratio. Entrenchment ratio is the ratio of the width of the flood prone area to the surface width of the bank full channel (Rosgen, 1996). The results indicate that assessment outcome decreases as entrenchment ratio decreases. A reduction in entrenchment ratio on a stream can be an indicator of lowered stream health. A reduction in entrenchment ratio could indicate that the stream is eroding downward in its bed thus losing access to its floodplain. This can lead to channel instability, loss of riparian vegetation, lowered water table and reduced habitat availability and quality. However, as with substrate size, there are inherent, natural differences in entrenchment ratio between stream types based upon position in the watershed, as well as geologic and topographic factors. For instance, a stream in a steep, narrow, rocky canyon will inherently have a lower entrenchment ratio relative to a low gradient valley stream.

Stream canopy cover. Assessment score increased as stream canopy cover increased, indicating the importance of woody riparian vegetation in these assessments. This is a logical relationship given that woody riparian vegetation can provide cover, serves as an important source of organic matter and nutrients for stream systems, increases habitat complexity, and in certain stream types is an important component of bank stability. While canopy cover provided by woody riparian vegetation is a generally important component of stream health, care must be taken when utilizing these assessments on stream reaches, which inherently do not provide suitable habitat for willows. Streams such as low gradient, fine sediment dominated meadows systems typical of Rosgen E streams tend not to provide water table or substrate conditions favorable for woody riparian vegetation. These stream types attain healthy conditions with appropriate cover by riparian dependent herbaceous species such as sedges (*Carex* spp.) and rushes (*Juncus* spp.).

Rosgen stream classification and assessment outcome. Entrenchment ratio, stream channel width to depth ratio, channel slope, and substrate type were significantly related to assessment outcomes. Entrenchment ratio, channel width to depth and slope are explicit determinants in Rosgen's Level I classification, and substrate is somewhat accounted for in Level 1 classification (Rosgen, 1996). The results illustrate the need to control for these parameters when comparing assessment outcomes across streams with naturally different levels of these parameters. Since Rosgen's classification system is well published and widely used we explored our data further to evaluate its utility for controlling for these parameters when making cross-stream comparisons.

Assessment correlations by Rosgen stream class. Table 2 reports the Pearson Correlation Coefficients (r) illustrating the correlation between the EPA's Habitat Assessment Field Data Sheet, NRCS' Stream Visual Assessment, and BLM's Proper Functioning Condition for each Rosgen stream class. The Habitat Assessment Field Data Sheet and Stream Visual Assess-ment outcomes are consistently more strongly correlated with each other than the Proper Functioning Condition is to either habitat-based assessment. These results indicate the need to employ both a habitat based assessment (HAFDS or SVA) and the Proper Functioning Condition to optimize stream health assessment efforts regardless of stream type.

Rosgen stream class. Mean assessment outcome was calculated for each Rosgen stream class. These means were tested for significant

Table 2. Pearson Correlation Coefficients for comparison of Habitat Assessment Field Data Sheet (HAFDS), Stream Visual Assessment (SVA), and Proper Functioning Condition (PFC) visual assessment outcomes stratified by Rosgen Stream Morphological Classifications A, B, C, E, F, and G. Data are from 234, 100 m (328.08 ft) rangeland stream reaches across California rangelands.

Rosgen stream class[1]	HADFS[2] x SVA[3]	PFC[4] x HAFDS	PFC x SVA
A	0.74	0.36	0.43
B	0.70	0.49	0.31
C	0.77	0.55	0.62
E	0.77	0.38	0.31
F	0.83	0.55	0.50
G	0.75	0.51	0.55

[1] **Rosgen (1996).**

[2] **Habitat Assessment Field Data Sheet (Barbour et al., 1999).**

[3] **Stream Visual Assessment (NRCS, 1998).**

[4] **Proper Functioning Condition (Prichard, 1998).**

Figure 2
Mean U.S. Environmental Protection Agency's (EPA) Habitat Assessment Field Data Sheet outcome (1 = limited habitat availability and quality, 20 = excellent habitat availability and quality) for 100 m (328.08 ft) rangeland stream reaches (n=234) by Level I Rosgen Stream Morphological Classification system. Significant differences are indicated by different letters (p<0.05).

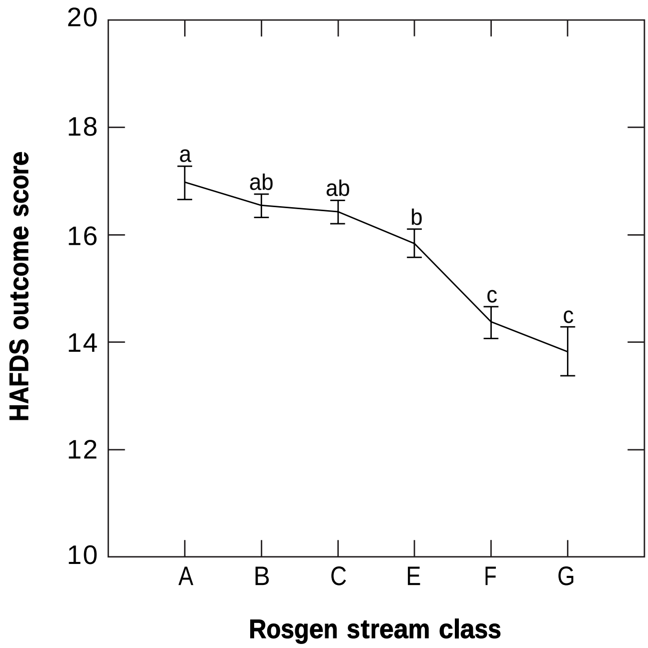
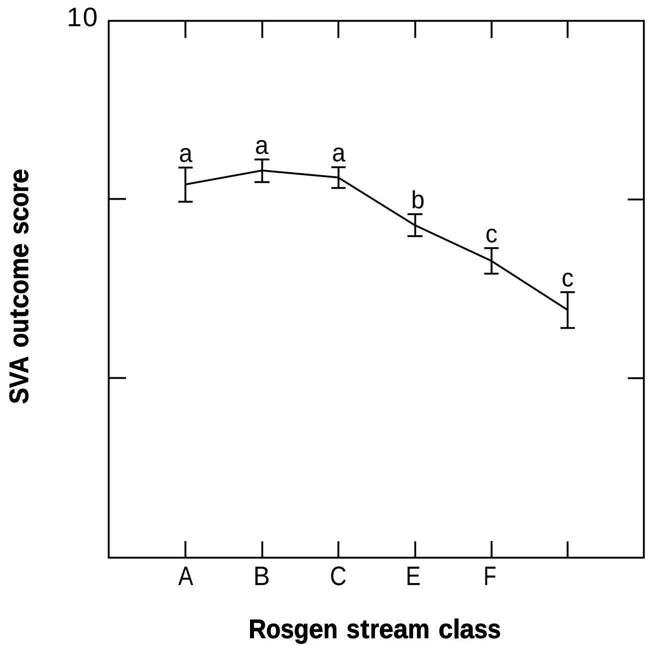


Figure 3
Mean U.S. Department of Agriculture's Natural Resources Conservation Service's Stream Visual Assessment outcome (1 = limited habitat availability and quality, 10 = excellent habitat availability and quality) for 100 m (328.08 ft) rangeland stream reaches (n=234) by Level I Rosgen Stream Morphological Classification system. Significant differences are indicated by different letters (p<0.05).



differences via ANOVA and Tukey's means separation procedures. Figures 2 through 4 report the results of these analysis. Significant differences in mean assessment outcome due to Rosgen stream class existed for all three assessments ($p<0.05$). This is not surprising given the significant relationships between assessment outcome and stream morphological features reported in Table 1. Within the sample of streams included in this study, Rosgen A streams tended to be located high in the watershed, and had relatively steep channel slopes with bedrock-boulder-cobble dominated substrates. Rosgen B streams were similar to A class streams but occurred at a slightly lower positions in the watershed, and had lower channel slopes with boulder-cobble-gravel dominated substrates. Rosgen C and E streams occurred in meadow situations. Rosgen C streams had slopes from 2 to 4% with substrate dominated by cobble and gravel. Rosgen A, B and C streams provided a diverse set of habitat niches, typically had low sediment accumulations, and contained varying amounts of large woody debris. Rosgen E streams had slopes less than 2% with fine substrates. Habitat niches for E streams were typically limited to deep pools, root mats, and small woody debris. F and G streams were recently eroded or actively eroding, entrenched, fine substrate dominated channels at slopes less than 4%. The reader is referred to Rosgen (1996) for more detailed descriptions of each Rosgen stream class.

Considering the role which entrenchment, slope, and substrate size play in determining assessment outcome and as determinants in Rosgen's classification system, the results reported in Figures 2 through 4 are not surprising. These results indicate that the most care must be taken when comparing habitat assessment (EPA's Habitat Assessment Field Data Sheet and NRCS' Stream Visual Assessment) outcomes from A, B, and C streams to E streams and to F and G streams (Figure 2 and 3). HADFS and SVA assessment outcomes are prone to generate lower scores for Rosgen E streams relative to A, B, and C streams, likely due to the effect of substrate size and habitat diversity. Rosgen F and G streams have a lowered potential for habitat since the systems may be actively eroding (G streams) or just stabilized (F streams) and are lacking many common habitat structures such as undercut banks, large woody debris, root mats, no riparian vegetation, or only colonizer species, increased fines, etc.

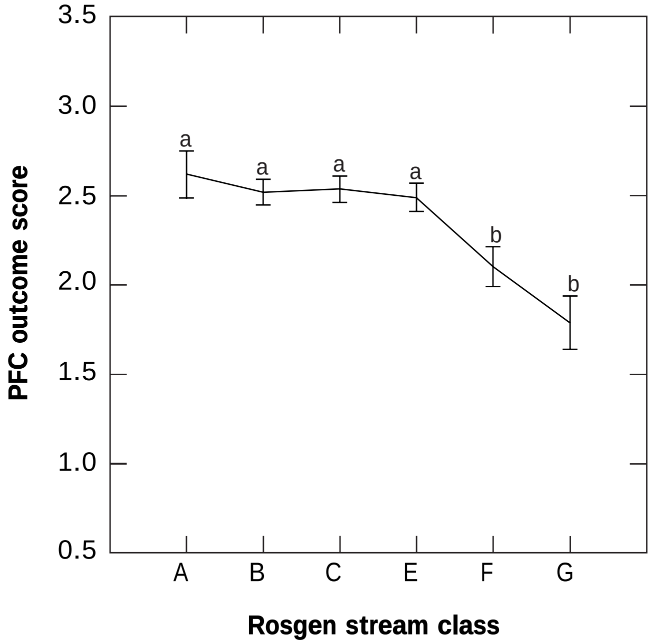
Figure 4 illustrates the robust nature of Proper Functioning Condition relative to Rosgen stream class. There was no significant difference in mean Proper Functioning Condition outcome for Rosgen's A, B, C, or E stream classes. Proper Functioning Condition outcome for these stream classes were all significantly different from F and G streams. These results indicate that the Proper Functioning Condition outcome more readily accounts for potential confounding stream morphological characteristics than do the Habitat Assessment Field Data Sheet or Stream Visual Assessment. The developers of both the Habitat Assessment Field Data Sheet and Stream Visual Assessment (Barbour et al., 1999; NRCS, 1998) clearly state that comparisons between streams should be conducted within similar stream types, and the results confirm this recommendation.

Summary and Conclusion

Strong positive correlations were found to exist between EPA's Habitat Assessment Field Data Sheet and NRCS' Stream Visual Assessment outcome. These results indicate that there is significant overlap in the components of riparian/stream health, which these assessments target. They provide similar

Figure 4

Mean U.S. Department of Interior's Bureau of Land Management's Proper Functioning Condition assessment outcome (1 = Nonfunctional, 2 = Functional at Risk, 3 = Functional) for 100 m (328.08 ft) rangeland stream reaches (n=234) by Level I Rosgen Stream Morphological Classification system. Significant differences are indicated by different letters ($p<0.05$).



information on habitat components of riparian and stream health, so the utility of applying both methods is limited. Both methods were found to be well documented and straightforward to apply in the field by a trained team. Relatively weaker correlations existed between the two habitat assessments (HADFS and SVA) and BLM's Proper Functioning Condition, which targets hydrologic function components of riparian/stream health. The application of one habitat assessment in combination with PFC is recommended to provide the most information on riparian/stream health.

Assessment outcomes were found to be influenced by fundamental stream morphological features such as entrenchment ratio, substrate size and channel slope, as well as by stream vegetative canopy cover. While the relationships between assessment outcome and these features are important to the ability of the assessments to detect problems within stream reaches, it could also present a problem when comparing across stream types. The Rosgen Stream Morphological Classification system (Rosgen, 1996) was found to account for much of the variability in streams due to morphology It is recommended that stream morphology be taken into account when making comparisons of assessment outcomes between streams, and that the Rosgen system appears to provide a simple approach to accomplishing this.

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