

**RIPARIAN ECOSYSTEM EVALUATION:  
A REVIEW AND TEST OF BLM'S PROPER FUNCTIONING CONDITION  
ASSESSMENT GUIDELINES**

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**ABSTRACT**

We present a review and refinement of the U.S. Bureau of Land Management (BLM) Proper Functioning Condition Assessment (PFCA) methodology for determining riparian ecosystem health in the arid West. This review and a proposed alternative methodology, focused on lower elevation tributaries on the Colorado Plateau, is based on the contributing authors' cumulative scientific expertise, and additional external peer review by independent experts. We present this report to the National Riparian Service Team and the Utah State BLM Office to aid the BLM in its review of the PFCA approach in riparian settings because the BLM is required under the *Utah Standards and Guidelines for Healthy Rangelands* (USGHR) to accurately assess the condition and causes of riparian ecosystem degradation. We reviewed the assumptions and constraints of the BLM's PFCA approach and identified strategies to improve the scientific credibility of the process, and its use in monitoring. We identified several important elements that are missing from the present PFCA approach, including data management, site scoring, and assessment of water quality, stream health, species of concern (including endangered, indicator and exotic taxa), wildlife habitat assessment, and direct human impacts. We also describe four regional-scale synoptic analyses needed to improve the process: (1) use of the PFCA approach at reference (control) sites, (2) human land use history (including agency management objectives for all sites), (3) regional hydrogeology, and (4) regional biology (particularly ecosystem distribution and sensitive species habitat requirements).

We propose a refined methodology that expands the existing PFCA criteria, relates those criteria specifically to southwestern riparian ecosystem processes, and clarifies the ecological accountability for decisions about riparian ecosystem condition. Our approach provides a more intensive, repeatable and less subjective framework for riparian ecosystem evaluation, while still remaining an efficient and cost effective rapid assessment technique. We believe that this review may help the BLM review the adequacy of its PFCA methods. Most importantly, we feel our procedure more adequately presents information required by the USGHR, and more accurately identifies the existing condition of streams and associated riparian ecosystems.

## INTRODUCTION

Riverine and riparian ecosystems are the most productive, biologically diverse, and threatened habitats in the American Southwest (Johnson and Jones 1977, Johnson et al. 1985, Knopf et al. 1988, Ohmart et al. 1988, Johnson 1991, Minckley and Brown 1994). Springs, wet meadows, marshes, and stream and lake margins are habitats that are... “inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and which, under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions” (U.S. Department of the Interior 1992). Riparian ecosystems are interactively linked through the hydrogeologic and geomorphic processes associated with the drainage’s antecedent and contemporary flow, flood disturbance patterns, sediment transport, and upland slope conditions, as well as land management practices (Hupp 1988, Gregory et al. 1991, Malanson 1993, Mitsch and Gosselink 1993, Auble et al. 1994, Leopold 1994). Riparian habitats support ecological processes and diverse assemblages of distinctive species that are not found in the surrounding uplands (Stevens et al. 1977, Minckley and Brown 1994). For example, Stevens and Ayers (in press) reported that natural riparian and spring habitats make up <1% of the landscape in northern Arizona, yet those habitats directly supported >35% of the higher plant and bird species, as well much higher invertebrate species richness, many facultative herpetofauna and mammal species, and commonly 2-3 orders of magnitude greater productivity than the surrounding arid uplands.

Despite their great ecological importance, land management activities, such as over-grazing, flow regulation, and other anthropogenic activities have been permitted to substantially compromise the ecological integrity of stream, wetland, and riparian ecosystems throughout North America (Fleischner 1994, Minckley and Brown 1994, Dale et al. 2000). Estimates of riparian habitat loss range from 40% to 90% in the arid southwestern states (Dahl 1990), and riparian habitats are considered to be one of the region’s most endangered ecosystems (Minckley and Brown 1994, Noss et al. 1995). Although southwestern stream ecosystems have been greatly altered, these systems are ecologically resilient and are likely to respond positively to improved management and restoration practices (e.g., Phillips 1998).

Interest in improving riparian and overall land management has stimulated studies, academic symposia, and legislation in the United States over the past 25 years (e.g., Fleischner 1994, Kirschner et al. 1995, Potts 1998, Olsen and Potyondy 1999, Dale et al. 2000; Johnson and Jones 1977, Johnson and McCormick 1978, Johnson et al. 1985, Warner and Hendrix 1985; the Endangered Species Act, the Clean Water Act, the National Wetlands Protection Act). More than 90% of the American Southwest is managed by federal agencies, particularly the Department of the Interior Bureau of Land Management (BLM) and Bureau of Reclamation, and the Department of Agriculture National Forest Service (NFS). Additional large landscapes are managed as National Park Service lands, U.S. Fish and Wildlife refuges, and Department of Defense military reservations. Grazing has been the most widespread management practice on federal lands, including wilderness areas, wildlife refuges, national forests, and some national park units (Fleischner 1994). The Federal Land Policy and Management Act of 1976 requires all federal agencies to manage public lands both for multiple use and long-term

ecological sustainability, and Dale et al. (2000) outline 8 general rules and the scientific information needed for ecologically appropriate landscape management.

Under these mandates, numerous assessment protocols have been developed for streams and riparian areas (e.g., Davis and Simon 1995, Winward 1989, 2000; National Research Council 1992, 1994; Society for Range Management 1995; Poff et al. 1997). The Environmental Protection Agency has established criteria for monitoring stream and riparian habitats, and their guidelines also involve more detailed geomorphic and hydrological calculations, as well as assessment and measurement of water quality and aquatic invertebrate community composition (e.g., MacDonald et al. 1991). Instream flow methodologies are routinely employed by the U.S. Fish and Wildlife Service to assess relationships between stream geomorphology and fish habitat quality (Jowett 1997). The U.S. Army Corps of Engineers (1987) has rigorously defined wetlands under the auspices of the Clean Water Act. The National Forest Service and the National Resources Conservation Service have developed and refined protocols for riparian ecosystem assessment (U.S. National Riparian Service Team 1997, Anderson et al. 1998). These methods emphasize 1) assessment of background information, 2) the use of reference reaches to determine change from the pristine condition and the range of natural variation, 3) riparian plant successional trajectories, 4) reviewing data for monitoring by comparison with future measurements, and 5) adaptive management and information feedback. These protocols commonly include numerous, specific ecological measurements, including geomorphic measurements, plant cover, demography, dendrochronology and successional status (e.g., Davis 1977, Winward 2000).

The BLM manages the majority of the middle and low elevation federal lands in the American Southwest, primarily for grazing (Fleischner 1994), and the BLM has a long history of rangeland assessment (Wagner 1989, Pellant et al. 2000). The BLM's riparian management policy is generally described in *Riparian-Wetland Initiative for the 1990's* (U.S. Department of the Interior 1991). This document establishes the agency's goal to: "1) restore and maintain riparian-wetland areas so that  $\geq 75\%$  are in proper functioning condition (PFC) by 1997 and 2) to achieve an advanced ecological status, except where resource management objectives, including the PFC, would require an earlier successional stage, thus providing the widest variety of habitat diversity for wildlife, fish, and watershed protection". To achieve this goal the BLM staff, assisted by experts from other federal agencies, developed an assessment procedure for determining the ecological integrity of stream and riparian ecosystems. This resulting proper functioning condition assessment (PFCA) is presented in a series of manuals (U.S. Department of the Interior 1992, 1993, 1994, 1998). It improved the efficiency of riparian assessment by using a rapid, qualitative approach that focuses primarily on physical geomorphology and vegetation structure to distinguish the most altered stream reaches so that appropriate management actions can be undertaken. Also, it was designed to help communicate the main principles of riparian system function to non-specialists. These guidelines have been embraced by other federal agencies (e.g., Winward 2000). Originally formulated at the national level as general guidelines, the PFCA process was expected to be refined for each ecological region (U.S. Department of the Interior 1994).

In 1995 the U.S. Department of the Interior (1995) issued updated Standards and Guidelines for grazing management for all BLM lands. Each state BLM office adapted

the national guidelines through state manuals to focus regional assessment and management. For example, in Utah the new national mandate is outlined in the *Utah Standards and Guidelines for Healthy Rangelands* (USGHR), which describes four standards to be applied to all rangelands (Utah BLM State Office 1997):

- “1. Upland soils exhibit permeability and infiltration rates that sustain or improve site productivity, considering the soil type, climate, and landform.
2. Riparian and wetland areas are in properly functioning condition. Stream channel morphology and functions are appropriate to soil type, climate and landform.
3. Desired species, including native, threatened, endangered, and special-status species are maintained at a level appropriate for the site and species involved.
4. BLM will apply and comply with water quality standards established by the State of Utah (R.317-2) and the Federal Clean Water and Safe Drinking Water Acts. Activities on BLM lands will fully support the designated beneficial uses described in the Utah Water Quality Standards (R.317-2) for surface and ground water.”

The USGHR serves as one of the primary links between habitat condition and land management practices on BLM lands, and it supports the PFCA process by triggering management decisions for non-functioning and functioning-at-risk riparian areas with downward or static trends. The USGHR dictates that if a riparian/stream site is not meeting standards, and if conditions are not improving towards meeting those standards, then administrative action will be taken. Although the BLM considers improperly managed grazing to be a serious threat to stream and riparian ecosystem integrity, changes in riparian grazing management practices are made only if grazing is clearly identified as the cause of riparian degradation.

In this paper, we use the PFCA framework, including USGHR, to review and refine riparian assessment protocols for southern Utah’s BLM lands. We assembled an independent scientific review panel to review the BLM’s PFCA guidelines, and refine them in relation to regional riparian ecosystem characteristics. This panel, which includes all the authors on this paper, analyzed existing PFCA documentation and reports from individual site visits, discussed conceptual and practical issues, and developed a draft refinement of the PFCA checklist. Following that meeting, we conducted site visits in the summers of 2000 and 2001 to eight stream segments in southern Utah to compare previous PFCA evaluations with our own, using the revised checklist. From those site visits, we refined our alternative PFCA checklist, and distributed the first and second draft documents to 19 other, independent experts. We present the conclusions of this review, including the refined PFCA protocols, and discuss the practical use of the new checklist.

The PFCA process represents an important step towards environmentally responsible land management by the BLM. One of our chief goals is to help the BLM realize its goal of assessing, reporting, and achieving properly functioning condition on 75% of the stream and riparian reaches under its jurisdiction in an scientifically quantifiable, repeatable, and efficient fashion. Our goal in this effort is not to try to push the BLM into performing scientifically comprehensive stream and riparian area evaluations on all streams under its care. Rigorous and quantitative methods for

assessing water quality, cover and composition of vegetative communities, and other aspects of stream and riparian health are available and the BLM is well aware of these approaches. Rather, our goal is to work with the agency to improve the rigor and scientific credibility of its rapid assessment technique in a fashion that complies with SGHR, thus serving to enhance sustainability of the region's most productive and biologically diverse landscapes.

## **GENERAL COMMENTS ON THE EXISTING BLM PFCA APPROACH**

### **Assumptions and Constraints**

Our PFCA review panel concurred that evaluation of riparian ecosystem health is intimately related to both stream and upland ecosystem conditions (Gregory et al. 1991, Malanson 1993). Complex interactions among flow, water quality, flood disturbance, sediment dynamics, and the ecological status of upland conditions affect the composition and trajectory of riparian ecosystem development and health. Therefore, achieving proper functioning condition (PFC) of riparian zones is impossible when streams and uplands are in poor condition. In this review we emphasize the importance of assessing aquatic conditions and processes as well as those in the riparian zone, and include consideration of the upstream basin. The condition of the associated uplands is considered here, but is primarily evaluated through the USGHR. Our review of the existing PFCA process was guided by four chief assumptions/constraints,

**1. *A Comprehensive River Concept:*** This concept is that a stream ecosystem includes not only channel and moving water, but also lower and upper floodplains and their associated flora and fauna.

**2. *Utility of Rapid Assessment Protocols:*** Although brief site visits are unlikely to accurately portray the causes of site conditions, particularly in typically complex riparian ecosystems (such cause and effect relationships are best developed through detailed studies), valuable information on ecological conditions can be obtained through a relatively brief site visit, and sites can be examined in greater detail if ecological conditions are judged to be unacceptable.

**3. *Efficiency:*** A PFCA process should be designed to accomplish the BLM's stated objectives in a manner that is scientific but easy to understand, easy to replicate, and easy to interpret in relation to the guiding documents, especially the USGHR. Therefore, we sought to clarify and specify the information needs for the PFCA process, and we streamlined this more refined approach as much as possible.

**4. *Geomorphic Consistency:*** Geomorphic characteristics vary dramatically between reaches in a drainage, and between streams in a region. Common differences involve whether the channel is sand- or gravel/cobble-floored, and whether the channel is geomorphically constrained or alluvial. Therefore, results of PFCA need to be considered in light of geomorphic consistency. The present PFCA protocol uses the phrase "in balance with the landscape," a concept that is likely to be understood differently by the

public, government technicians and the scientific community, and is a concept that is difficult to assess without quantitative measurements. This phrase over-emphasizes stream channel equilibrium, which may not be apparent immediately following large floods. Therefore, we prefer the phrase “geomorphically consistent,” which incorporates the effects of antecedent conditions, and applies not only to abiotic site characteristics, but also to habitat and biological characteristics. Application of this concept in site evaluations requires considerable expertise, and may strongly influence site evaluations. Increased information from reference sites will greatly improve the application of this concept to site evaluations.

### **Scientific Credibility of the PFCA Process**

We urge the BLM to consider PFCA as a scientific ecosystem analysis process, one using thoroughly trained and consistent observers who make detailed and, where possible, quantitative, field observations and measurements, and who compare their results against similar measurements made at control (reference) sites. Previous studies have identified large differences among observers engaged in rangelands assessment. For example, Rasmussen et al. (1999) analyzed the results of a rangelands assessment training course for range technicians, other BLM staff, experienced ranchers, and environmentalists. Although relatively good agreement between the training team and either individuals or interdisciplinary teams was achieved on evaluations of physical and biological conditions on properly functioning and non-functioning sites, Rasmussen et al. (1999) reported poor correspondence for evaluation of the functioning-at-risk status between individuals, interdisciplinary teams, and the BLM’s professional uplands PFCA team. This indicates the potential for inter-observer error in site evaluation, and the need for unbiased, consistent assessment.

The preferred composition, level of expertise, and independence of PFCA teams is not clearly described in the existing documentation. Extensive familiarity with site history and local flora are extremely helpful but may not, by themselves, be sufficient for such evaluations. Additional skills, including a detailed understanding of geomorphology, water quality, ecosystem processes, temporal and spatial scale dynamics, and sensitive species biology are needed, and familiarity with reference site conditions and the range of natural variability are also required.

Three options exist for the BLM to improve the scientific credibility of PFCA. The first and most scientifically credible option involves development of a competitively bid contract to a small, efficient PFCA team from the region’s universities and private sector consultants. This expert team should include at least a geomorphologist, an aquatic ecologist, a riparian ecologist, and a data manager. The team should operate at a ecoregional or state level, and should be trained at reference sites. In addition to greatly improving overall scientific credibility, this approach will enhance the consistency, thoroughness, and cost effectiveness of the assessment. This team would identify problems or anomalies that may have a direct bearing on local management, and would provide the BLM with quality-controlled data, which should be prepared for peer-reviewed scientific publication. This team should have full access to district and state staff for information on climate, stream flow, and land use history. This team should be able to conduct a large number of site visits annually (perhaps >100/yr), and over several

years include all sites in the ecoregion or state level. It is assumed that such a team would publish their results in a scientifically peer-reviewed journal.

Alternatively, if the BLM regional office cannot fund such scientifically rigorous assessment, the next most appropriate approach would be to develop a well-trained state-level assessment team composed of agency staff. To its credit, the BLM has developed a highly qualified national PFCA training team; however, we recommend that a similarly qualified, highly efficient state level team should be assembled. Again, this team should consist of at least three field experts and a data manager. This BLM team should be trained at reference sites and should have an efficiency equivalent to that of the independent team described above. Protocol evaluation and reporting should be subject to scientific peer-review, and the team's findings should be prepared for publication in a peer-reviewed scientific journal.

The third alternative involves the use of district office staff to conduct riparian assessments. The present riparian PFCA approach endorses additional staff training. We recommend that this team be trained at reference sites and their PFCA results should be reviewed by qualified independent experts to enhance scientific credibility. Similarly, their results should be presented to the public through the peer-reviewed scientific literature.

### **PFCA for Monitoring**

A single site visit can be used to qualitatively judge the present condition of a site, but cannot provide reliable information on longer-term trends in ecological health. Stream and riparian systems exist in a state of dynamic equilibrium (the "perpetual succession" of Campbell and Green 1968), with serial interactive recovery from past floods of different magnitude occurring on various levels. Detection of riparian ecosystem trends due to management actions is complicated by variability in the rate of change on different terraces (an effect partially related to varying productivity and disturbance intensity). Repeated site visits using the same methodology (the definition of monitoring) and sound data management are required to establish trends in ecosystem condition. Monitoring considerations are not presently represented in the present PFCA approach.

The objective of PFCA to provide trend data is better met if the BLM considers this process in the context of a long-term monitoring approach, one requiring the efficient, repeatable acquisition of information, effective compilation and management of site visit and background information on site history, and interpretation of that information in the context of ecological change. PFCA was not originally designed as a monitoring approach, but to trigger monitoring activity. Therefore, given limited personnel, funding and time, PFCA site visits may be the only evaluations a reach receives. Therefore, we recommend that the BLM consider the use of a more rigorous PFCA as a simplified long-term monitoring approach, a shift that elevates the importance of consistent data collection and statistical interpretation. A single paired comparison by two different teams several years apart cannot serve as a decision to adjust management; however, a change in trend in PFCA scores (of a magnitude to be determined when sufficient site data have been interpreted against reference conditions) should trigger more detailed investigations. This shift will require additional PFCA team training, calibration through paired evaluations of reference sites and analysis of inter-team scoring

variability (which we expect to be high), and additional statistical analysis of the scoring process, particularly weighting.

### **PFCA for Education**

The BLM's PFCA was also designed as an educational tool to communicate to grazing permittees on the health of their riparian lands. Federal education of concessionaires is a difficult task because, although permittees may have intensive, long-term knowledge of some aspects of their resources, they are likely to be biased towards some resources and against others, and because they may have little appreciation for regional issues. The attempt to use of PFC for both site assessment and education unfairly couples these elements, simplifying assessment at the expense of interpretation. We suggest that the BLM and other agencies using PFCA consider decoupling these two objectives, thereby keeping the site information collection robust, and presenting users with interpreted results to discuss the management issues with the permittees. Of course, all data should be kept fully available to the permittees, but the use of personal contact and in-depth understanding of the site issues may better facilitate user education.

## **ELEMENTS MISSING FROM THE EXISTING PFCA**

### **Synoptic Analyses**

Several overview analyses are needed to improve interpretation of site conditions, especially where local site history and streamflow data are not available. These overview analyses should be conducted by independent researchers where possible, to improve scientific credibility and limit interpretational biases, and studies should be in sufficient detail to provide specific information to district offices about specific reaches and associated upland conditions. These synoptic analyses should be readily available to agency staff and the public. We identified at least four synoptic analyses needed for effective PFCA.

1) Management is most effective when it is focused on well-defined, achievable goals. In the case of riparian habitat management, assessment of ecosystem condition requires comparison against the standard of reference (control) sites; however, an array of such reference sites in which to train a PFCA team has not been designated in the Southwest. Riparian habitats considered suitable as ecological reference sites should be located, described in detail, and analyzed through PFCA to provide controls against which treated sites can be evaluated. Reference sites should have close to natural conditions, and must be as free as possible from anthropogenic disturbance, especially livestock grazing, water diversion, and ground water pumping. Reference sites should be selected across a wide elevational gradient and in different stream types. Reference sites also will be useful for understanding the range of natural ecological variability in the Colorado Plateau, and for training PFCA teams. The data collected from these sites should be used to develop a regional model of stream and riparian habitat structure and characteristics. Reference sites are generally rare in southern Utah, but exist in national parks, wilderness areas, and other remote landscapes. For example, several hundred virtually pristine tributaries of the

Colorado River exist in Grand Canyon just to the south, and others occur in Zion National Park and in the region's several other national parks, recreation areas, and wilderness areas. Identification and measurement of conditions in reference sites will require cooperation among land managing agencies, and this interaction will clarify landscape management goals across agency boundaries. If a sufficiently large array of reference sites cannot be identified, a series of sites considered to be of sufficient ecological integrity should be selected by an independent panel of experts. Without such an analysis of reference areas the PFCA process is unlikely to succeed. Therefore, we strongly recommend that the reference sites be developed to evaluate scientific and management biases, train PFCA teams, and serve as controls against which treated sites can be judged.

2) Antecedent disturbances and site history play a large role in the present condition of any ecosystem (e.g., White 1979). Therefore, it is appropriate to acquire baseline data and site history data. An analysis of the history and trends of land use is needed to understand the extent, duration and possible future changes in land use over time. This analysis should include land use history, economic resources distribution, demographic and economic trends, livestock stocking rates and seasons-of-use, and the distribution and history of road construction. In addition, it should specify the agency management objectives for all lands, and how different management plans inter-relate.

3) Fluvial geomorphology and flow history are the most important drivers of riparian ecosystem development. Because riparian ecosystem characteristics and dynamics vary between stream types, and because adequate stream classification systems exist (i.e., Rosgen 1996), a synopsis of existing stream types and their flow histories can be compiled. The climate and flow history of the region and of specific watersheds should be described for the period of record to identify major flooding and drawdown events (e.g., Moody et al. 1998), sediment history, water quality changes, and the history (if any) of flow regulation. Dimensionless flow duration curve and flood frequency analyses are useful for interpretation of baseflow changes and the frequency and timing of high flows. Ancillary information on ground water supplies, well data, ground and surface water quality, soils, and other physical factors should be included in this overview.

4) A regional riparian biological synthesis is needed to describe ecosystem distribution (as floristic assemblages) and the distribution and habitat requirements of fish and wildlife, especially the sensitive, endemic species, and non-native species. This will clarify which species are known or suspected to exist in the region, as well as trends in populations of sensitive species. For example, fisheries and aquatic habitat data may be available from past BLM surveys, basin surveys of instream habitat, reconnaissance traverse (headwater to mouth, or reach specific), U.S. Fish and Wildlife Service instream flow habitat analysis (PHABSIM, and/or IFIM), State habitat and fish surveys, or other habitat surveys. Biotic Condition Index (BCI) scores may also be available to assess stream health in relation to macroinvertebrate numbers, biomass, taxa, and diversity. Also, any endangered species surveys or research data from the region should be compiled.

Background site data (Appendix A) and the above syntheses are required for effective PFCA, and also provide essential insight into present physical and biological conditions, processes, and ecosystem response times. These data and reports should be archived in the information management system to facilitate data review, trend analysis interpretation, and subsequent monitoring and management activities.

### **Data Management and Interpretation**

The present PFCA process does not clearly define data management and archival protocols, issues that are central to the credibility of PFCA. Interpretation of regional patterns and scientific defensibility of management decisions requires ease of access to historical as well as recent data. Background data (including synoptic analyses) need to be reviewed by the PFCA team prior to site visits, if possible, but the PFCA results to which our panel had access revealed little consideration of historical data. In addition, it was apparent that there had been little effort to review the voluminous existing available data to understand local and regional patterns. Historical and site visit data management protocols should be clarified at the local, state and national levels by the BLM, and we strongly recommend that the BLM consider and implement a sound data management strategy for its PFCA data. In all of the above PFCA team options, the data collected should be electronically compiled and managed for ease of review and comparison with future site visits. Those data should be made available on-line to the public in a national database and in accord with federal information standards.

The existing PFCA manual describes site specific geomorphic measurements that can be used to calculate changes in streamflow and sediment transport (U.S. Department of the Interior 1998); however, there appears to be little linkage between the measurement of these geomorphic variables and the application of those data to PFC checklist questions 3-5, 11, 13, and 15-17. This lack of clarification may limit the ability of the PFCA team geomorphologist to score those questions. Such measurements are time intensive and require at least meander length measurement and leveling surveys, data which should be collected with appropriate georeferencing and repeatability, and which should become monitoring information.

### **Spatial Scales**

The spatial scale of PFCA outlined in existing PFCA manuals requires clarification, and depends on the extent to which the channel is geologically constrained. Riparian ecosystems function at a variety of spatial scales, including microsite, local, reach, whole basin, and coarser scales, often with considerable variation in structure, productivity, composition, and the degree to which key processes operate within each scale (Day et al. 1988, Weins 1989, Stevens et al. 1995). Therefore, the reach under consideration must be viewed over a significant length of channel. In alluvial channels, we recommend that three meander lengths be used as a standard reach length, and that a 200 m-long representative transect be selected by the team on which to make additional specific riparian measurements. In strongly geologically constrained, or highly uniform, channels, a 1.0 km-long segment of channel reach should be considered, again with a 200 m-long representative transect. This spatial scale should help guarantee that riparian

ecosystem conditions are scaled appropriately to agency goals, and should limit the duration of site assessment.

### **Physical, Habitat and Biological Components**

Several physical and habitat components of ecosystem health are relevant to PFCA, but are not included in the current BLM protocols, including water quality and stream health, species of concern (including endangered, indicator and exotic taxa), wildlife habitat assessment, and direct human impacts. Importantly, many of these omitted components relate directly to the USGHR. Thus, under the current BLM PFCA procedure, a study reach could be described as functioning properly, but may still be out of compliance with USGHR.

***Water Quality:*** The BLM's present PFCA does not include water quality indicators, even though water quality is one of the four standards with which the BLM is required to comply. Evaluation of water clarity, algal growth, the distribution of very fine sediments, and a rapid assessment of the stream invertebrate assemblage are all readily performed, and provide a qualitative assessment of water quality and stream health. The EPA has developed rigorous water quality metrics and rapid assessment protocols for evaluating stream degradation (U.S. Environmental Protection Agency 1991). Professional stream ecologists conducting stream studies routinely measure water temperature, pH, specific conductance and dissolved oxygen concentration, and those variables should be measured with every site visit. More detailed water chemistry should be measured basin-wide on a 5-10 basis, as part of a large, hydrogeochemical synthesis (above), rather than individual PFCS visits.

***Fish and Wildlife Habitat:*** The present PFCA protocols do not include aquatic and terrestrial fish and wildlife habitat quality evaluation. Important aquatic habitat parameters include channel embeddedness, particle size distribution, cover distribution, and pool depth and distribution. Important riparian habitat variables include: the diversity of vegetation structure, habitat heterogeneity, and riparian habitat connectivity. Regarding this latter issue, the USGHR states that habitats need to be connected at a level to enhance species survival.

***Wildlife:*** Wildlife species provide insight into riparian ecosystem health and should be noted during the site visit; however, PFCA should not be considered as a definitive statement on wildlife distribution. That information should be compiled in a separate wildlife synthesis (above) or through specific wildlife studies. Observations by the PFCA team biologist may add to that information base, but site visits are unlikely to reveal much about the species present. Background knowledge on the presence of various invertebrate, fish, herpetofauna, bird, and other wildlife species in a reach will substantially improve interpretation of the site's ecological condition.

***Non-native Species:*** Another critical missing component of the PFCA involves the distribution and roles of non-native species in the study area. Non-native species, particularly non-native plants, fish, and fish parasites, threaten the integrity of many

ecosystems by altering composition and ecosystem functioning, and by reducing habitat availability (Mack et al. 2000, Tellman *in press*). The region's non-native plant species are relatively well known (Welsh et al. 1987, Whitson et al. 1991) and can be readily identified during the site visit. The biological synthesis should be based, in part, on aquatic invertebrate sampling (if those data exist), and should reveal the distribution of non-native fish, which are usually well known (Sigler and Miller 1963, and subsequent works). The synoptic analyses proposed above should indicate which non-native species are colonizing the region, what impact such species may have on habitat structure and ecosystem processes, and what species are expected in the future.

***Mammalian Herbivory Impacts:*** The impacts of mammalian herbivore grazing and trampling on riparian vegetation and stream banks are likewise largely absent from the current PFCA methods. The primary herbivores include livestock, but cervids and beaver also may strongly influence vegetation and habitat structure. For the USGHR to be effective, it is necessary that the BLM identifies when livestock grazing is deemed responsible for riparian degradation, as opposed to other vertebrate herbivores. It is not clear how the BLM can make this determination if the PFCA protocol does not require evaluation of the extent of streambank trampling or consideration of livestock soil and browsing damage.

***Anthropogenic Impacts:*** Lastly, observations of other direct human impacts should be included in the PFCA, including: flow regulation and channel modification; site management for campgrounds, parking lots, or development; road impacts; and non-native species introductions. Without noting these impacts, evaluation of how site conditions match agency management goals is difficult. Care must be taken to avoid biases related to access, as most survey team access is via roadways.

### **Scoring BLM's PFCA Results**

A significant problem with the present PFCA involves scoring of checklist items and how the individual "scores" translate into a final rating of Properly Functioning Condition (PFC), Functioning-at-Risk (FAR), or Non-Functioning (NF). The present checklist items are answered with either a "yes," or a "no," without quantitative reference to conditions. The PFC technical manuals provide limited instruction to field staff on how to answer difficult checklist items, and leave much room for subjective judgment. The linkage between indicator conditions and the final rating is not described clearly, and the technical manuals provide insufficient guidance on how to use "yes" and "no" answers with other information to establish a final rating. This may preclude independent verification of PFCA ratings. Furthermore, under the current PFCA procedure, a reach can be defined as functioning properly, but be out of compliance with USGHR, as discussed above.

## **REVISION OF THE PFCA CHECKLIST: A PROPOSAL FOR REFINEMENT**

### **Checklist Design and Review**

We refined the BLM's PFCA field checklist with the above issues in mind (Appendix B, and Appendix C with Scoring Definitions and field instructions). This checklist was primarily designed for use in lower elevation constrained and semi-alluvial riparian habitats that typify federal land management units on the southern Colorado Plateau. It ideally involves comparison with an as yet undesignated group of reference areas.<sup>1</sup> We have sufficient experience in a wide array of stream ecosystems to recognize the large range of natural variation in ecosystem characteristics and processes. Nonetheless, a top priority for the land managing agencies should be to develop and study the ecological patterns that characterize reference sites in different geomorphic settings. A cornerstone of our revised checklist is the concept of *geomorphic consistency* - that some of the ecological patterns described vary in a natural fashion, and may not be attributable to human activities.

The use of reference areas is essential to understanding this concept and the range of natural variability. If a reference site and comparison site have the same VDW, VBG and DA, then the stream channels and vegetative components should also be similar (personal communication, P. Bengeyfield). If reference areas do not exist in the region, that does not necessarily mean that the user cannot use our approach. The managers have to fall back on expertise and experience in healthy systems.

Our alternative PFCA system should work reasonably well throughout the lower and middle elevations (< 1800 m) on the southern Colorado Plateau, including southern Utah, southwestern Colorado, northern New Mexico and northern Arizona. Further refinement of the proposed methods is needed to improve quantification of conditions and variability in reference areas, adjustment for stream type, geomorphic variation, and basin size. Many of the issues we address are relevant in a wide array of biomes and, with modification, this alternative protocol should be applicable to higher elevation riparian settings on the Colorado Plateau, and low elevation settings in other biomes. The methods proposed here will require substantial revision in more mesic landscapes, such as the Pacific Northwest..

While both the old and revised PFCA checklists remain primarily qualitative in scoring, our revised checklist uses a 1-5 point system for describing the level of functionality for each checklist item. This approach is the numerical equivalent of the new BLM upland rangeland health evaluation system (*Indicators of Rangeland Health*, Pellant et al. 2000), and allows for more refined discrimination by the observers. A study reach can only receive an overall PFC rating if the average score of all the checklist items is sufficiently high to achieve a cumulative assessment rating that qualifies as PFCA. This requires careful scrutiny of each Checklist item. Each checklist item is used to compute a component average and an overall final assessment rating. Individual scores represent an interpretable value along the gradient of that component's ecological integrity. This allows for specificity and more objectivity in determining the final PFCA rating.

This revised PFCA checklist (Appendix B) and the accompanying Scoring Sheet

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<sup>1</sup> although our alternate PFC checklist can be used by experts with sufficient experience in the region to understand what reference baseline conditions should be for a given reach in the absence of an available reference area.

and description of its use (Appendix C) was reviewed by 19 of our scientific peers. These reviewers are well-known experts in their fields, have experience in the West, and represent a range of disciplines including hydrology, fluvial geomorphology, desert fish ecology, riparian ecology, wildlife biology, botany, and range management. They represent institutions ranging from universities, the U.S. Forest Service, the U.S. Geological Survey Biological Resources Division, private consulting firms, the Natural Resource Conservation Service, and the BLM.

### **Site Visits**

The PFCA team should visit the field study site between late spring and early fall, when vegetation is fully developed and when surface flow continuity is most critical. This will provide data on the most stressful time for the aquatic and riparian domains. The PFCA team should first walk the entire study reach together, at which time some information is collected for the site rating. The study reach should be approximately three meander lengths or at least 0.5 km long, and a suitably representative 200 m-long transect along the stream's length should be established along which to conduct more detailed measurements. For aquatic analyses, the transect will involve the channel where it can be waded safely. For riparian vegetation variables, a lower and upper riparian zone (see below) belt transect should be selected on one side of the stream. All locations (start and end points of the study reach and the transect, observation points, photo points, etc.) should be georeferenced with a GPS unit. Site photographs should be taken at least at the upstream end of the transect looking downstream, and the downstream end of the transect looking upstream. Photographs should be taken from marked, easy-to-relocate physical features and should include the configuration of geologic features or the horizon.

The various checklist indicators (Appendices B and C) are recorded in the field, and additional comments should be made on the data sheet to assist in interpretation of results. An on-site debriefing is recommended to allow the team members to coordinate their evaluation and recommendations. Each team member should fill out his/her expert section of the checklist in relation to existing conditions, not potential conditions. We found that, with adequate training and experience with the revised PFCA protocol, a team of three individuals can complete the assessment in <3 hr. Study sites that include multiple stream types should be evaluated separately. The reach also may be subdivided and separately assessed on the basis of vegetative communities (preferably expressed in relation to the National Vegetation Classification Standards (The Nature Conservancy 2001), geologic strata, or other appropriate classifications.

We reiterate the caveat that this revised checklist must be viewed in the context of the geomorphic setting and by observers who are thoroughly familiar with reference reaches in the region. Many constrained (bedrock and talus slope-dominated) channels in the Southwest support little to no riparian habitat, while alluvial reaches that are not much affected by human activities (e.g., in national parks and other protected landscapes) display considerable temporal variation in riparian characteristics, depending on the time since the last major flood. Without recognizing these issues, a PFCA team could conclude that even fully natural riparian habitats are dysfunctional. Again, this highlights the need to develop a network of reference sites to serve as management controls, and to use those

sites to develop expertise and consistency within the PFCA team for successful application of PFCA.

### Scoring Definitions

The scoring definitions for the PFCA Scoring Sheet (Appendix B) are defined in a narrative (Appendix C). Each item on the checklist receives a score between 1 and 5, if applicable (otherwise “n/a,” or “unknown,”), based on conditions at the time of the assessment. Given the large range of natural variability inherent in southwestern riparian systems, we strongly disagree that the PFCA team can judge a site’s “potential”, defined by the BLM as “the highest ecological status a riparian-wetland area can attain given no political, social, or economical constraints” (U.S. Department of the Interior 1998).

At the end of the checklist is a trends section to determine change over time for study reaches that have received multiple PFCA’s using these methods. An observer can only assign a trend value to the various checklist categories if the reach has received at least one previous PFCA.

### PFCA Analysis

Two analyses of these scores should be conducted collaboratively by the PFCA team and the data manager(s). In the first, all scores in each section (Water Quality, Hydrology/Geomorphology, etc.) are averaged (excluding non/applicable = “n/a” and unknown = “unk” designations) to achieve a mean score for that section. All section mean scores, excluding the human impacts section, are averaged to receive a final PFCA score for the entire checklist. In general, an over-all score of 1 or 2 is likely to indicate a Non-Functioning (NF) condition, a score of about 3 likely indicates a Functioning-at-Risk (FAR) condition, and a score of 4 or 5 likely indicates PFC. Rigorous statistical analysis of the data obtained over a several-year period under the revised protocol will be warranted to evaluate the applicability of the use of mean scores, as opposed to other statistics.

The second data analysis involves calculation of the mean percent deviation of a study site from the empirical or modeled reference condition. Until further data are available to refine this approach, we recommend that this value simply be calculated as:

$$S_c = \left( \sum_{i=1}^n 100 * ((S_{iR} - S_{ij}) / S_{iR}) \right) / n$$

where the relative mean category score ( $S_c$ ) is the mean of the percent differences between the individual indicator score ( $S_{ij}$ ) for each of the  $n$  individual PFCA variables ( $i$ ) at a given site ( $j$ ), in relation to the mean score for that variable at comparable reference sites ( $S_{iR}$ ). Individual scores ( $S_{ij}$ ), category scores ( $S_c$ ; i.e., the wildlife habitat score), and grand mean site scores can be compared with reference condition scores at each assessment scale. Until sufficient data are available for statistical comparison, it seems reasonable to determine the relative mean PFCA score as: >80% = PFC, 70-80% = FAR, and <70% = NF.

Although a single composite site score is desirable for judging site health, we and the other reviewers were hesitant to recommend that a grand mean of mean category scores decisively represents the final interpretation of site status. For example, a stream

reach may be biologically degraded, but functioning well from a physical and hydrological perspective. Alternatively, a reach's streamflow may be highly altered but the ecosystem might appear otherwise healthy. Averaging all scores in these cases could result in an intermediate value for the study reach when it is actually dysfunctional. To some extent, this effect is buffered because the rating system is somewhat weighted towards biological variables; however, interpretation of site conditions should involve a comparison of the final scores against the individual section scores to improve understanding of ecological function.

## **JUSTIFICATION OF REVISED PFCA VARIABLES**

The following text describes and justifies the various PFCA variables to be documented from the site visit.

### **Water Quality (WQ)**

**WQ Qualifier. Flow:** The extent of natural surface flow is the single most important factor affecting riparian ecosystems, and has been altered in many southwestern streams. Two issues of concern are: a) the extent of flow alteration, including magnitude, duration, frequency, ramping rate and seasonal timing of low and high flows; and 2) the distribution of flow within the reach. The present river management/restoration paradigm contends that relatively natural flows are required to support natural geomorphology and biotic assemblages (Poff et al. 1997). Understanding basin-wide impacts of flow regulation cannot be accomplished through a single visit, but involves a detailed hydrography analysis. Field observations can help confirm the perenniality or lack of flow. Fully natural flows may be contrary to management criteria for some ecosystem components and processes, resulting in the proliferation of non-native fish (e.g., carp and catfish) and plants (e.g., tamarisk and Russian olive; Stevens 1989, Stevens et al. 2001).

Non-perennial streams obviate concerns over some water quality, hydrology, and habitat issues; however, many intermittent streams contain more-or-less permanent pools that can support invertebrates and fish, and subsurface flow that may support extensive phreatophytic vegetation. Even ephemeral streams may contain subsurface flow that supports phreatophytic vegetation, and may be evaluated for riparian PFC as well.

**WQ 1. Algal Growth:** Dense algal growth in streams is often recognized as an undesirable feature, and as an indicator of ecological stability and nutrient enrichment. Algal growth may influence water quality by changing dissolved oxygen and nutrient dynamics, as well as invertebrate assemblage dynamics (Kirk 1983, Stevens et al. 1997b).

**WQ2. Turbidity.** Water clarity is influenced by organic and inorganic material suspended in dissolved loads, and is a strong driving factor in aquatic production and stream bacteria loading (Kirk 1983). Increased fine sediment concentrations in small streams can result from increased erosion, which may be augmented by livestock grazing, trampling, and watering.

**WQ 3. Shading.** Solar exposure plays a substantial role in stream productivity and thermal characteristics (Vannote et al. 1980). Decreased streambank vegetation cover, increased channel width, and reduced stream depth may increase solar exposure and water temperature. In contrast, dense overstory vegetation may negatively affect autochthonous stream productivity by shading. In both cases, the alteration of stream ecosystem productivity may affect benthos and fish density and distribution.

### **Hydrology/Geomorphology (HG)**

Channel and stream geomorphology strongly affect fish and riparian habitat availability, integrity and function, and numerous measurements have been devised, including stream width, water velocity, depth, flow variability, meander ratios, channel gradient, floodplain width, substrata, and these measurements have been incorporated into instream flow and channel characteristics (e.g., Richards 1987, Stromberg 1993, Rosgen 1996, Jowett 1997 and references therein). Measures of stream gradient, valley bottom width, cross-sections and meander ratios have been successfully used to evaluate channel condition and determine stream type (Bengeyfield and Svoboda 1998, Bengeyfield 1999); however, Jowett (1997) cautions that the risk of environmental degradation is likely to be higher in small streams, and therefore stream size should be an important consideration in stream function. With these issues in mind, and with the hydrographic synthesis proposed above, we selected geomorphic variables to measure that have demonstrated utility in classifying stream types and helping ascertain channel conditions.

**HG Qualifier:** If the stream historically was perennial, and has been dewatered, many hydrological and geomorphic processes are altered, and the system should be regarded as dysfunctional.

**HG 1. Sinuosity:** Channel configuration is affected by gradient, discharge and sediment transport interactions, and may become altered by flow regulation, vegetation colonization and direct human manipulations (Leopold 1994). Alluvial channels that are anomalously straight may indicate reduced flows or other anthropogenic modifications of the flow regime.

**HG 2. Flow Regime:** Historic streamflow gauging data is commonly used to interpret basic stream ecosystem characteristics, such as flood and low flow return frequency, and change over time in relation to climate and human impacts. Modification of flows by more than about 30% is likely to influence riparian community structure, either increasing or decreasing riparian vegetation cover and composition in the lower riparian zone (Stevens et al. 1995).

**HG 3. Floodplain Inundation:** Lack of overbank flooding, or flooding at unusual times of the year, reduces nutrient availability, germination of native phreatophytes, growth and survivorship of established plants, and may alter plant species composition and wildlife habitat quality.

***HG 4. Sediment Deposition:*** Fine sediment cover on the stream floor can reduce benthic primary and secondary production standing mass and negatively affect fish spawning. Such sediment cover may result from bank erosion, devegetation and erosion of the uplands, and/or upstream channel modification. However, fine sediment deposition is to be expected in southwestern streams, and the evaluation here should be based on the geomorphic consistency of that deposition.

***HG 5a. Vertical Channel Bank Stability:*** Oversteepened or vertical cutbanks dominate many stream channels in the Southwest. Steep cutbanks limit the physical dynamics of aquatic ecosystem development, prevent overbank flooding, and lower water tables, which in turn can fail to support riparian vegetation. Additionally, overly steep banks can limit wildlife access to water.

***HG 5b. Lateral Channel Stability:*** Healthy alluvial rivers are dynamic and lateral bank stability is expected to vary along the channel; however, livestock trampling, devegetation, human recreational use, roadways, and other forms of anthropogenic disruption may create geomorphically inconsistent levels of channel stability, widening or narrowing channels. Geomorphically inconsistent lateral instability is likely to alter erosion rates.

***HG 6. Hydraulic Habitat Diversity:*** Fish diversity and population health is commonly related to habitat diversity. Ecologically healthy southwestern alluvial streams contain a wide array of habitat types that are important for fish, including variably stable terraces, runs, pools, cobble or boulder debris fans, oxbows and other off-river side channels, backwaters, sand-floored runs, and other geomorphic features.

***HG 7. Soil Integrity:*** Riparian soils reflect existing flow dynamics, management, and vegetation, and affect potential vegetation dynamics and wildlife habitat distribution and quality. Surface soils in riparian zones vary substantially, from poorly developed, highly disturbed entisols along stream banks to well developed mollisols, usually on less-frequently flooded terraces (Brock 1985). Depending on the extent of natural and altered flood frequency, mammalian impacts, and human disturbance, surface soils vary considerably in their integrity, making soils assessment an important component of ecosystem assessment.

***HG 8. Beaver Activity:*** Beavers are unquestionably keystone species because they modify geomorphology, hydraulic and fish habitat distribution, and riparian vegetation; however, their distribution is not universal, and their impacts in flood-prone streams and geologically constrained streams may be minimal on the Colorado Plateau.

### **Fish/Aquatic Habitat**

***F/AH Qualifier:*** If the stream historically was perennial, and has been dewatered, most of its value as fish and aquatic habitat will be lost, and the system should be regarded as dysfunctional.

***F/AH 1. Pool Distribution.*** The number, size, distribution, and quality of pools, as well as their relationship to riffles in a stream, are indicators of fish habitat quality. A geomorphically consistent distribution of pools to riffles is generally thought to maximize habitat diversity, and in some settings a 1:1 ratio of pools to riffles is used as an index of good fish habitat condition. Pools generally occupy a portion of a stream with reduced current velocity, with water depth usually deeper than the surrounding areas, and are frequently used by fish for resting, feeding, and cover (U.S. Department of Agriculture 1985, USDA-NPNF 1991).

***F/AH 2a. Underbank Cover:*** Adequate, geomorphically consistent underbank cover is associated with good fish habitat for resting and protection from predators. This cover is usually indicated with vigorous vegetative growth, dense root masses, and stable soil conditions. These circumstances are usually associated with low gradient, meandering stream reaches rather than those of higher gradient and rockier streambank condition (U.S. Department of Agriculture 1985, Lloyd 1987).

***F/AH 2b. Overbank Cover:*** Geomorphically consistent overhanging terrestrial vegetation can be an important cover component, provides bank protection from high flows, helps filter sediment, provides an important source of energy and insect input into the stream channel, and is associated with good fish habitat for resting and protection from predators. This cover condition provides an essential and needed habitat component for fish production and survival (U.S. Department of Agriculture 1985, 1992; Lloyd 1987).

***F/AH 2c. Shading:*** Solar exposure plays a substantial role in stream productivity and thermal characteristics (Vannote et al. 1980). Decreased stream bank vegetation cover, increased channel width, and reduced stream depth may increase solar exposure and water temperature. In contrast, dense overstory vegetation may negatively affect autochthonous stream productivity by shading. In both cases, the alteration of stream ecosystem productivity may affect benthos and fish distribution (USDA 1985).

***F/AH 3. Embeddedness:*** Geomorphically inconsistent embeddedness may limit the productivity of the aquatic ecosystem, especially fish production. The filling of interstitial gravel and boulder spaces with silt, sand and organic material reduces habitat suitability for feeding, cover and spawning (egg to fry survival) by limiting space and macroinvertebrate production. Measures of embeddedness provide an index to aquatic habitat condition and quality (U.S. Department of Agriculture 1985, 1992; Lloyd 1987).

***F/AH 4. Large Woody Debris (LWD):*** The amount, composition, distribution and condition of geomorphically consistent woody materials in the channel and on the streambank may provide important fish habitat for nursery cover, feeding, cover, and contributes channel stability, nutrients, and food production that are important to aquatic ecosystem health (USDA 1985, 1992; USDA-NPNF 1991). Interruption of the transport of large woody debris is widely regarded as being an ecologically important habitat impact on regulated streams (i.e., Minckley and Rinne 1985), as it is an important source

of disturbance during floods on smaller southwestern streams, and it may provide nutrient contribution.

***F/AH 5. Benthic Invertebrates:*** The composition and density of geomorphically consistent aquatic invertebrates are strong indicators of stream health. Macroinvertebrate production in a stream can be an important factor for fish food and survival, and is related to natural and anthropogenic events that affect invertebrate habitat quality (USDA 1985, 1992; Stevens et al 1997; Kennedy et al. 2000). Numerous indices have been proposed using benthic invertebrate composition, and these are expressed in a numerical rating, such as the Biotic Condition Index (BCI; Winget and Mangum (1979), or other indices described by Rosenberg and Resh (1996).

***F/AH 6. Terrestrial Invertebrates:*** Geomorphically consistent terrestrial invertebrate production and input (drop) into the stream are an important food source for fish production. The amount of overhead terrestrial vegetation complexity and canopy associated with or in close proximity to the streambank are important factors contributing to high densities and diversity of insect drop (USDA 1985, 1992).

***F/AH 7a. Native Fish:*** The composition and abundance of the native fish community is a strong indicator of stream PFC (U.S. Department of Agriculture 1996).

***F/AH 7b. Non-native Fish:*** The distribution and abundance of non-native fish species is one of the most important threats to native fish assemblages (Minckley 1991). Non-native species may consume native species, compete for habitat space and food, transmit diseases, and result in the loss of genetic integrity of native species (U.S. Department of Agriculture 1996). In many cases, management activities are focused on non-native species, but their habitat requirements should not be emphasized to the detriment of the native fauna.

***F/AH 8. Habitat for Aquatic Species of Concern:*** Many aquatic species of concern in the western United States depend on healthy stream ecosystems. A primary responsibility of stream ecosystem management is to provide adequate resources and habitat to maintain healthy populations of such species, and to help promote the recovery of those species that have experienced significant declines due to recent human activities. Special management attention is required for federally or state listed threatened or endangered fish on the Colorado Plateau, including: razorback sucker; humpback, Virgin, and bonytail chubs; Colorado pikeminnow; Virgin River spinedace, Colorado river cutthroat trout and other species. The importance of habitat structure is considered to be a primary determinant of a species distribution, and has been widely evaluated, particularly for federally listed species. Habitat complexity is important not only as a representation of the primary productivity and basic food supply within the system, but also to the extent it provides structural complexity for breeding habitat, thermal shading, and protection from predators.

**Riparian Vegetation (RV)**

The composition, zonation, and structural cover of riparian vegetation is of general interest because it provides a diverse array of direct and secondary food resources, cover and breeding habitat for livestock and/or wildlife, as well as providing management criteria. For example, measurement of browse levels, stubble height, forage utilization, and other metrics has been used to evaluate livestock rotation between pastures (Benegyfield and Svoboda 1998). An obvious structural characteristic of riparian vegetation is that it occurs in several belts lying parallel to the channel (Campbell and Green 1968, Nilsson 1984, Johnson 1991), and this zonation is influenced by grain size (Stevens 1989, Stevens et al. 1995) and may be altered by flow regulation or other human impacts (Turner and Karpiscak 1980, Johnson 1991, Stevens et al. 2001). Carothers et al. (1974), Whitmore (1975), Brown and Trossett (1989), and others demonstrated that riparian plant composition strongly affects avifaunal breeding and foraging. The distribution of ground, shrub, middle canopy and upper (gallery) canopy cover have been associated with nesting and migrant bird and other vertebrate distribution (Carothers et al. 1974, Stevens et al. 1977, Brown and Trossett 1989, Stacey 1995).

***RV 1a-h. Native Vegetation Composition:*** Geomorphically consistent native vegetation composition is an important determinant of wildlife habitat use, as well as the ecological integrity of the study reach (Stevens and Ayers in press). After major floods, recovery of Lower Riparian Zone (LRZ) ground and shrub cover and composition requires several years in most riparian systems, and early seral stages are anticipated to exist on point bars and other flood-prone surfaces. While relatively few rare or sensitive wetland and riparian plant species occur along stream channels, many are found in low to middle elevation springs and seeps in this region, where they are a specific management concern.

Riparian corridors often serve as invasion routes for non-native plant species (Stevens and Ayers in press). However, there are indications that systems highly diverse in native species can better withstand such invasions (Pimm 1991). Non-native plant species threaten the ecological integrity of many habitats, and are undesirable because they influence the ecosystem structure, productivity, habitat quality, and ecological function, including fire frequency (Noble 1989, Lonsdale 1999). Furthermore, growing evidence suggests that non-native plant invasions are most likely to occur in the most productive ecosystems (Stohlgren et al. 1999, Stevens and Ayers in press). Excessive diversity and areal cover of non-native species is a common issue for many riparian habitats in the Southwest, and may be altered through appropriately timed management activities (Stevens et al. 2001).

The Upper Riparian Zone (URZ) is the interface between riparian and upland ecosystems. Upland ecosystems may provide source areas for non-native plant species (particularly grasses), or may be influenced by non-native plant species, for example through alteration of the fire frequency regime (Stevens and Ayers in press).

***RV 2a-b. Vegetation Cover:*** Vegetation cover is important in reducing stream energy, especially ground and shrub cover in the LRZ (less so in the URZ, which is more subject to erosion during high magnitude events, during which vegetation will have little influence). Cover of all types is important to invertebrate and wildlife species, particularly

birds (Whitmore 1975, Brown and Trossett 1989). The structure of the cover is differentially important to different components of the fauna, and maximum breeding bird diversity arises in a complex function from canopy, midcanopy habitat composition, structure, food resource availability, and the condition of associated aquatic and upland ecosystems (Carothers et al. 1974, Stacey 1995).

***RV 3. Demography:*** The distribution of size classes of characteristic native dominant species is an important indicator of recruitment success, ecosystem sustainability and wildlife habitat availability. The demographic structure of native sensitive plant species is also a management concern, and should demonstrate population sustainability.

***RV 4a-b. Non-native Plant Cover:*** The extent of cover of non-native plant species is important to understanding the influence of non-native species on the riparian ecosystem. Although total diversity may remain high, strong dominance by non-native phreatophytes or grasses may eliminate key attributes of wildlife habitat quality. A far more complex issue involves increasing use of non-native plant species by native (sometimes including endangered) birds or other fauna (Stevens et al. 2001). Administrative decisions in such cases should reflect both concern for individual taxa and overall ecosystem health.

***RV 5. Large Woody Debris (LWD) Production:*** Large woody debris is important to both aquatic and riparian wildlife (USDA 1985, 1992; Minckley and Rinne 1985; USDA-NPNF 1991; see F/AH 5, above). Interruption of LWD transport is an important habitat impact on regulated streams, and also naturally occurs in some, but not all, geomorphic settings. If the site is capable of, and actively supporting, mid-canopy and gallery forest trees, including cottonwood, tree willows, ash, box elder or conifers, it can contribute to LWD production.

***RV 6a-b. Evidence of Mammalian Herbivory on Ground and Browse Cover:*** Ungulate, lagomorph, rodent and invertebrate herbivores can exert strong impacts on soils, ground cover and general riparian ecosystem condition. Utilization levels greater than 10-15% in riparian zones, especially in Rosgen Type C channels, such as meadows, retard vegetation recovery, and utilization levels of 50% or higher generally precludes recovery of willows and other woody perennial vegetation (Holecheck et al. 1998).

***RV 7. Soil Moisture:*** Soil moisture regimes strongly affect riparian ecosystem productivity and processes, such as germination. Absence or poor health of vegetative cover may be geomorphically consistent in some constrained channels or in naturally ephemeral reaches; however, wetland vegetation, and riparian shrubs, trees and other woody taxa are expected in perennial, alluvial reaches.

***RV 8a-b. Plant Vigor:*** Vigorous perennial plant growth is typical of most riparian ecosystems, where ground water availability is normally suitable. Plant growth may be restricted by dewatering (Stromberg and Patten 1992) or by immersion in reaches with augmented flow (Stevens and Waring 1985).

**Wildlife Habitat (WH)**

A large proportion of the terrestrial wildlife species in the arid regions of the western United States depends on riparian ecosystems at some point of their life cycle, for activities such as feeding, drinking, resting, thermal protection, or reproduction. A primary responsibility of riparian ecosystem management is to provide adequate resources and habitat to maintain healthy wildlife populations, and to help promote the recovery of those species that have experienced significant declines due to recent human activities. Moreover, the USGHR states that wildlife habitats need to be connected at a level to enhance species survival.

**WH 1. Habitat for Terrestrial Sensitive Species:** Special management attention is required for federally or state listed threatened or endangered taxa known to inhabit streams and riparian zones, a list that on the Colorado Plateau includes: Kanab ambersnail (*Oxyloma haydeni kanabensis*, Meretsky et al. *in press*), bald eagle (*Haliaeetus leucocephalus*, Brown et al. 1989), Mexican spotted owl (*Strix occidentalis lucida*, Seamans et al. 1999), southwestern willow flycatcher (*Empidonax trailii extimus* Sogge et al. 1997), northern leopard frogs (*Rana pipiens*, Blomquist and Sredl 2002 and references therein), among others.

The importance of habitat structure is considered to be a primary determinant of a species distribution, and has been widely evaluated, particularly for birds and including federally listed species (e.g., Whitmore 1975, Brown and Trossett 1989, Sogge et al. 1997). The percentage of vegetative cover in different parts of the riparian ecosystem is important not only as a representation of the primary productivity and basic food supply within the system, but also to the extent it provides structural complexity for breeding habitat, thermal shading, and protection from predators.

**WH 2-3. Habitat Patch Density:** Willows, and some other dominant shrubs of riparian ecosystems, reproduce vegetatively as well as by seed. As a result, in undisturbed systems, some riparian shrubs grow in dense patches that provide thermal cover and nesting or breeding habitat for a wide variety of terrestrial wildlife, including many invertebrates, amphibians, reptiles, birds and mammals. Such vegetation, both native and exotic, also often produce food resources that are important to wildlife, and they can play a key role in sediment deposition during periods of over-bank flow. Also, many alluvial reaches of southwestern streams contain a high cover of middle canopy trees. These trees provide key habitat for many insects, as well as nesting and foraging sites for birds and some small mammals.

**WH 4. Canopy Connectivity:** Many natural, dynamic alluvial streams in the Southwest, particularly those with wide flood plains, support large areas of continuous upper canopy overstory. Canopy connectivity provides movement corridors and improved habitat for many invertebrates, herpetofauna, birds and a few (especially large) mammals. They also are important for shading the understory and channel, as well as limiting erosion. Thus, consistent with the geomorphic setting and over a sufficient spatial scale, healthy riparian ecosystems are expected to support some areas of continuously connected canopy. Since

dominant species recruitment is generally episodic, these canopy areas are likely often to be of different ages and structures.

**WH 5. Fluvial Landform and Habitat Diversity.** Because of their dynamic nature, southwestern alluvial streams that are functioning naturally will create a diversity of different fluvial landforms, including terraces, bars, fluvial marshes, as indicated in HG 6 and F/AH 1 and 8 (above). These landforms provide different habitats for different kinds of wildlife. For example, some bird species (e.g., rails and many waterfowl) nest only in wetlands, while others (e.g., kingfishers and some swallows) nest in cutbanks, and some sandpipers nest only on sand or cobble bars (Stacey 1995), while many riparian avifauna require various wetland, shrubland, woodland, or forest canopy structures and combinations. Conversely, in a highly degraded system with erosion and downcutting, there may be only a single fluvial form - steep and relative straight banks without vegetation. Within the context of the geomorphic setting, the reaches with the largest number of fluvial landforms generally will provide the largest number of different habitats for wildlife.

### **Human Impacts (HI)**

The array of human impacts on southwestern stream and riparian ecosystems is enormous and interactive, and the histories of individual stream ecosystems are typically poorly known, making it difficult to distinguish among primary and secondary anthropogenic effects. These impacts include, but are not limited to: alteration of flow, channel geometry, and water quality; intensified grazing; mining; road construction; logging/wood-cutting or burning; chemical treatment, point source and non-point source pollution; introduction of non-native species, including competitors, predators and disease organisms; hunting; extirpation of associated species; urbanization; and interactions between some or many of these impacts. Some insight on the extent of human impacts on southwestern ecosystems has been obtained through rematched photography, including studies by Hastings and Turner (1965), Turner and Karpiscak (1980), Webb et al. (1991), Webb (1996), and others, and other useful information has been compiled through long-term studies and interviews with long-term observers (e.g., Stevens et al. 1997a).

**HI 1. Dewatering.** The most serious human impact on stream ecosystems is dewatering, and western appropriative water rights law makes dewatering an unfortunately commonplace practice. Without water, geomorphic integrity, aquatic and riparian processes, and resources are lost. Dewatering irrevocably places economic values above ecosystem sustainability, a perspective contrary to that of most federal agency mandates.

**HI 2. Upland Watershed.** Upland conditions can have a profound effect on riparian and stream health. One of the most important characteristics of upland zones that can affect hydrology is the amount of vegetative (including cryptobiotic soil) cover. Significant lack of vegetative cover to anchor soils can result in geomorphically inconsistent erosion and increased sediment loading in the stream (Ellison 1960).

**HI 3. Livestock.** The presence of livestock in riparian areas can negatively affect ecosystem integrity. Livestock can reduce water quality, trampling can reduce bank stability and soil quality; grazing can reduce vegetation complexity, diversity, cover and resilience; and the presence of livestock may influence invertebrate and native wildlife distribution (Fleischner 1994). Jones (2000) reviewed the literature on livestock grazing impacts on arid land ecosystems, reporting that 69% of 132 studies reviewed demonstrated significant detrimental effects. She reported that cattle grazing commonly affects soils, litter cover, plant biomass, and rodent diversity.

**HI 4. Development/Other Impacts:** Riparian areas always have been the focus of human activities. Numerous construction activities in riparian areas affect ecosystem integrity. Campgrounds, parking lots, trail and road construction, fencing and pastures, agricultural development (with attendant fertilizer and pesticide residues), mining activities, building construction, and urbanization may have lasting impacts on stream and riparian systems. Some structures, such as bridges and dams, may block high flows or debris from moving naturally through the flood plain. Improperly placed structures can also trigger erosion due to scour around the base of the structure. Restoration activities may solve some of these problems, but restoration is likely to require extended time periods.

**HI 5. Geomorphic Change.** Anthropogenic activities, such as channelization, dams, and ground water extraction, may directly alter stream geomorphology. Stream channels may adjust to these impacts, and this adjustment may greatly affect the physical and biotic ecosystem properties.

**HI 6a-b. Road Impacts:** Roads can severely affect the integrity of stream channels, and aquatic and riparian ecosystems. Roads are commonly constructed on floodplains, and result in channelization. Heavily used roads usually lead to accelerated erosion and associated diminished water quality when they are placed along streams and near riparian areas (Froehlich 1978, Burroughs and King 1989). Roads serve as invasion routes for non-native species, and can interrupt or eliminate wildlife movement (Forman and Alexander 1998). Roads vary in size and use level, from rarely used two-rut tracks to freeways.

### **Trend Analyses**

Trend data for each of the above categories can only be developed through comparison with previously collected data. Interpretation of monitoring data requires statistical analyses of quality-controlled data, and novel approaches are presented in Busch and Trexler (in press). Trend assessment for all categories is included in the revised checklist.

## **FIELD TESTS OF THE REVISED PFCA**

### **A Comparison of PFCA Approaches**

A comparison of the existing and the revised PFCA protocols was needed to better understand the limitations of each approach to ecosystem assessment, as well as the

efficiency of the revised PFCA approach. Therefore, we conducted site visits to five locations in southern Utah that had undergone previous BLM PFCA review. We used the revised checklist and methods described in Appendices B and C (below) to conduct our assessment. This analysis provided a sufficient field test of our methods, and is described below; however, we do not consider this to be a comprehensive empirical review of PFC management data. We strongly recommend that such a review be conducted, but awaits systematic compilation of previously collected PFCA data. We use this comparative analysis to illustrate some of the challenges involved in riparian ecosystem assessment.

## **Methods**

**Study Sites:** The study sites selected were tributary canyons of the Escalante, Paria and Colorado rivers in Grand Staircase-Escalante National Monument (GSENM) and San Juan Resource Area. The study sites included: Deer Creek, The Gulch, Harris Wash, Cottonwood Creek (Fig. 1), and Indian Creek. The BLM's initial PFCA data indicated that these sites were rated as representing a range of conditions from FAR to PFC condition. Deer Creek (Fig. 2) is a small perennial stream and the study reach is about 1 km in length, and was rated by the BLM as PFC. It has a campground near its downstream end, and a small, two-rut dirt road runs parallel to, and crosses, Deer Creek. The site is dominated by Fremont cottonwoods, and has been free from cattle grazing for 30 years. The Gulch (Fig. 3) is likewise a small (but probably ephemeral) stream on which livestock grazing has been excluded for several decades, but is still used to move cattle between separate grazing pastures. Also dominated by cottonwood, it has a more open character than Deer Creek, and was rated by the BLM as PFC. Harris Wash (Fig.4) is a broad, open ephemeral/intermittent stream, which is dominated by tamarisk and cottonwood and is seasonally grazed. This tributary was rated by the BLM as FAR. Cottonwood Creek (Fig. 5) is a tributary of the Paria River, and is a narrow stream confined by Mesozoic shales, with wider floodplains dominated by Fremont cottonwood and rabbitbrush. This tributary was rated by the BLM as PFC. Indian Creek (Fig. 6) is a perennial tributary of the Colorado River, east of Canyonlands National Park in the San Juan Resource Area. The assessment reach was dominated by tamarisk, is currently grazed, had a road crossing, and was rated by the BLM as PFC.

**Data Collection and Analysis:** We visited the study sites in summer and early fall 2000, and 2001, and used our revised checklist to assess the ecosystem function of the five sites. We obtained BLM PFC data sheets for these sites, and compared the original to the alternate PFCA results.

## **Results**

Alternate PFCA scores for 4 of the 5 study reaches examined were lower than those of the BLM (Table 1), and all sites had moderate to high intensity of human impacts.

The Deer Creek reach exhibits reduced sinuosity and upper riparian zone percent ground cover, and it ran parallel to, and was crossed midway by, a dirt road. We viewed these factors, as well as the presence of a nearby campground, as marginally detrimental

to wildlife habitat in the reach, but gave it a composite score of 3.9 (likely PFC), essentially the same as the BLM's PFC rating.

Although The Gulch reach had been protected from grazing for the past several years, altered canopy demography (few old trees) and canopy structure, a highly degraded uplands, and an old roadway controlling some of the stream channel, caused us to rate the stream as a 2.9 (FAR), while the BLM had rated it as PFC. We concluded that several more decades of protection from grazing may be required to recover The Gulch to a fully functioning status.

At the time of our surveys, Harris Wash was an ephemeral or intermittent stream that had been seasonally heavily grazed, with conspicuous stem damage on the native and abundant non-native shrub and mid-canopy vegetation, and extensive trampling of the floodplain soils by cattle. It scored low (2.2) and we considered it to be NF, whereas the BLM considered it to be FAR.

The Cottonwood Creek reach was a narrow, ephemeral or intermittent stream tightly constrained by bedrock shales. It was relatively open, with little potential fish cover and poor wildlife habitat cover. The floodplains had been extensively trampled by cattle, and we watched it dry up for the first time in several months, as evidenced by larval Ephemeroptera being collected by *Pogonomyrmex* ants. This reach received a composite score of 3.0 using our alternative PFC checklist. The BLM had rated the same reach PFC.

Indian Creek was strongly dominated by non-native vegetation at the time of our site visit, and had few habitat characteristics that were conducive to wildlife populations. Additionally, there were numerous severely cut banks and other signs of geomorphically inconsistent erosion. We disagreed with the BLM's PFC rating, as the reach received a composite score of 2.2 using our alternate checklist. Thus, we considered this stretch of Indian Creek to be dysfunctional.

Addition of variables may affect overall site rating scores. Therefore, we re-ran the comparative analysis using only those categories identified by the BLM in its traditional PFCA approach, to determine whether inclusion of additional information altered our PFCA scores. After exclusion of water quality and wildlife categories, the alternate PFCA scores remained within  $\pm 0.1$  of our original revised PFCA scores, an insufficient difference to change any of our original composite scores for these sites.

## DISCUSSION

Rigorous riparian ecosystem health assessment is much needed by land managers, both for reasons of compliance with federal and state laws, and to meet long-term environmental management mandates and objectives. The assessment protocols need to be comprehensive, efficient, reliable, repeatable, and easily interpretable. The revised PFCA approach proposed here meets these criteria and adds considerable scientific credibility and repeatability to the BLM's PFCA approach. Our results differed from those of the original BLM methods for several reasons. First, our checklist considers numerical rating of indicator states (across a range of 1=poor to 5=excellent), rather than "yes" or "no" qualitative ratings. Also, we included additional sections with individual variables, including: water quality, fish and wildlife habitat and human impacts sections.

These elements were not included in the original BLM approach. We also re-organized some of the indicators on BLM's checklist. For example, erosion on the original BLM checklist was translated into sediment distribution, vertical bank and lateral channel stability, and soil conditions. Also, our checklist considered only current conditions, while the BLM approach seems to occasionally evaluate trend or predicted future conditions without clear comparative data over time.

One of the most important qualities of any assessment protocol is that it can be conducted efficiently and relatively rapidly. We spent an appropriate amount of time on our site visits (typically 2.5-3 hr), including an intensive debriefing session. The amount of time spent per site is likely to drop slightly with increased efficiency, and as the PFCA team communication improves.

We found that our alternate PFCA protocols produced lower scores of riparian ecosystem health than did the conventional protocol. In part, this is attributable to the unwillingness of our panel to provide very many perfect (5) scores to variables because of unknown conditions and unknown interactions, particularly between upland and upstream conditions and the study reach. However, many of our scores were low because of poor environmental conditions that may not have been apparent to the BLM team(s). Again, this points to the need to have experts from several fields perform the site assessments. Our process would have been facilitated had much of the needed background synthesis information on hydrography, land use history, and species-habitat relations been compiled.

Addition of other variables may, by itself, reduce mean site rating scores. Therefore we compared variables in the BLM's standard protocol with a reduced comparison of our results for just those categories evaluated by the original BLM protocol. This analysis confirmed that our patterns remain consistent even at lower intensity of sampling. This truncated comparison revealed that our rating scores remained within  $\pm 0.1$  scoring value of the full PFCA score, a difference too small to change our scoring of any of the 5 study reaches. However, this result does not justify reduced sampling, as our protocol is intended to provide sufficient information on the present condition to relate to future changes, particularly in the areas of water quality, fish and wildlife habitat, and human impacts.

Two important issues challenge the success of PFCA. First, ecosystem assessment without comparison to control reference sites means that management objectives remain undefined, and therefore impossible to achieve. Reference sites need to be identified and studied in detail, as they provide the targets for riparian management. Collaborative, interagency effort will be required to locate sites that are essentially undisturbed in protected landscapes throughout the Southwest. If a sufficient number of "pristine" sites cannot be located in the Southwest, efforts should be made to identify sites that exist in a sufficiently healthy condition to be generally acceptable for such comparative analyses. Although data from reference sites do not presently exist, we expect that providing a comparison of treated versus control sites will substantially improve interpretation of the results of this alternate PFCA approach.

Secondly, information management of PFCA data is warranted, and an information management system needs to be established (probably best as a national, interagency national database), so that regional and trend analyses and syntheses can be

conducted and interpreted. PFCA data should be subjected to detailed statistical analyses at local, regional and national scales, and over a sufficiently long time frame (i.e., decades) in accord with the ecological scales under which riparian ecosystems function. This information should be used to trigger management actions in a clearly justified and prescribed manner.

We expect that this administrative organization and information management will improve the application of PFCA data to management and education, and will undoubtedly result in further refinement of PFCA protocols. Additional testing of the methods proposed here is warranted, particularly after they are grounded in reference areas, and we anticipate that revision of these methods will provide more comprehensive and quantifiable information on which to base management decisions, while maintaining much of the efficiency of the original PFCA approach. At present, we anticipate that 5-10 yr of monitoring data are needed before analyses can reveal the minimum number of variables needed to adequately assess riparian ecosystem health.

## CONCLUSIONS

Our intent in this process has been to help the BLM meet its stated riparian ecosystem assessment goals. We believe our proposed alternative PFCA method will relate more directly to the USGHR objectives, and also describe more specifically existing ecosystem conditions. In the short-term, the management implications of this work are that the present PFCA system appears to over-estimate the health of riparian ecosystems sampled, and does so in a manner that limits independent verification. Although scarcely mentioned in the oversight guidelines, the PFCA process can be used for long-term monitoring, as well as for assessment of riparian sites (including springs) throughout the Southwest. We recommend that the BLM consider its need for trend data and the potential application of PFCA as a monitoring protocol in relation to long-term data management and stewardship of riparian ecosystems. A pressing need exists to identify, sample, and protect reference riparian sites throughout the West as control sites, against which management evaluation can be used. Only with well-controlled, long-term data on these sites is ecosystem evaluation likely to provide realistic understanding of ecosystem potential and dynamics.

The longer-term implication of this work is that riparian ecosystem assessment needs to be approached in a systematic, scientific fashion, rather than as a simple, short-term exercise. Many riparian ecosystem processes are poorly known, and have not been studied over the lifetimes of the dominant fish and tree species. Therefore, riparian systems need to be observed and measured over decades, as they respond to erratic high flows, human activities, and changing climate. Riparian control and treatment sites are perhaps best viewed as the U.S. Geological Survey views its streamflow gauge network: modest amounts of data are gathered and compiled at discrete intervals, and after several decades, sufficient information exists to begin to describe system dynamics. The U.S. Geological Survey emphasizes the importance of long-term data management in its streamflow gauge network, a perspective conspicuously missing from the BLM's present protocol.

Improvement of the PFCA process will allow the BLM to better address riparian ecosystem assessment and management in Utah, including the Draft Environmental Impact Statement on Grazing for the Grand Staircase-Escalante National Monument, as well as permit renewals for allotments in the San Juan Resource Area. The BLM is now, more than ever, under scrutiny by ranchers, concessionaires, scientists, conservation organizations, and other managing agencies, and is committed to grazing management that is based on the best available scientific data. The procedures outlined here should help the BLM meet these challenges in an efficient, scientifically credible, and cost-effective manner.

We hope that the National Riparian Service Team and Utah State BLM office will engage in continued cooperative interaction to determine how the BLM PFCA procedure can more adequately relate to the USGHR and more completely reflect the existing conditions of southern Utah's riparian ecosystems. Our revised PFCA procedure is designed for use in lower and middle elevation systems of the Colorado Plateau. We encourage the BLM to consider the concepts presented here into their review of PFCA protocol for the southern Utah field offices, and we feel these concepts and approach may be applicable to other field offices in southwestern Colorado, northern New Mexico and northern Arizona. We hope the BLM and other federal land managing agencies will bring together similar teams of university scientists and other experts in other parts of the West, including the Pacific Northwest, to develop PFCA procedures appropriate to those biomes.

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