FEATURE:
FISH HABITAT

An Evaluation of Management Objectives Used to Assess Stream Habitat Conditions on Federal Lands within the Interior Columbia Basin

ABSTRACT: We evaluated eight habitat objectives used by land management agencies within the Interior Columbia Basin to determine if the current riparian management objectives (RMOs) were representative of conditions found at reference sites, had values which differed significantly between reference and managed watersheds, and whether these RMOs could be consistently applied across the study area. We found that many of the reference reaches did not meet objectives such as wetted width-to-depth, percent undercut banks, number of pieces of large wood, and numbers of days exceeding 15°C. We also found no significant difference between randomly selected managed and reference reaches for four objectives: wetted width-to-depth ratio, bank stability, percent undercut, and pool frequency. Finally we found that some RMO values differed among forest types. As a result of these findings, none of 726 reference or managed reaches we evaluated exceeded all objectives when applied to a site. We recommend that objectives, if adopted, should be selected using the following guidelines: (1) be based on consistently collected data from the area of interest, (2) show a demonstrated response to management, and (3) account for landscape characteristics that may influence the value of the objective. Such an approach would insure more managed sites than reference sites exceed the objective, that the difference would be due to management rather than differences in landscape setting, and that the objective is based on data rather than professional opinion.

Revisión de los objetivos de manejo utilizados para evaluar las condiciones del hábitat fluvial en tierras federales dentro de la cuenca interna de Columbia

RESUMEN: Se evaluaron ocho objetivos, relativos al hábitat, que utilizan las agencias de manejo dentro de la cuenca interna de Columbia para determinar si los actuales objetivos de manejo ribereño (OMR) fueron representativos de las condiciones encontradas en los sitios de referencia, si tuvieron valores que difirieron marcadamente entre cuencas sujetas a manejo y aquellas de referencia, y para determinar si los OMR pudieran ser aplicados consistentemente a lo largo del área de estudio. Se encontró que muchos de los sitios de referencia no cumplieron con objetivos como relación ancho-profundidad en contacto con el medio, porcentaje de bancos socavados, número de piezas grandes de madera y número de días con más de 15°C. Tampoco se encontraron diferencias significativas entre cuencas sujetas a manejo y cuencas de referencia en cuanto a cuatro objetivos: relación ancho-profundidad en contacto con el medio, estabilidad del banco, porcentaje de socavación y frecuencia de albercas. Finalmente se encontró que algunos valores de los OMR difirieron según el tipo de bosque. Como resultado de estos hallazgos, ninguna de las 726 cuencas de referencia ni sujetas a manejo que fueron evaluadas excedió todos los objetivos cuando éstos se aplicaron a un sitio. Se recomienda que los objetivos, de ser adoptados, debieran ser seleccionados de acuerdo a los siguientes lineamientos: (1) estar basados en datos muestreados consistentemente en el área de interés, (2) haber tenido una respuesta demostrada a las acciones de manejo, (3) considerar características paisajísticas que pudieran influenciar el valor del objetivo. Tal enfoque podrá asegurar que más sitios sujetos a manejo, en comparación a los de referencia, excedan el objetivo, y que el objetivo se base en datos más que en opiniones profesionales.

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INTRODUCTION

The evaluation of the effects of land management on aquatic and riparian habitat has been a particularly vexing problem for managers and biologists. The decline of native fishes, changes in aquatic community structure and function, deleterious effects to water quality, and changes to stream habitat have often been attributed to land management practices (Meehan 1991; Figure 1).

Geomorphic processes that form habitat may be altered by improper land management in several ways. For example, forest management practices that remove large wood from streams and riparian areas or place roads in riparian areas where they contribute excessive fine sediment can result in the loss of pool habitats (FEMAT 1993). Improper livestock grazing may cause the removal of riparian vegetation (Platts 1981; Kauffman et al. 1983) and the direct, mechanical breakdown of stream banks from livestock hoof damage (Kauffmann et al. 1983; Marlow and Pogacnik 1985). This may increase fine sediment which can fill pools or degrade spawning habitat for salmonids.

Federal agencies have used key stream habitat objectives to evaluate the effects

Figure 1. Riparian area and stream habitat influenced by livestock grazing in the Upper Columbia River basin.

of their land management practices on streams (FEMAT 1993; PacFish—USDA 1995; InFish—USDA 1995; NMFS 1996). The expression of stream conditions generally involves the identification of key variables that are responsive to the effects of land management and then establishing values that are measureable and quantifiable. Values chosen as benchmarks are derived from laboratory studies that explore life history requirements and thresholds for survival or field studies that link changes in habitat with declining fish populations or deleterious effects to water quality.

While the application of stream habitat objectives can clarify habitat management benchmarks, detractors counter that the application has been too narrowly interpreted. One of the primary criticisms of numeric stream habitat objectives is the failure to account for widespread spatial and temporal variability in stream conditions (Lee et al. 1997; Bisson et al. 1997). A second criticism is that geomorphic components such as the natural production and delivery of fine sediment make it difficult to be able to separate land management effects from background levels (McDonald et al. 1991). Stream habitat objectives have been criticized because they are perceived as arbitrary and too strict (Benner 2004). These criticisms suggest stream habitat objectives, if they are to be applied, must account for natural variability and have a solid science foundation.

Ideally, a meaningful stream habitat objective should be sensitive to land management effects, easily and consistently measured, and broadly applicable to the target population of streams. Stream habitat objectives that are sensitive to land management and show impacts should theoretically have a larger proportion of managed sites that do not meet habitat objectives when compared to reference sites. We define "reference" in this case as streams where minimal land use effects have occurred. Reference streams are ideally drawn from a population of watersheds that have minimal land management effects, but represent the full range of ecological conditions found in the absence of management. Objectives should be derived from a large, randomly selected set of reference reaches (Urquhardt et al. 1998) and might represent a specific percentile value (EPA 2000; McCormick et al. 2001; Suplee et al. 2007). For example, where the standard is set at the 75th percentile, 25% would be labeled impaired.

Probably the most widely used objectives for stream habitat evaluation are riparian management objectives (RMOs) developed in the mid-1990s in response to the decline of anadromous fish on federal lands in the western United States. The U.S. Department of Agriculture Forest Service and U.S. Department of Interior Bureau of Land Management developed interim guidance for the management of federal lands as part of the Pacific Anadromous Fisheries Strategy (PacFish; USDA/USDI 1995) and expanded the same standards to bull trout (*Salvelinus confluentus*) and other salmonid species in the Inland Native Fish Strategy (InFish; USDA 1995). Concurrent with these land management planning documents, the National Marine Fisheries Service (NMFS) devised objectives within a document titled "Matrix of Pathways and Indicators" (MPI) for use as a consulting tool when evaluating the effects of management projects under the Endangered Species Act (NMFS 1996). The MPI selected many of the same stream objectives as PacFish/InFish but added objectives for stream sediment.

Riparian management objectives define specific stream habitat standards as a quantifiable way to describe high quality habitat on federal lands. The intent of these RMOs was to provide benchmarks to agency biologists and managers for evaluating the current conditions of streams (Table 1). Stream habitat objectives that failed to meet these benchmarks were supposed to be reviewed to determine causation and then appropriate measures initiated to change land management practices or restore the watershed.

The derivation of RMOs within PacFish/Infish came from a synthesis of data from stream inventories and monitoring studies throughout the western United States where "high quality" habitat occurred (USDA/USDI 1995). This synthesis was conducted by management and research biologists from within the U.S. Forest Service and the Bureau of Land Management. The final dataset consisted of stream habitat data from both the east and west sides of the Cascade Range. Some RMOs within PacFish/Infish differ because of differences in precipitation, climate, local landscape, and species occurrence within the larger planning area. For example, the potential size of large wood recruited into streams west of the Cascade Divide is generally larger than on the east side due to higher moisture available for tree growth and greater productivity. Data from this exercise were not used in our evaluation.

A subset of six variables was selected as the final list of RMOs from a larger list that included substrate metrics, finer-scale habitat classification, and additional habitat descriptors. Three of the RMOs—pool frequency, water temperature, and wetted width-to-depth ratio—were deemed important in all streams while three others were important in specific vegetation conditions. These were bank stability and lower bank angle in non-forested, grazing lands and frequency of large woody debris in forested systems. These same six RMOs were adopted in the InFish Strategy that was implemented in 1995 (USDA 1995). Two additional stream substrate objectives were also evaluated for the MPI (NMFS 1996): percent fine sediment in riffles and dominant substrate size (Table 1).

Riparian management objectives were quantified with a single number or a number that was qualified with a "greater than or less than" modifier. Objectives having a direct relationship to a biological endpoint such as temperature were chosen to reflect the known threshold for some physiological response (Table 1).

Even though the RMOs have been widely applied, we found little post hoc analysis of their use. We use this article to review RMOs that are currently in use throughout much of the Interior Columbia River Basin. We ask three questions that relate to the application of RMOs across a broad geographic area. First, are the current RMOs consistent with values found in the population of reference streams sampled within the interior Columbia basin? Second, do values for RMOs differ in reference streams and managed streams? Finally, if these differences occur, how do geoclimatic conditions change those relationships and how might that affect the application of RMOs over broad areas?

METHODS

We compared RMOs to data collected from stream reaches evaluated during the summers of 2003–2005 by the PacFish/InFish Biological Opinion (PIBO) effectiveness monitoring program (Figure 2). Stream reaches came from watersheds that were selected probabilistically with methods described by Kershner et al. (2004b). RMO evaluations only included streams less than 4% gradient in 3rd to 7th order stream reaches.

All sampled watersheds were identified as either reference or managed. Watersheds were considered reference (n = 136) if there had been no permitted livestock grazing within the past 30 years, less than 10% of the watershed had undergone timber harvest, there was no evidence of mining in proximity to riparian areas, and road density was less than 0.5 km/km^2. Managed watersheds (n = 590) included a full complement of management activities including timber harvest, road building and maintenance, livestock grazing, mining, and recreation. Not all management activities were present in every watershed.

We used a one-way analysis of variance to determine if mean values differed between managed and reference reaches. Differences in medians were assessed using a Brown-Mood test (Brown and Mood 1951). We used this non-parametric test to confirm our results from ANOVA. Significance level for all tests in this article were set at $P < 0.1$ to balance the possibilities of Type I and II errors. All analyses were performed using the Statistical Applications for Science (SAS v 9.1 2003) software. For our analysis of pool frequency data, we used a two-way analysis of variance where blocks were stream width categories.

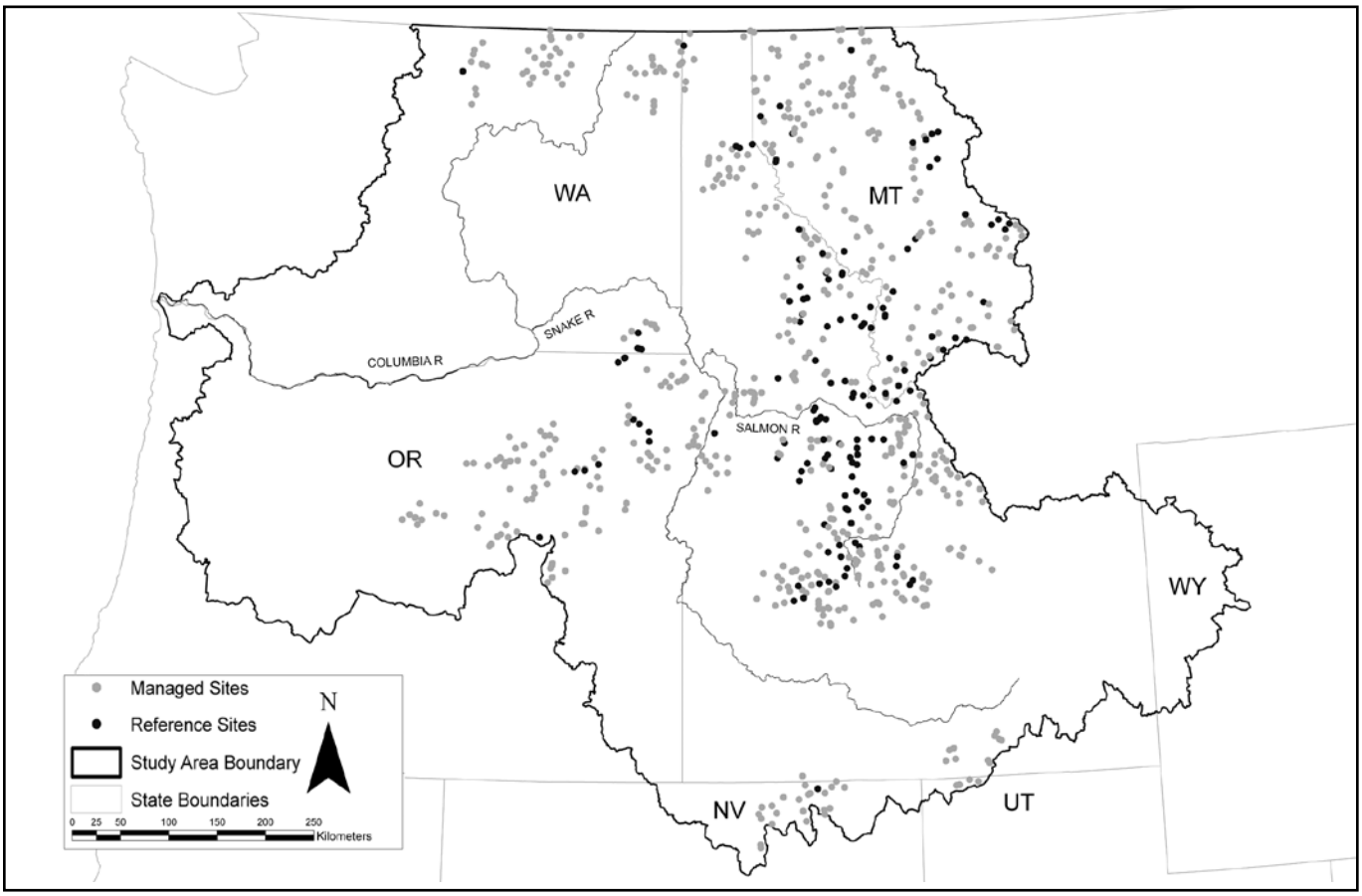
Table 1. Stream habitat standards evaluated in this study. Most of the standards are Riparian Management Objectives listed within the PacFish/InFish strategy. Deviations from standard listed in the Matrix of Pathway and Indicators (MPI) are identified (RMO in italics).

Stream Attributes Used as Standards

Width/Depth Ratio—The wetted width of a stream divided by its mean depth.
< 10
Bank Stability—The percent of the banks that are stable. No protocol is listed for determining bank stability but this value is only to be applied to meadow streams. The MPI standard is greater than 90% and no specific stream types of listed.
> 80% stable (Pacfish/Infish)
Lower Bank Angle—The percent of the stream banks within a reach that are undercut. This standard is only applicable to meadow streams. There is no MPI standard for this attribute.
> 75% of banks with < 90° angle
Large Woody Debris—The number of pieces of wood meeting a specific size criterion per given length of stream. There is no difference between PacFish/InFish (but there are two regions) and MPI for this standard.
> 20 pieces per 1,609 m; > 30 cm (12 in) diameter; > 10.7 m (35 ft) length. (PacFish/Infish east of the Cascade Crest)
Stream Temperature—The number of days above a defined maximum stream temperature. There is considerable variation in the three documents for this standard; 15°C for adult holding in InFish, 15.5°C for spawning in PacFish, and below 13.9°C for MPI. The variation likely is due to the different species which are being addressed.
No days where maximum temperature exceeds 15°C (InFish, spawning and rearing)
Percent Fines in Gravel—The amount of small sediment (< 0.85 mm) in areas where salmonids spawn. This standard is only found in the MPI.
< 12%
Dominant Substrate—The dominant substrate on the stream bottom. This standard is only listed in MPI. No specific size was given so we chose the lower end of the suggested size classes.
Dominant size class is gravel or cobble (median substrate size > 32 mm)
Pool Frequency—The number of pools counted for a specific length of streams stratified by stream width. The intent of this goal is that the number of pools exceed the standard established for a given stream width class. The only difference between PACFISH/INFISH standards and MPI is the presence of a 4.5 size class. Both documents have more stream size classes than presented here but these apply to the streams sampled for this study. No specific protocol is identified for determining pool habitat.

Wetted width (m)	*3.05 (10ft)*	*6.1 (20ft)*	*7.6 (25 ft)*	*15.2 (50ft)*
Pools per kilometer (PacFish/Infish)	*60*	*35*	*29*	*16*

Figure 2. Map of sampling locations within the Columbia River basin.



One of the original assumptions in the development of RMOs was that values for each objective were consistent across the landscape encompassed by the strategies. We tested this assumption by comparing two groups of forests: one representing drier forest types in eastern Oregon and southeastern Washington (Malhuer, Umatilla, Wallowa-Whitman) and the other being forests that receive more annual precipitation in northern Idaho and western Montana (Idaho Panhandle, Flathead, Kootenai, and Lolo; Table 4). We used analysis of variance for both management types and forest types. We tested for both main effects as well as interactions in the model.

RESULTS AND DISCUSSION

Are the current RMOs consistent with values found in the population of reference streams sampled within the interior Columbia basin?

We compared median and mean values of RMOs collected in reference reaches and compared them to RMOs listed in PacFish, InFish, and MPI (Table 1). The median values of three objectives: bank stability, median particle size, and percent fines and the mean values of large wood, percent fines, median particle size, and pools per kilometer exceeded the RMOs in reference reaches (Tables 2, 3). None of the values for wetted width-to-depth ratios and percent reach undercut met the RMOs in all cases and almost two-thirds of the reference reaches exceeded the 15°C temperature standard for at least one day (Table 2). In contrast, the median values of percent riffle fines, both the mean and median of the median particle size, and all but one width class (> 6.1 to ≤ 7.6m) for pools per kilometer exceeded the RMOs in managed reaches.

Do values for RMO differ in reference streams and managed streams?

When we tested the differences between reference and managed reaches we found significant differences in the means and medians of four of the objectives: large woody debris, number of days the maximum water temperature exceeded 15°C, percent riffle fines, and median particle size (Table 2). While we observed differences in the values for wetted width-to-depth ratio, bank stability, percent undercut banks, and pools per kilometer, those differences were not statistically significant (Tables 2, 3). Surprisingly, two of the variables showed differences in a direction that was opposite than what we expected. The wetted width-to-depth ratios for managed reaches were lower than those in reference reaches, but those results were not statistically significant. We saw a similar result in the pools per kilometer in streams that were in the categories < 3.05 m and > 7.6 – < 15.2 m where there were more pools in managed reaches (Table 3).

Table 2. A comparison of values from reference and managed reaches from watersheds on federal lands in the Columbia River basin. Bank stability and percent undercut are determined from meadow reaches while large wood values are from forested reaches. RMOs are listed for comparison. A ^ indicates reference means/median were significantly different ($P < 0.1$) in the direction expected between reference and managed conditions. Because bank stability and undercut banks were only included if they were evaluated in meadows, the sample sizes were considerably smaller in the managed/reference comparisons; 20 in reference and 128 in managed.

		Reference (*n* = 136)		Managed (*n* = 590)	
Attribute	**RMO**	**mean**	**median**	**mean**	**median**
Width-to-depth Ratio	< 10	69.9	59.3	67.7	46.9
Bank Stability (%)	> 80	77.5	83.0	75.1	79.0
Undercut Banks (% by reach)	> 75	27.5	24.5	23.1	17.8
Large Wood (# per 1609 m)	> 20	28.0^	13.0^	16.8	9.0
# days > 15°C	0	18.1^	16.0^	23.6	26.0
Riffle Fines (%)	< 12	6.8^	2.8^	17.6	5.8
Median Particle Size (mm)	> 32	65.2^	56.5^	43.8	36.7

Table 3. A comparison of pool frequency data for reference and managed reaches from watersheds on federal lands in the Interior Columbia River basin. Data come from single reaches within each watershed. Data are then stratified based on wetted stream width. After accounting for these strata there are no significant differences in pool frequencies between management type ($P = 0.54$).

		Pools/kilometer					
Wetted Width			**Reference**			**Managed**	
Size Class (m)	**RMO**	**(*n*)**	**mean**	**median**	**(*n*)**	**mean**	**median**
0.0 to ≤ 3.05	> 60	19	64.9	59.0	245	79.2	75.2
> 3.05 to ≤ 6.1	> 35	58	45.6	43.5	185	42.2	40.4
> 6.1 to ≤ 7.6	> 29	20	30.6	30.4	47	28.1	26.1
> 7.6 to ≤15.2	> 16	38	19.4	19.3	75	22.3	19.9

Table 4. A comparison of mean values for RMO and two covariates between two forest types within the Columbia River Basin. The three dry forests were from eastern Oregon and Washington (Malheur, Umatilla, and Wallowa-Whitman). The four wet forests were from northern Idaho and northwest Montana (Idaho Panhandle, Lolo, Kootenai and Flathead). An "X" in the zone portion of the significance column indicates a significant difference between forest types. An X in the interaction portion of the significance column indicates that the effects of management on that attribute differ between zones. Bank stability, undercut banks, and pool frequency were not used in this analysis due to insufficient sample sizes.

	Dry		Wet		Significance		
Attribute	**Ref (14)**	**Managed (94)**	**Ref (21)**	**Managed (143)**	**Zone**	**Management**	**Interaction**
Elevation (m)	1250.9	1267.7	1155.9	1065.0	X	NS	NS
Annual Precipitation (mm)	1064.3	665.2	1307.8	1053.6	X	X	NS
Width-to-depth Ratio	91.7	84.8	74.9	79.5	NS	NS	NS
Large Wood (# per 1620 m)	35.5	19.2	22.8	20.9	NS	X	NS
# days greater than 15°C	19.7	35.9	14.5	15.8	X	X	X
Riffle Fines (%)	9.3	13.9	2.0	15.6	NS	X	NS
Median Particle Size (mm)	104.5	50.0	61.0	47.2	X	X	X

Do various geoclimatic conditions change those relationships?

We found a number of differences in RMOs between reference and managed watersheds that were located in different forest types. Stream reaches sampled in dry forests were generally located at higher elevations and received less precipitation than wet forests (Table 4). Two of the seven RMO evaluated (# days greater than 15°C, median particle size [mm]) did differ significantly between forest types and management type (Table 4; bank stability, percent undercut, and pool frequency were not included because of limited sample size). Two others showed only differences between management (large woody debris and riffle fines). We found fewer riffle fines and more large woody debris in reference streams.

Are Habitat Standards Meaningful?

Riparian management objectives were designed as an early warning of potential negative land management effects on stream habitat. Values that did not meet RMOs were believed to potentially represent unsuitable conditions for anadromous and important resident salmonids. Our analysis of data from a limited number of federally-managed sites in the interior Columbia River basin indicates that the usefulness of these objectives may be questionable. None of the 726 reference and managed reaches surveyed met all RMOs. Modifications in the selection of RMOs and their application are clearly needed if the results in this study represent conditions across the broader landscape.

We found no significant differences between reference and managed reaches for four RMOs: wetted width-to-depth ratio,

bank stability, percent undercut bank, and pool frequency. This runs somewhat counter to previous analyses of data collected prior to the additional data used in this study, where percent undercut banks were greater in reference stream reaches (Kershner et al. 2004a; Henderson et al. 2005).

The two sediment attributes we evaluated, percent fines and median particle size, showed some differences between reference and managed watersheds, but the majority in both settings met the RMOs with the exception of the mean of the percent fines in managed settings. Most striking were the differences between forest types for median particle size (Table 4). Sediment size at a site is influenced by a variety of factors including bankfull width, stream depths, and gradient (Yang 2003), yet RMOs in their current form don't vary. Incorporating some measure of these physical processes into the expectation of particle size has been suggested by many authors (Olsen et al. 1997; Kappesser 2002) and would likely be useful in the determination of new management objectives.

Perhaps most surprising are the inconsistent and sometimes non-existent relationships between RMOs and the data collected from reference reaches (Henderson et al. 2005). The original RMOs were based in part on habitat conditions that were selected from a group of streams that were deemed to have the highest quality habitat. High natural variability of streams throughout the range of lands covered by PacFish/InFish may complicate the setting of threshold-based values that define "good habitat." In addition, the determination of "reference" conditions to set RMOs for the 1995 Biological Opinion was limited by the small sample of habitats available and the lack of a consistent definition of "reference" (Kershner et al. 2004b). Watersheds where there has been little anthropogenic management are rare throughout the Columbia River basin and we limited our selection of reference sites to watersheds that haven't been grazed in 30 years, had minimal or no roads or logging influence, and minimal mining activities. It is possible that land use practices discontinued decades ago still may be influencing the characteristics of these reaches and that these watersheds are still recovering.

There are other issues that may influence our ability to detect differences between managed and reference reaches. An issue that has been identified in many monitoring programs is the problem associated with consistently measuring habitat objectives (Roper et al. 2002, 2008). For example, measurements of entrenchment ratio (ratio of flood prone width to bankfull width), sediment size, width-to-depth ratio, and gradient all differed among crews in a recent protocol test in the John Day Basin (Roper et al. 2008). These differences influenced the crews' ability to consistently identify Rosgen stream types. A number of these same variables were used in our analysis as potential covariates or as specific RMOs.

An additional source of variation may be the characteristics of the sample reaches within a watershed. All values presented in this article come from small to moderate sized watersheds and stream reaches with gradients < 4%. Low gradient reaches are generally viewed as good sites to monitor changes in stream habitat because they are responsive to changes in water and sediment (Montgomery and MacDonald 2002), but additional work may be needed to verify the utility of this assumption.

Figure 3. Reference sites within a burn area during two photo sequence periods. Significant changes in habitat occurred after the burn.

There should be no expectation that reference streams will always exhibit favorable habitat conditions and that management-influenced streams will always be degraded (Kershner 2004a; Figure 3). One of the drawbacks of the use of RMOs has been to ignore or discount the role of disturbance in shaping stream habitats. Natural disturbances play a large role in shaping the setting of streams and the conditions within them (Benda et al. 1998; Poole et al. 2004). All streams will most likely not meet all habitat objectives during some point in their history as the series of natural disturbances resets them. In fact, some of our reference sites come from wilderness areas that have experienced severe disturbance from wildfires and associated debris flows. These conditions provide valuable information when describing the distribution of conditions that may be possible in a reference setting and provide important information on recovery trajectories in the absence of land management.

The need for a network of reference sites has been called for elsewhere (Bisson et al. 1997) and currently there are several large-scale monitoring efforts using consistent protocols to sample reference watersheds within the interior Columbia River basin (Kauffman et al. 1999; Kershner et al. 2004b). Probably the most difficult challenge is finding reference sites over a variety of landscapes that have not seen significant land management or to find a group of sites that have long-term data where habitat condition trajectories can be followed. Until we have better information on the trends of these sites, it will be difficult to determine whether conditions have recovered from past land management or influenced by other disturbances.

We observed little difference in the pool frequency between reference and managed stream reaches. While other studies have reported much larger changes in the pool frequency following severe floods (Lisle and Hilton 1992), timber harvest practices (Woodsmith and Buffington 1996), grazing (Magilligan and McDowell 1997), our initial analysis also failed to detect significant differences (Kershner et al. 2004a). Pool frequency/percentage may be a relatively insensitive measure of land use changes or masked by the inability of crews to consistently identify and measure pools (Roper et al. 2002; Archer et al. 2004; Whitacre et al. 2007). Other pool attributes have been used by investigators as indicators of habitat change. For example, both residual pool depth (Lisle and Hilton 1992; Kershner et al. 2004a) and the number of deep pools (McIntosh et al. 1994, 2000) have been shown to be strong indicators of land management effects. The choice of these two objectives rather than pool frequency/percentage may be better choices as RMOs (McIntosh et al. 2000; Kershner et al. 2004a).

The application of criteria delineating non-forested (meadow) from forested streams may be an artificial construct that provides little additional information to differentiate management influence on a specific RMO. For example, livestock grazing has been reported as increasing width-to-depth ratios as a consequence of the removal of riparian vegetation (Kauffman et al. 1983; Platts 1991; Knapp and Matthews 1996) and the direct, mechanical breakdown of stream banks from livestock hoof damage (Kauffmann et al. 1983; Marlow and Pogacnik 1985). One concern in separating streams is the lack of an objective definition for a "non-forested, meadow stream"

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or a "forested stream." The second concern is that there is little evidence that these objectives should be limited to meadow sites. Kershner et al. (2004a) found that after accounting for differences in annual precipitation, stream size, and stream gradient, there were significant differences between reference and managed streams in both settings. Clearly, additional work needs to be conducted to more accurately describe the differences in the two strata and then define characteristics that may be more susceptible to change if this separation is to be useful. Other variables that reflect the vegetative condition of the two types might be most relevant to detect differences from land management (Coles-Ritchie et al. 2007).

We saw differences in some RMOs when we used forest type to analyze the effect of geoclimatic variables on our results. We expected that there might be differences in water temperature given the elevation and precipitation differences that occurred between the two zones, but were somewhat surprised at the strong differences in median particle sizes. The differences from the separation of forest types are clearly strongest in these variables and some stratification may be useful for determining future RMOs. While we saw differences in management type for the percent fines and large woody debris, we expected larger differences by forest type, particularly for large wood. However, any interpretation of these results must be viewed with some caution due to the relatively small sample sizes in reference sites. As the number of monitoring sites across the basin continues to expand, additional analyses may indicate stronger differences.

Given the results of this analysis and other findings from this project, it is clearly time to revisit these habitat objectives and decide how best to modify or potentially eliminate objectives that provide little meaningful insight into the quality of stream habitat in managed landscapes. For example, in a previous analysis, we found that only 2% of the reference reaches met the RMO for wetted width-to-depth ratio and that 16% met the reference criteria for percent undercut banks (Henderson et al. 2005). These may be examples of RMOs warranting exclusion or reconsideration. While there is a temptation to recommend the removal of habitat objectives from any analysis, it is difficult to decouple the use of RMOs from management analyses given the rich history of studies that link land management to stream habitat changes (Meehan 1991).

Within the management and research community, there are vocal critics of the use of habitat objectives, particularly in the context with which they have been applied in the Columbia Basin and elsewhere (Benner 2004). This criticism has been directed at the arbitrary nature of how they were determined, the rigid nature of the interpretations, and the use of reference conditions that represent only one end of the distribution of values. In addition, questions have arisen regarding the appropriateness of combining RMOs into a composite score or using some other means to get an overall habitat rating.

A number of efforts have attempted to combine biotic and abiotic variables into scoring systems derived from reference and non-reference data. The Index of Biotic Integrity (IBI) has been widely used to develop a scoring system using biological attributes in aquatic systems (Karr et al. 1986). This index has been modified by a number of investigators to combine a suite of population, water quality, and habitat information into an index used to assess stream conditions (Lazorchak et al. 1998b; McCormick et al. 2001). McCormick et al. (2001) defined reference sites using chemical criteria, watershed land use, road density, habitat filters, and a watershed condition class rating. They used the distribution of IBI scores at reference sites to set thresholds from good to poor. Scores that exceeded the mean of the 25th percentile for reference sites were rated as "good" biological integrity while scores below the mean of the 10th percentile were rated poor. Hill et al. (2003) used a periphyton index of biotic integrity (PIBI) that combined stream chemistry and riparian disturbance metrics to compare reference and disturbed streams. They used the 75th, 25th and 5th percentile scores at reference sites to set thresholds for describing conditions. This kind of approach may be one way to display these habitat conditions in ways that are more useful to managers.

Another potential way to use these objectives is to view them as ecosystem health diagnostics, much like physicians use criteria to evaluate human health. A typical assessment of human health follows a sequence that (1) identifies symptoms, (2) identifies and measures vital signs, (3) makes a provisional diagnosis, (4) conducts tests to verify the diagnosis, (5) makes a prognosis, and (6) prescribes a treatment (Haskell et al. 1992). We believe that RMOs represent potential vital signs for stream habitat. RMOs that can be accurately and precisely measured, respond to disturbances in a measureable way, and are quantifiable may provide good indicators of habitat change. Because there will always be overlap in the distribution of stream conditions in managed and reference sites, habitat objectives should not be used as a final decision-making tool, but rather as an early warning indicator to make a provisional diagnosis. Rather than rigid pass/fail criteria, managers would use the summary ratings or scores from an analysis to trigger an assessment of the conditions that may be causing conditions that may not meet the objectives. In this way, biologists can evaluate trends, potentially mitigate proposed management, and develop restoration strategies where habitats are degraded.

In conclusion, the primary problem with using the RMOs in PacFish/InFish is that approximately the same percentage of reference and managed sites failed to meet the objectives identified in the PacFish/InFish guidelines. RMOs for large wood, stream temperature, percent fines in riffles, and median particle size differed significantly between reference and managed sites, but the specific value chosen as the RMO was not attained in more than 50% of reference sites. For these attributes, simply changing the RMO criteria may be sufficient. Other RMOs may require a more extensive analysis or may ultimately not be useful. We recommend that objectives, if adopted, should be selected using the following guidelines: (1) be based on consistently collected data from the area of interest, (2) show a demonstrated response to management, and (3) account for landscape characteristics that may influence the value of the objective. Such an approach would ensure more managed sites than reference sites exceed the objective, that the difference would be due to management rather than differences in landscape setting, and that the objective was based on data rather than professional opinion or relatively limited data from a small geographic area.

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