FEATURE
FISH HABITAT

The Wyoming Habitat Assessment Methodology (WHAM): A Systematic Approach to Evaluating Watershed Conditions and Stream Habitat

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ABSTRACT. Assessment of habitat and fish assemblages to determine the extent of anthropogenic alterations and define conditions relative to management goals is an important activity of management agencies. Assessment activities have been traditionally conducted at relatively small spatial scales (e.g., reaches and channel units), but many problems facing managers occur at larger spatial scales (e.g., watersheds and stream segments). A single methodology that can encompass all spatial scales is unrealistic; therefore, agencies need systems where assessment techniques focusing on several spatial scales can be integrated. A successful system requires a framework that uses a logical organizational structure and focuses on an assessment process. We describe such a conceptual framework, termed the Wyoming Habitat Assessment Methodology (WHAM), currently used by the Wyoming Game and Fish Department. The WHAM consists of three organizational levels that parallel the hierarchical structure of lotic systems. Level I focuses on habitat characteristics at watershed and stream-segment scales, and provides a foundation for other assessments. Level II focuses on habitat and fish at the reach and channel unit scales. Level III assessments are project-specific evaluations that may entail one or more scales. The WHAM is integrative in that progressing levels of assessment are dependent on previous levels, and it facilitates use of data when making management decisions.

Level I assessments focus on habitat characteristics at watershed and stream-segment scales, and provide the foundation for fish and habitat evaluations at smaller spatial scales.

INTRODUCTION

Identifying anthropogenic factors that affect habitat and fish is important for guiding management activities. Several sampling and inventory methodologies have been developed for streams (see reviews in Johnson et al. 2001; NRCS 2001). However, these methodologies generally lack a conceptual framework allowing for assessment of effects of human activities on habitat and fish, particularly those effects that act across multiple spatial and temporal scales (e.g., Osborne et al. 1991; Hubert and Bergersen 1998).

Stream systems can be viewed from multiple spatial scales (Fausch et al. 2002), the largest scale being the watershed (10^5–10^6 m of stream), followed by segments (10^3–10^5 m), reaches (10^2–10^3 m), channel units (10^1–10^2 m), and microhabitats (<10 m). Stream systems are hierarchical in that processes at large scales create and maintain habitat and fish assemblages at smaller scales (Montgomery 1999; Fausch et al. 2002). Most management activities have emphasized reach, channel-unit, or microhabitat scales (e.g., Bain and Stevenson 1999; Fausch et al. 2002), but many management problems are rooted in processes at watershed and stream-segment scales (Fausch et al. 2002). Consequently, managers need to encompass multiple scales when conducting assessments of habitat and fish assemblages (Gallagher 1999).

Standardized sampling protocols have been developed to describe temporal trends and spatial patterns (McMahon et al. 1996). The American Fisheries Society (AFS) has provided substantial guidance regarding the standardization of habitat terminology and measurement procedures. For example, Armantrout (1998) authored a glossary of aquatic habitat terms to promote a standardized terminology for improving communications, and Bain and Stevenson (1999) described standardized protocols for measuring habitat in streams and rivers. While most of these sampling protocols provide guidance on collecting data at a single spatial scale (e.g., microhabitat or reach), multiple-scale approaches are needed to address contemporary management problems and to assure that the scale of data collection is concordant with management needs and actions.

Our purpose is to describe a habitat and fish assessment process used by the Wyoming Game and Fish Department (WGFD) that includes standardized sampling and evaluation methods across multiple spatial scales. The framework of the process may provide guidance to management agencies struggling to develop integrated assessment protocols.

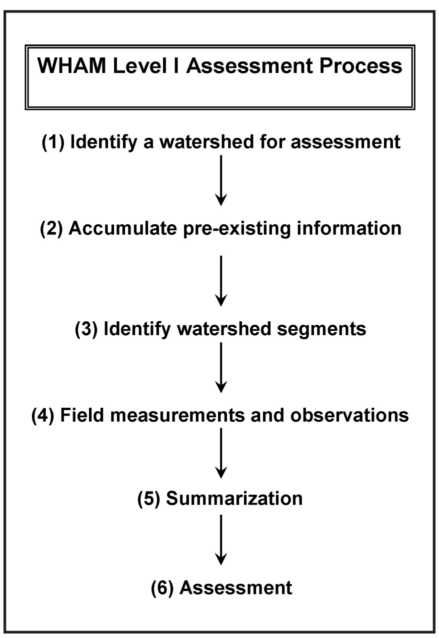
WYOMING'S APPROACH

The WGFD has developed the Wyoming Habitat Assessment Methodology (WHAM) for structuring habitat and fish assessments. Detailed descriptions of sampling methodologies at each level of the WHAM are beyond the scope of this article (for details see Binns and Eiserman 1979; Quist and Hubert 2004; Quist et al. 2004), but we provide examples of assessments at each level. The WHAM progresses across three organizational levels (i.e., Levels I, II, and III) paralleling the hierarchical nature of streams. Level I focuses on large-scale watershed features, such as valley form and stream geomorphology, and disturbances, both natural and anthropogenic. Level II focuses on physical and biological characteristics at reach and channel-unit scales. Level III addresses project-level or site-specific issues. Progress through each level is cumulative in that each level of assessment builds upon previous levels.

LEVEL I ASSESSMENT

Level I is the basic component of WHAM and provides the foundation for other levels (Quist and Hubert 2004) by providing a comprehensive characterization of upland, riparian, and aquatic habitat conditions across a watershed with the goal of identifying management problems and opportunities in a watershed. The focus of Level I is on watershed processes, but the watershed is dissected into smaller, more manageable, sampling units (i.e., stream segments). This approach provides information on habitat within stream segments and synthesis of this information enables an assessment of factors influencing the watershed.

Figure 1. The process of conducting a Wyoming Habitat Assessment Methodology (WHAM) Level I assessment on lotic systems in Wyoming. The focus of a Level I assessment is the watershed and stream-segment scales.



Level I consists of six steps (Figure 1) and measurement of several variables representing large scale features and processes (Table 1). The first step identifies the watershed location followed by the accumulation of pre-existing information (Step 2) on geologic features, hydrologic conditions, climate, vegetation communities, fish and wildlife assemblages, prior management activities, and anthropogenic influences. This information identifies potential logistic constraints to sampling and management activities, provides insight on the types of habitat and disturbances likely to be occurring in the watershed, and contributes to informed assessments when field data are added.

The next step (Figure 1; Step 3) is to segregate the watershed into stream segments. Segments are delineated by identifying major changes in topography (e.g., canyons versus alluvial valleys), tributary inputs, and water development activities (e.g., impoundments or water diversions). Subsequently, biologists traverse stream segments to record and geospatially reference [i.e., using a global position system (GPS)] field observations (Step 4) on eight general categories of habitat: (1) general descriptive information, (2) valley and channel morphology, (3) stream attributes, (4) riparian characteristics, (5) upland characteristics, (6) soil characteristics, (7) beaver (*Castor canadensis*) activity, and (8) natural and anthropogenic disturbances (Table 1). These data are summarized (Step 5) to provide an overview of the watershed.

The sixth step is to evaluate the accumulated information. Evaluation does not include detailed quantitative analyses, but is qualitative in that summarized information can be interpreted into a detailed description of the watershed. Such an assessment can provide a comprehensive understanding of the watershed and assist managers in identifying management concerns and opportunities.

LEVEL II ASSESSMENTS

Level II focuses on features at reach and channel-unit scales that influence the occurrence and abundance of fishes. Two methods are used in Level II: (1) the Habitat Quality Index (HQI; Binns and Eiserman 1979) for coldwater streams or (2) the Warmwater Stream Assessment (WSA; Quist et al. 2004, Quist et al. 2006) for warmwater streams.

Habitat Quality Index (HQI)

The HQI provides a method for sampling habitat in coldwater streams (Binns and Eiserman 1979) and is comprised of five steps (Figure 2). The first step is to identify sampling reaches. Level I identifies potential logistic constraints (e.g., topography, landownership) and areas of management concern, enabling a focus on reaches where an HQI might be conducted. The next step is to measure several habitat characteristics: water quality, flow characteristics, instream cover, and channel morphology (Table 1). In addition, prey for salmonids (e.g., macroinvertebrate abundance and diversity) may also be measured. Using these data, the HQI provides a rating system that allows for habitat evaluation. The rating system allows each habitat attribute to be assessed as to whether it represents poor (score=0) to excellent (score=4) habitat for salmonids in Wyoming (Binns and Eiserman 1979). Habitat attribute ratings can be used in conjunction with multiple regression equations to predict the average standing stock of trout for Wyoming given the scores. Thus, the HQI allows assessment of individual habitat features as well as the probable abundance of salmonids given the habitat.

Warmwater Stream Assessment (WSA)

The WSA provides sampling and assessment methods for both habitat and fish through seven steps (Figure 2; Quist et al. 2004, Quist et al. 2006). After a sampling reach is identified (Step 1), existing information is accumulated, including that from Level I. One component of this step is to develop a list of native species expected to occur based on historic (1880s) and recent (1940s present) fish surveys (Quist et al. 2004).

In the field, the reach is sketched to provide a reference map (Figure 2; Step 3) and habitat characteristics are categorized (Table 1). Reach-scale habitat measurements (Step 4) include estimates of turbidity, frequency of intermittence, and channel morphology, and channel-unit habitat measurements include water depth, substrate composition, and instream cover. Fish are sampled throughout the reach using standardized methods (e.g., electrofishing, seining).

Summary tables and decision trees provide assessments of acquired information. A summary table is a data matrix that summarizes critical habitat features required by each species and habitat characteristics present in the reach. Species expected in the reach, as well as species collected but not expected (e.g., invasive species), are listed along with their habitat requirements (ranges of habitat values obtained from the literature and previous research in Wyoming). Habitat requirements are then compared to the availability of habitats in the reach to provide an indication as to which habitat features are likely promoting or limiting the occurrence of individual species. Decision trees for each species are based on information on their distribution and ecology in Wyoming, and integrate information on zoogeographical constraints, habitat requirements, and biotic interactions. Decision trees follow the concept of hierarchical faunal filters (Matthews 1998) where passage of a species through a filter is dependent on the ecology of the species and the composition of the filter. The first filter asks whether the reach is within the native distribution of the species. If the answer is "yes," subsequent questions focus on habitat features required by the species. If answers to all questions are "yes," the species is expected to be present in the reach. A "no" answer suggests that a species should be absent in the reach and provides an indication of the habitat features that are likely limiting its occurrence. The combined insight gained from the summary table and deci-

Table 1. Examples of information gathered during each level of the Wyoming Habitat Assessment Methodology (WHAM).

CATEGORY	VARIABLES
Level I	
General characteristics	Hydrologic Unit Codes (10- and 12-digit HUCs), GPS coordinates, elevation, land ownership, channel gradient
Valley and channel morphology	Valley form, Rosgen channel type (Rosgen 1996)
Aquatic habitat features	Stream width, dominant substrate, occurrence and prevalence of streambank erosion
Riparian habitat features	Dominant vegetation type (e.g., growth form, species), encroachment of upland species, riparian width, occurrence of vegetation recruitment, occurrence of invasive species
Upland habitat features	Dominant vegetation type (e.g., growth form, species), riparian width, occurrence of vegetation recruitment, occurrence of invasive species
Soil features	Occurrence of hydric soils, occurrence and type of soil erosion
Beaver activity	Occurrence of remnant and active beaver populations, extent of beaver activity, beaver habitat suitability (e.g., presence of food and building supplies)
Disturbance	Occurrence, extent, and historical context (e.g., past or present) of natural (e.g., fire, waterfalls) and anthropogenic (e.g., grazing, logging, diversion structures) disturbances
Level II	
Habitat Quality Index (HQI)	
General characteristics	Same as for Level I
Water quality	Water temperature (i.e., point estimates at sampling, maximum temperatures), nitrate concentration
Discharge and flow	Critical period discharge (mean daily discharge during August and first half of September), average daily flow (mean daily discharge for water year), annual stream flow variation (annual peak discharge / annual low discharge), mean water column velocity
Channel morphology and streambank condition	Mean stream width, channel-unit composition, occurrence and prevalence of eroding streambanks
Instream cover characteristics	Coverage of aquatic macrophytes, woody debris, undercut banks, overhanging cover, and deep-pool habitat
Prey production	Occurrence and density of aquatic macroinvertebrates
Warmwater Stream Assessment (WSA)	
General characteristics	Same as for Level I
Reach-scale habitat	Channel-unit composition, categorical description of turbidity and frequency of intermittence
Channel-unit habitat[a]	Maximum depth, substrate composition, substrate embeddedness, coverage of aquatic macrophytes, wood debris, undercut banks, overhanging cover, and deep-pool habitat
Fish assemblage	Occurrence and abundance (total number, catch-per-unit-effort) of individual fish species

[a]Habitat features are recorded for individual channel units.

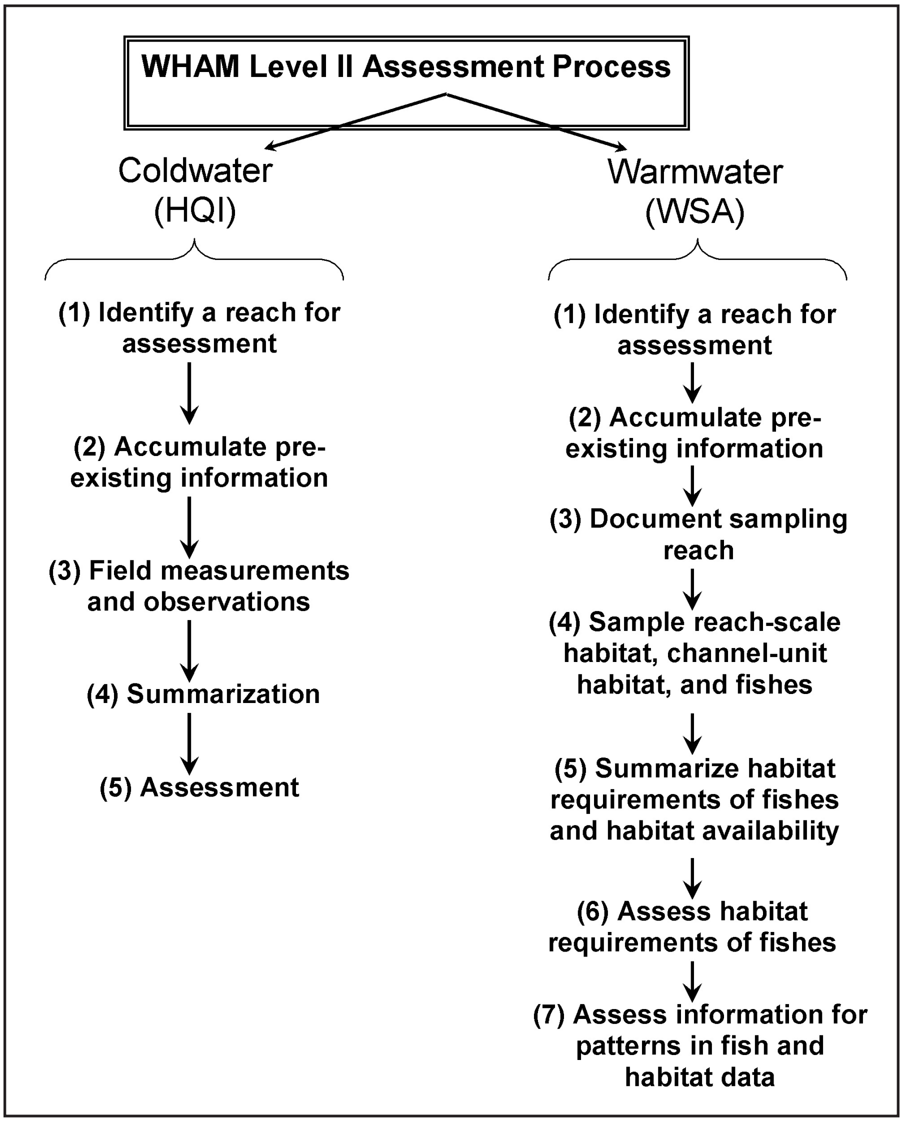


Figure 2. Framework for conducting a Level II assessment in coldwater and warmwater stream systems. A Habitat Quality Index (HQI) evaluation focuses on reach and channel-unit habitat in coldwater stream systems. A Warmwater Stream Assessment (WSA) focuses on reach and channel-unit habitat in warmwater stream systems.

sion trees provides an assessment of factors affecting both native and introduced fishes.

LEVEL III ASSESSMENTS

The purpose of Level III is to address management problems unique to a specific stream segment, stream reach, channel-unit type, or microhabitat. Examples requiring Level III assessment may include evaluations on the effects of bridge or dam construction, efficacy of habitat enhancement activities, or influences of oil and gas development on instream habitat characteristics. Level III generally involves measurement of variables beyond those included in Levels I and II and utilizes protocols specific to each project (e.g., Annear et al. 2004).

EXAMPLE OF THE WHAM PROCESS

To illustrate the WHAM process, an example is presented from upper Muddy Creek (Figure 3), a small tributary in the Colorado River drainage of Wyoming.

Level I Assessment

The first component of the WHAM was a Level I assessment. Based on knowledge of the system and examination of topographic maps, seven stream segments were established (Figure 3). Each segment was traversed and observations on riparian and upland characteristics, stream characteristics, and disturbances (natural and anthropogenic) were made following the Level I protocol.

It was found that most of upper Muddy Creek and Littlefield Creek had perennial flows (Figure 3; segments 3–7), but Muddy Creek and its tributaries were intermittent beginning in Segment 2 downstream to its mouth. The headwaters of Littlefield, McKinney, and Muddy creeks were in narrow, moderately steep valleys, with channel gradients of 2–4% and channel substrates composed predominantly of gravel. Riparian vegetation generally consisted of grasses, sedges (*Carex* spp.), rushes (*Scirpus* spp. and *Juncus* spp.), with patches of willows (*Salix* spp.) and water birch (*Betula occidentalis*). Riparian vegetation and streambanks appeared to be widely impacted by livestock grazing. Downstream of the headwaters, most channels had gradients less than 2% with silt clay—substrates and were deeply incised with 2- to 4-m high eroding banks. Habitat for beaver was limited due to the lack of large woody material (e.g., willows, aspen *Populus tremuloides*), likely due to the interaction of intense livestock grazing, fire suppression required for aspen regeneration, extensive chemical treatment of willows in the 1960s, and limited colonization due to channel incision.

Anthropogenic disturbances in the watershed included livestock grazing, improved and unimproved roads, and water development. Grazing by sheep and cattle appeared to be a primary factor influencing the upper Muddy Creek watershed. An extensive network of gravel and dirt roads enhances the rate of runoff and erosion. Barriers to upstream movements by fishes and their interaction with stream habitat were an additional source of anthropogenic impact. Numerous structures had been built to prevent further incision of the stream bed and to divert water from the creek into irrigated meadows. Additional barriers to fish movement included structures built as part of cutthroat trout (*Oncorhynchus clarki*) restoration activities near the headwaters and poorly-designed culverts.

Level II Assessment

Habitat Quality Index (HQI). One area of interest in the upper Muddy Creek watershed was the Grizzly Wildlife Habitat Management Area (WHMA) encompassing the headwaters of Muddy and Littlefield creeks. State ownership has enabled instream habitat improvements and cutthroat trout restoration efforts to be conducted for

Figure 3. Map of the upper Muddy Creek watershed in south-central Wyoming. Circles represent stream segment boundaries (e.g., segment 1 = S1) used for the Level I assessment. Stars represent reaches sampled for Level II evaluation: Habitat Quality Index (HQI) or Warmwater Stream Assessment (WSA).

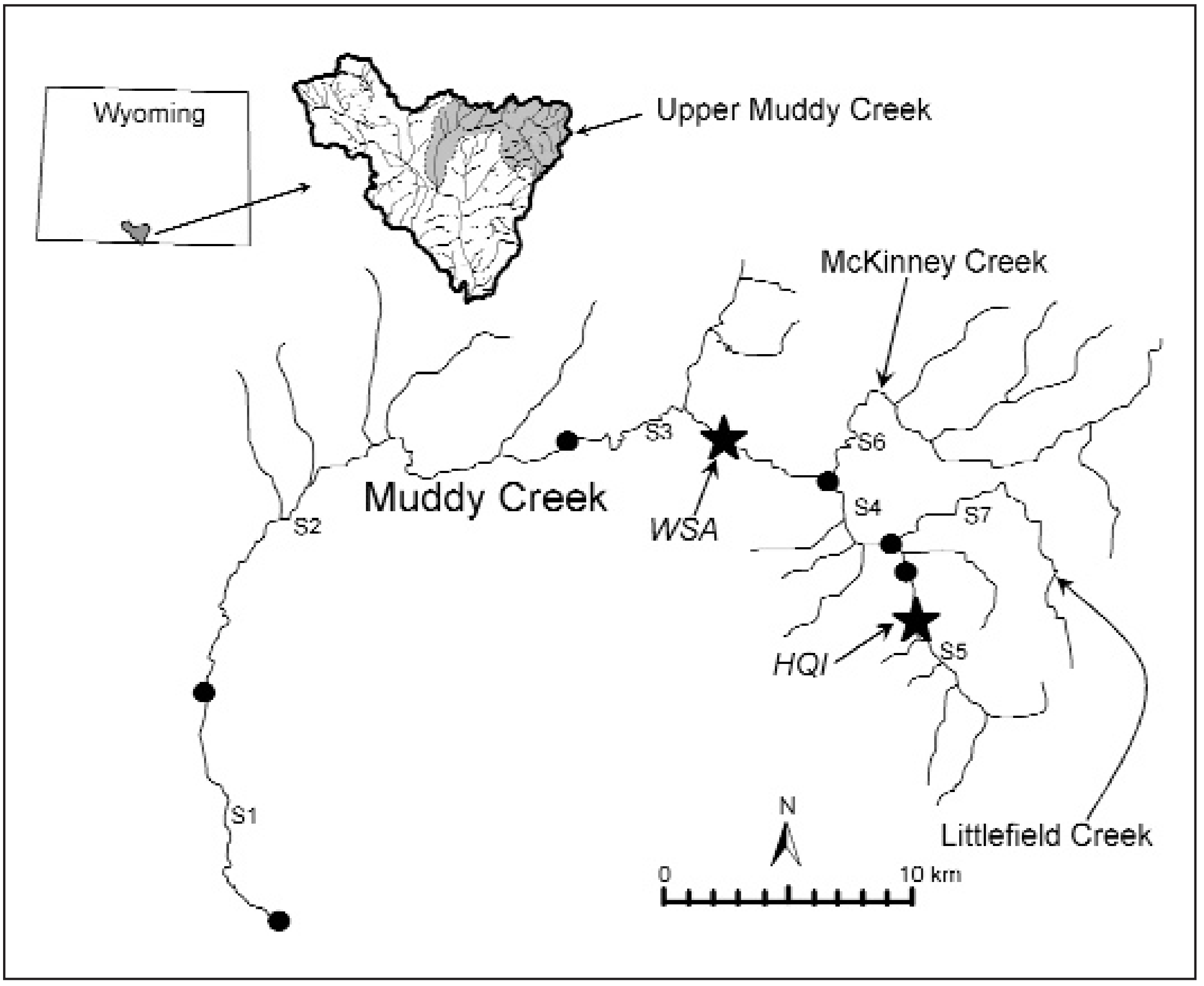


Table 2. Habitat variables sampled from Muddy Creek, Wyoming, in 1991 and 2003 as part of a Habitat Quality Index (HQI) assessment. Ratings reflect habitat suitability (0 = poor; 4 = excellent) for trout in Wyoming streams (Binns and Eiserman 1979).

	1991		2003	
Variable	Value	Rating	Value	Rating
Late summer streamflow[a] (%)	40	3	40	3
Annual streamflow variation[b] (%)	70	2	30	3
Maximum temperature	78	1	75	2
Nitrate (mg/L)	0.01	1	0.01	1
Cover (%)	10	1	27	2
Eroding bank (%)	85.0	0	1.8	4
Food abundance (number / m^2)	15	2	16	2
Velocity (m/s)	0.22	2	0.16	2
Width (m)	2.2	2	1.4	1

[a] Calculated as the critical period flow (CPF = mean daily flow during August and the first half of September) divided by average daily flow (ADF = mean daily flow for the water year).

[b] Calculated as the annual peak flow divided by the annual low flow.

salmonids. A HQI of a reach of upper Muddy Creek within the WHMA indicated that habitat quality was poor for salmonids in 1991 due to lack of instream cover (e.g., deep pools and undercut banks; Table 2). Eroding banks were ubiquitous and the reach was relatively wide and shallow (mean depth=0.18 m). Predicted trout biomass was only 4.2 kg/ha. Following efforts to improve habitat (e.g., changes in grazing practices, fencing), a HQI was conducted on the same reach in 2003. The amount of instream cover and predicted trout biomass (12.9 kg/ha) had both increased, but predicted trout abundance was still relatively low compared to other streams in Wyoming.

Warmwater Stream Assessment (WSA). Recently, attention has focused on native fishes of the upper Colorado

Table 3. Summary table for the Warmwater Stream Assessment (WSA) used to assess fish and habitat in Muddy Creek, Wyoming.
Substrate categories include silt (Si), sand (Sa), gravel (Gr), cobble (Co), and boulder (Bo). Cover categories include aquatic vegetation (AV) and woody debris (WD). Species include roundtail chub (RTC), bluehead sucker (BHS), speckled dace *Rhinichthys osculus* (SPD), white sucker *Catostomus commersoni* (WHS), and flannelmouth sucker (FMS).

			EXPECTED AND PRESENT			EXOTIC	EXPECTED AND ABSENT
		Reach	**RTC**	**BHS**	**SPD**	**WHS**	**FMS**
Intermittence	Frequent						
	Rarely	X					
	Never						
Turbidity	Low						
	High	X					
Deep pools (> 0.5 m):	Present	X	X	X		X	X
Deep pools (>0.5 m) with:	Si	X					
	Sa	X	X	X		X	X
	Gr	X	X	X		X	X
	Co	X	X	X		X	X
	Bo						
	AV	X	X				
	WD	X	X				
	Si + AV	X					
	Si + WD						
	Sa + AV	X					
	Sa + WD						
	Gr + AV	X					
	Gr + WD						
	Co + AV						
	Co + WD						
	Bo + AV						
	Bo + WD						
Riffles:	Present	X	X	X	X	X	
Riffles with:	Gr	X		X	X	X	X
	Co	X		X	X	X	X
	Bo	X		X	X	X	X
Runs with:	Gr	X		X	X	X	X
	Co	X		X	X	X	X
	Bo	X		X	X	X	X
Exotic predators:	absent	X	X	X			X

River basin, particularly roundtail chub (*Gila robusta*), bluehead sucker (*Catostomus discobolus*), and flannelmouth sucker (*C. latipinnis*). Level I identified that instream structures may influence habitat and distributions of these species in the upper Muddy Creek watershed. One of several WSAs was conducted immediately downstream of a structure used to divert water for irrigation (Figure 3). The resulting summary table (Table 3) indicated that roundtail chubs, bluehead suckers, and speckled dace were expected and sampled, flannelmouth suckers were expected but absent, and white suckers were an exotic species present in the reach. Decision trees (Figure 4) provided further insight. Because we answered "yes" to all questions, we expected to find roundtail chubs, bluehead suckers, and flannelmouth suckers in the reach. Flannelmouth suckers were absent from our samples, suggesting that factors other

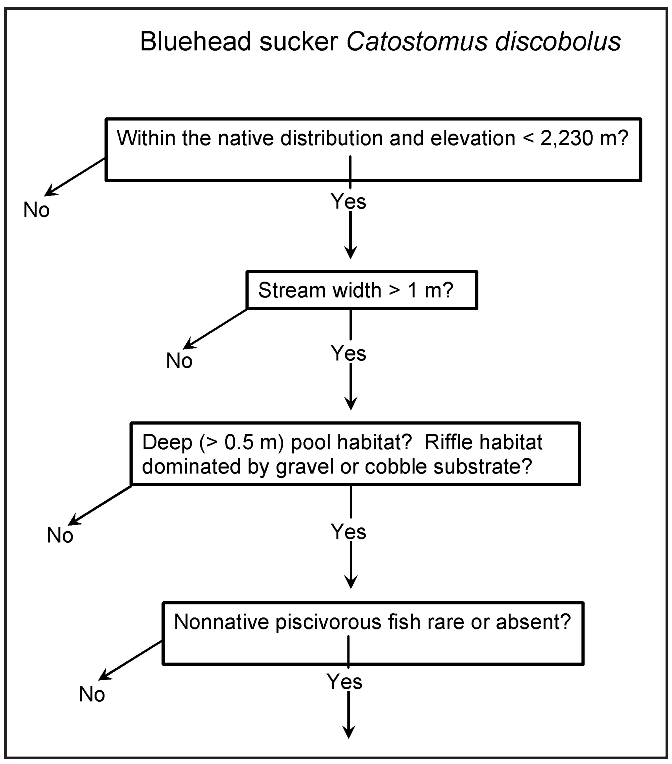


Figure 4. Decision tree used in the Warmwater Stream Assessment to evaluate the occurrence of bluehead suckers. A "yes" answer indicates that the species should be present, while a "no" answer indicates that the species is likely absent from the reach.

than instream habitat may prevent their occurrence. Integrating knowledge from the Level I and the results from WSAs upstream in the watershed suggested that the irrigation diversion structure may prevent upstream movements by flannelmouth suckers to suitable spawning and nursery habitat.

Level III Assessment

The cumulative knowledge obtained from the Level I and Level II (i.e., HQI and WSA) has obvious value to natural resource managers in the Muddy Creek watershed. However, additional questions may surface from these assessments that cannot be answered from the accumulated information. For instance, managers may have questions regarding instream flow requirements, specific influences of riparian or upland conditions on hydrology, decadence of aspen stands, changes in habitat or prevention of fish movement due to instream structures, or the role of roads on sediment dynamics in Muddy Creek. Such questions and the techniques required to answer these questions can be considered Level III assessments. For example, a Level III assessment is occurring in upper Muddy Creek to determine the effects of instream structures and stream intermittence on movements of native, warmwater fishes.

BENEFITS AND UTILITY OF THE WHAM

Research and management activities on stream systems have emphasized reach, channel-unit, or microhabitat scales (Osborne et al. 1991; Fausch et al. 2002). Such approaches are useful and will continue to be important components of habitat measurement systems, but approaches that focus on larger scales are increasingly important to natural resource managers. The WHAM is a structured approach that provides managers with a conceptual framework for multi-scale management activities. The three levels of assessment used in the WHAM mimic the natural hierarchy of stream systems. Level I focuses on watershed and stream segment scales, Level II focuses on reach and channel-unit scales, and Level III may occur at one or all of these scales. When assessments are conducted in sequence (i.e., Levels I, II, and III), each level provides further insight. The greatest strength of WHAM occurs when all levels become part of one cohesive process.

Fisheries management programs can become hindered by lack of data analysis and evaluation. When programs ignore detailed evaluation of information, managers may be captured in the activity trap (Hubert and Bergersen 1998) with the accumulation of data being the endpoint. The WHAM produces "inventory" data, but goes further to provide a structured format for evaluation and interpretation. The sampling protocols of WHAM make field work efficient and focused, and provide information that facilitates informed management decisions. Like any aspect of natural resource management, the WHAM is anticipated to change and evolve, but regardless of how it may change, it provides a structure for planning and conceptualizing activities, promoting efficiency, and focusing on evaluation of information that may serve as a useful template for other management agencies.

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