

Spatial Patterns of Fish Assemblage Structure in a Tributary System of the Upper Colorado River Basin

Michael C. Quist

Department of Natural Resource Ecology and Management
Iowa State University, Ames, Iowa 50011-3221 USA

Michael R. Bower^a and Wayne A. Hubert

U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit
University of Wyoming, Laramie, Wyoming 82071-3166 USA

and

Frank J. Rahel

Department of Zoology and Physiology
University of Wyoming, Laramie, Wyoming 82071-3166 USA

ABSTRACT

This study was conducted to describe the distributions of both native and nonnative fishes and to identify spatial patterns in fish assemblage structure of Muddy Creek in the upper Colorado River basin of Wyoming using data collected from 77 reaches during 1999-2004. Fish assemblages in high-elevation reaches were characterized by brook trout (*Salvelinus fontinalis*) and represented a coldwater faunal zone. Reaches at lower elevations were characterized by warmwater fish species. The upper segment of the warmwater faunal zone contained four native (i.e., bluehead sucker [*Catostomus discobolus*], flannelmouth sucker [*C. latipinnis*], speckled dace [*Rhinichthys osculus*], roundtail chub [*Gila robusta*]) and two nonnative (i.e., white sucker [*C. commersoni*] and creek chub [*Semotilus atromaculatus*]) species. The lower segment of the warmwater faunal zone included species present in upstream segments and three additional nonnative species (i.e., common carp [*Cyprinus carpio*], redbelly darter [*Richardsonius balteatus*], and fathead minnow [*Pimephales promelas*]). Differences in fish assemblage structure between coldwater and warmwater faunal zones were likely due to physiological constraints of species adapted for either coldwater or warmwater habitats. Changes in fish assemblages over the warmwater faunal zone are due to introduction and naturalization of nonnative fishes and anthropogenic barriers preventing upstream movements and colonization by some of these species.

INTRODUCTION

Understanding spatial patterns in fish assemblage structure is critical for the conservation and management of native fishes (Matthews 1998, Jackson et al. 2001, Wright and Li 2002). A large body of knowledge has accumulated regarding the spatial distribution of fishes in stream systems. A prominent concept in stream ecology focuses on longitudinal gradients that structure fish assemblages through either the addition of species or faunal zonation. Species addition is the gradual addition of species with downstream progression (Matthews 1998). In some streams, species are simply added without replacing other species (e.g., Sheldon 1968, Morin and Naiman 1990); whereas in other systems, species are added while others disappear from the assemblage (e.g., Gard and Flitner 1974, Matthews 1998). Zonation occurs when ecologically-similar species form unique assemblages in response to abrupt changes in habitat, such as thermal conditions or channel morphology (Huet 1959, Winemiller and Leslie 1992, Kirchhofer 1995).

^a Current address: U.S. National Park Service, Death Valley National Park, Death Valley, California 92328 USA.

Nearly all studies focusing on spatial patterns of fish assemblage structure have been conducted in the eastern and midwestern U.S. (e.g., Lotrich 1973, Matthews 1986). These studies generally support the notion that species richness increases with downstream progression (Angermeier and Schlosser 1989). Many changes in fish assemblage structure are gradual with little or no evidence of biotic zonation; so biotic zonation is often ignored as a feature of fish assemblage structure in eastern and midwestern regions (Matthews 1998). In contrast, many streams in the western U.S. originate in montane habitats and then transition, often abruptly, to prairie or desert habitats. As such, coldwater and warmwater faunal zones are common. However, only recently have spatial patterns in fish assemblage structure been investigated for western streams (e.g., Hughes and Gammon 1987, Rahel and Hubert 1991, Wright and Li 2002, Quist et al. 2004). Not only are more studies needed to contribute knowledge on the organization of fish assemblages, but threats to native fishes from water development and invasions of nonnative species illustrate the importance of understanding factors affecting fish assemblage patterns in western streams (Richter et al. 1997, Minckley et al. 2003).

Our purpose was to examine spatial patterns in fish assemblage structure in Muddy Creek (Little Snake River watershed of the upper Colorado River basin) of Wyoming. Specifically, we sought to determine how species were distributed and whether there were distinct assemblage types (i.e., repetitive species associations) in the watershed.

MATERIALS AND METHODS

Muddy Creek, a tributary to the Little Snake River in southcentral Wyoming (Fig. 1), is an area of high conservation value for native fishes because it historically contained populations of Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) and

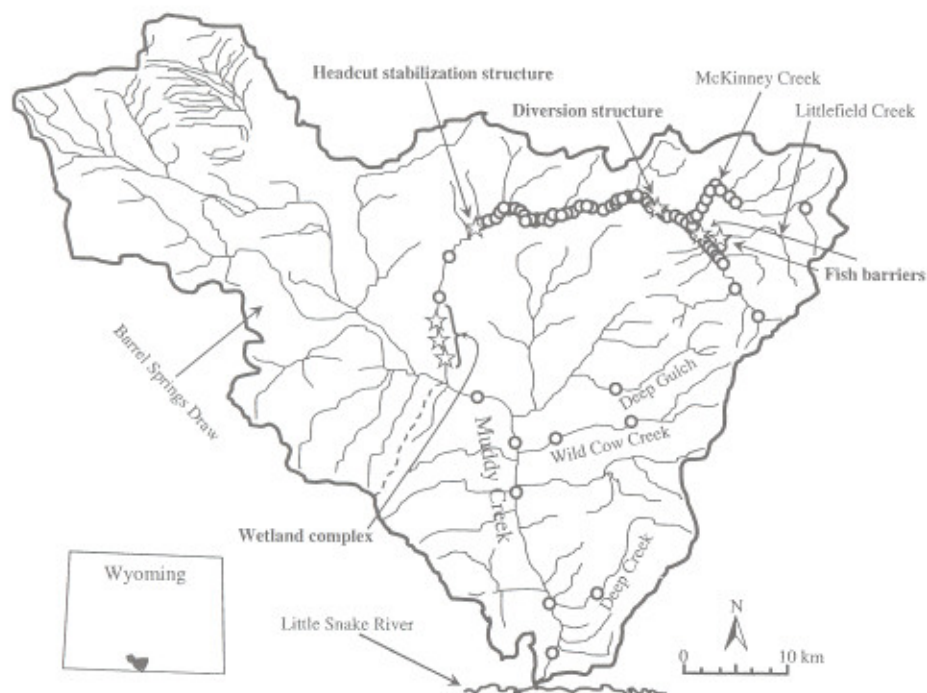


Figure 1. Map of the Muddy Creek watershed, Wyoming. Sampled reaches (1999-2004) are indicated by open circles.

currently contains populations of roundtail chub (*Gila robusta*), bluehead sucker (*Catostomus discobolus*), and flannelmouth sucker (*C. latipinnis*), all species of high conservation concern (e.g., Bezzerides and Bestgen 2002). The watershed is about 2,500 km², and elevation varies from 2,500 m in the headwaters to 1,900 m at the confluence of Muddy Creek with the Little Snake River. Topography in the watershed is variable with gentle to moderately-sloping flats and hills, badlands, and canyons with steep slopes. Most of Muddy Creek and its tributaries have perennial flow, but Barrel Springs Draw and Muddy Creek downstream of its confluence with Barrel Springs Draw are generally intermittent during July and August. Streams in headwater areas flow through narrow, moderately-steep valleys and have channel gradients of 2-4%. Wetted stream widths are generally less than 2 m, and substrate is dominated by gravel with some cobble, boulder, and sand. As streams flow off the mountains and onto the plains, channel gradients are reduced (< 1%), stream width increases (< 5 m), and substrate becomes dominated by silt and sand in pool habitats and gravel in riffle habitats. The stream has high turbidity during periods of high flow and experiences wide fluctuations in temperature and dissolved oxygen during summer. Primary forms of instream structure include woody debris (e.g., waterbirch [*Beula occidentalis*], willow [*Salix* spp.]), and submerged aquatic vegetation (e.g., *Potamogeton* spp.).

Muddy Creek has experienced water development for agricultural uses, bank stabilization, and instream structures built to prevent upstream movement of nonnative brook trout (*Salvelinus fontinalis*) as part of cutthroat trout restoration activities. Progressing upstream from the mouth of Muddy Creek, the first barriers to upstream movements by fishes are a series of dams (> 1.0 m high) constructed in the 1980s to create wetlands and store water for agricultural use. The next barrier is a concrete structure (~10 m high) constructed in 2002 to stabilize a large headcut that was progressively moving upstream. A small irrigation diversion structure constructed in 2002 farther upstream may prevent upstream movement of fishes during low flow periods but is probably not a barrier during high flow periods. Lastly, two fish barriers were constructed as part of cutthroat trout restoration activities—one on Muddy Creek (1995) and one on Littlefield Creek (1999).

Fish were sampled during June-August 1999-2004 in 200 m reaches with a backpack electrofishing unit. Immediately following electrofishing, fish were also sampled in each reach using a bag seine in pool and run habitats. Seventy-seven reaches were sampled, 68 of which were upstream of the wetland complex. All captured fish were identified to species, counted, and released.

Elevations of sampled reaches were estimated by combining global positioning system coordinates with a digital elevation model for the watershed. The median, percentiles, and range of elevation where each species was found were calculated using the Statistical Analysis System (SAS Institute, Cary, North Carolina) to provide insight on longitudinal patterns of species occurrence. Similarities in the presence or absence of species among reaches were evaluated by calculating Jaccard's index of similarity for each pair of species (Jongman et al. 1995). The unweighted pair-group method was used to cluster the matrix of similarity indices. Results of this analysis produced a dendrogram depicting those species that were most often collected in sympatry (Matthews 1998). Cluster analysis was conducted using NTSYSpc version 2.1 (Exeter Software, Setauket, New York).

RESULTS

Five native and six nonnative species were sampled (Table 1). Speckled dace (*Rhinichthys osculus*), creek chub (*Semotilus atromaculatus*), white sucker (*Catostomus*

commersoni), and roundtail chub were the most common species and were present in over 75% of the sampled reaches. We found similar patterns of occurrence when only data collected upstream of the wetland complex were considered. The most common species upstream of the complex included two introduced species (white sucker and creek chub) and two native species (speckled dace and roundtail chub). Common carp, fathead minnow, and redbreasted shiner were not sampled upstream of the wetland complex.

Brook trout occurred in high-elevation reaches (Fig. 2). Mountain sucker (*Catostomus platyrhynchus*), bluehead sucker, creek chub, and speckled dace occurred with brook trout in a few reaches, but they also occurred throughout the watershed in sympatry with other warmwater fishes. The only exception was mountain sucker, which was generally restricted to higher elevations. We observed no evidence of a gradual addition of native species with progression downstream. Three nonnative species (common carp, redbreasted shiner, and fathead minnow) were added downstream of the wetland complex.

Jaccard index values of similarity varied from 0 to 0.86, indicating that some species were never collected together while other species were almost always found in sympatry (Fig. 3). Brook trout and mountain sucker often occurred together in coldwater portions of the system. Creek chub and speckled dace almost always occurred in the same reaches and were often sampled in association with white sucker, roundtail chub, bluehead sucker, and flannelmouth sucker. This group of species generally comprised fish assemblages upstream of the wetland complex. Redbreasted shiner and common carp were often collected in the same reaches and, along with fathead minnow, represented fish assemblages in the lower segment of Muddy Creek.

Table 1. Occurrence of fish species in Muddy Creek, Wyoming. * = nonnative species.

Species	All reaches (N = 77)		Reaches upstream of the wetland complex (N = 68)	
	Number of reaches	%	Number of reaches	%
Salmonidae				
Brook trout*	5	6.5	5	7.4
Cyprinidae				
Common carp*	2	2.6	0	0
Creek chub*	67	87.0	59	86.8
Fathead minnow*	1	1.3	0	0
Redbreasted shiner*	3	3.9	0	0
Roundtail chub	58	75.3	55	80.9
Speckled dace	69	89.6	63	92.6
Catostomidae				
Bluehead sucker	50	64.9	46	67.6
Flannelmouth sucker	42	54.5	40	58.8
Mountain sucker	6	7.8	6	8.8
White sucker*	63	81.8	55	80.9

DISCUSSION

We observed biotic zonation in Muddy Creek, with two distinct faunal zones—a coldwater faunal zone dominated by brook trout and a warmwater faunal zone comprised of native and nonnative cyprinids and catostomids. The warmwater faunal zone may be

further described as having upper and lower segments, where fish assemblages upstream of the wetland complex included bluehead sucker, flannelmouth sucker, white sucker, speckled dace, roundtail chub, and creek chub, and fish assemblages downstream of the wetland complex included all fishes found in the upstream warmwater segment plus fathead minnow, common carp, and redbreast shiner.

A short transitional area was observed between the coldwater zone and the warmwater zone with a fish assemblage comprised of mountain sucker, speckled dace, creek chub, white sucker, and bluehead sucker. Of these species, only mountain sucker was not also found in strictly warmwater habitats, suggesting that it may be the sole representative of a coolwater or transitional faunal zone. Once in the warmwater zone, fish assemblages generally contained the entire suite of native fishes with no addition of native fishes with downstream progression.

Changes in fish assemblage structure with progression downstream in the warmwater zone were due to addition of nonnative fishes and influences of instream structures that prevent upstream movements by fishes. Specifically, common carp, fathead minnow, and redbreast shiner were added to the fish assemblage in the lower segment of the warmwater zone, and their presence in upstream areas was likely prevented by the wetland complex. Fathead minnow and common carp have general habitat requirements (e.g., Cooper 1987, Matuszek et al. 1990, Quist et al. 2003). Redbreast shiner is commonly found in both coldwater and warmwater streams (e.g., Zaroban et al. 1999, Wright and Li 2002). Thus, if these three nonnative species had access to the upper segment of Muddy Creek, they would likely invade the entire warmwater zone.

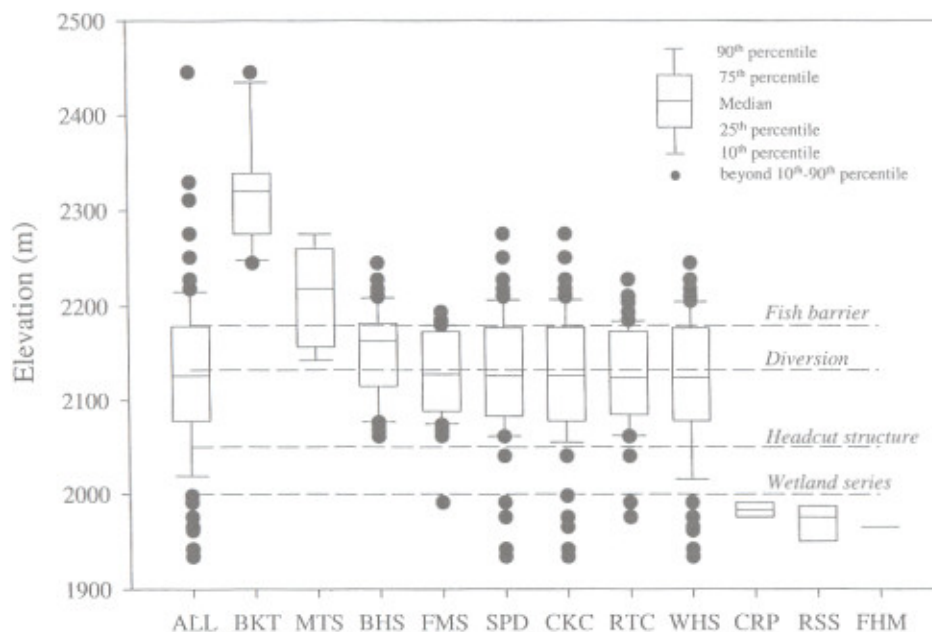


Figure 2. Box plots of elevation (m above sea level) for 77 stream reaches in the Muddy Creek watershed, Wyoming, during 1999-2004. ALL = all reaches; BKT = brook trout; MTS = mountain sucker; BHS = bluehead sucker; FMS = flannelmouth sucker; SPD = speckled dace; CKC = creek chub; RTC = roundtail chub; WHS = white sucker; CRP = common carp; RSS = redbreast shiner; and FHM = fathead minnow (FHM was collected from only one reach).

Muddy Creek did not exhibit a gradual addition of fish species from the headwaters to the plains, but a rapid transition from species associated with cold, mountain streams to species associated with warm, plains streams. Once on the plains and in the warmwater zone, there was no addition of native species with downstream progression. Changes in fish assemblage structure with downstream progression were associated with addition of nonnative fishes and influences of barriers to upstream movement by nonnative fishes. The observed pattern of fish assemblage structure is probably not unique to Muddy Creek because many headwater streams in the upper Colorado River basin have similar geomorphology and human disturbances (i.e., barriers).

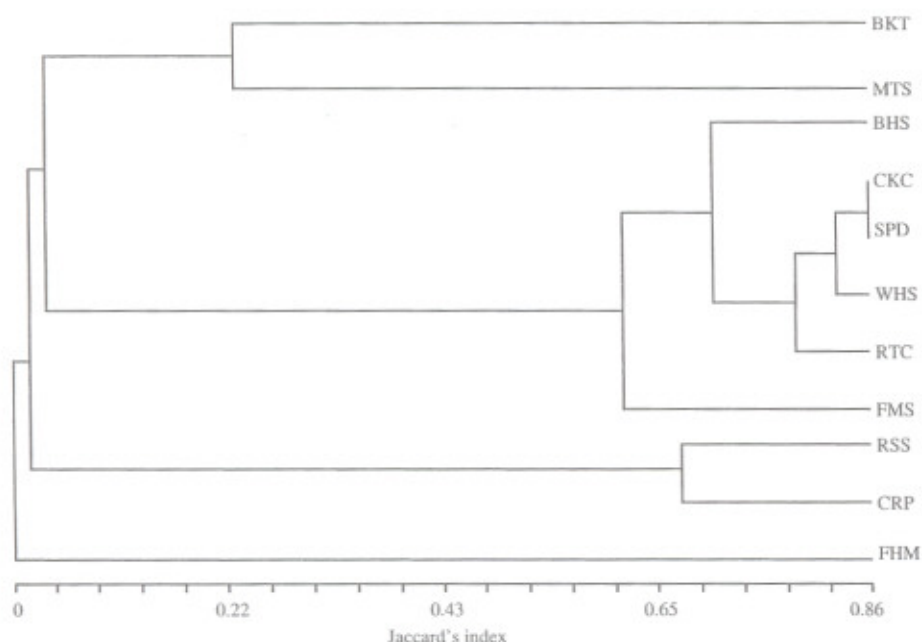


Figure 3. Dendrogram depicting reach similarity among species sampled from 77 stream reaches in the Muddy Creek watershed, Wyoming, during 1999-2004. ALL = all reaches; BKT = brook trout, MTS = mountain sucker; BHS = bluehead sucker; FMS = flannemouth sucker; SPD = speckled dace; CKC = creek chub; RTC = roundtail chub; WHS = white sucker; CRP = common carp; RSS = redside shiner; and FHM = fathead minnow.

ACKNOWLEDGMENTS

We thank R. Beatty for assistance in the field. Clay Pierce, Mary Litvan, David Rowe and two anonymous reviewers provided helpful comments on an earlier version of the manuscript. Funding was provided by the U.S. Bureau of Land Management, Wyoming Cooperative Fish and Wildlife Research Unit (the Unit is jointly sponsored by the U.S. Geological Survey, Wyoming Game and Fish Department, University of Wyoming, and Wildlife Management Institute), and Iowa State University.

LITERATURE CITED

- Angermeier, P. L. and I. J. Schlosser. 1989. Species-area relationships for stream fishes. *Ecology* 70:1450-1462.
- Bezzerrides, N. and K. Bestgen. 2002. Status review of roundtail chub *Gila robusta*, flannemouth sucker *Catostomus latipinnis*, and bluehead sucker *Catostomus*

- discobolus* in the Colorado River basin. Colorado State University, Larval Fish Laboratory Contribution 118, Fort Collins.
- Cooper, E. L., editor. 1987. Carp in North America. American Fisheries Society, Bethesda, Maryland.
- Gard, R. and G. A. Flitner. 1974. Distribution and abundance of fishes in Sagehen Creek, California. *Journal of Wildlife Management* 38:347-358.
- Huet, M. 1959. Profiles and biology of European streams as related to fish management. *Transactions of the American Fisheries Society* 88:155-163.
- Hughes, R. M. and J. R. Gammon. 1987. Longitudinal changes in fish assemblages and water quality in the Willamette River, Oregon. *Transactions of the American Fisheries Society* 116:196-209.
- Jackson, D. A., P. R. Peres-Neto, and J. D. Olden. 2001. What controls who is where in freshwater fish communities—the roles of biotic, abiotic, and spatial factors. *Canadian Journal of Fisheries and Aquatic Sciences* 58:157-170.
- Jongman, R. H. G., C. J. F. ter Braak, and O. F. R. van Tongeren. 1995. Data analysis in community and landscape ecology. Cambridge University Press, New York.
- Lotrich, V. A. 1973. Growth, production, and community composition of fishes inhabiting a first-, second-, and third-order stream of eastern Kentucky. *Ecological Monographs* 43:377-397.
- Kirchhofer, A. 1995. Morphological variability in the ecotone—an important factor for the conservation of fish species richness in Swiss rivers. *Hydrobiologia* 303:103-110.
- Matthews, W. J. 1986. Fish faunal "breaks" and stream order in the eastern and central United States. *Environmental Biology of Fishes* 17:81-92.
- Matthews, W. J. 1998. Patterns in freshwater fish ecology. Chapman and Hall, New York.
- Matuszek, J. E., J. Goodier, and D. L. Wales. 1990. The occurrence of Cyprinidae and other small fish species in relation to pH in Ontario lakes. *Transactions of the American Fisheries Society* 119:850-861.
- Minckley, W. L., P. C. Marsh, J. E. Deacon, T. E. Dowling, P. W. Hedrick, W. J. Matthews, and G. Mueller. 2003. A conservation plan for native fishes of the lower Colorado River. *BioScience* 53:219-234.
- Morin, R. and R. J. Naiman. 1990. The relation of stream order to fish community dynamics in a boreal forest watershed. *Polske Archiwum Hydrobiologii* 37:135-150.
- Quist, M. C., P. A. Fay, C. S. Guy, A. K. Knapp, and B. N. Rubenstein. 2003. Military training effects on terrestrial and aquatic communities on a grassland military reservation. *Ecological Applications* 13:432-442.
- Quist, M. C., W. A. Hubert, and D. J. Isaak. 2004. Fish assemblage structure and relations with environmental conditions in a Rocky Mountain watershed. *Canadian Journal of Zoology* 82:1554-1565.
- Rahel, F. J. and W. A. Hubert. 1991. Fish assemblage and habitat gradients in a Rocky Mountain-Great Plains stream: biotic zonation and additive patterns of community change. *Transactions of the American Fisheries Society* 120:319-332.
- Richter, B. D., D. P. Braun, M. A. Mendelson, and L. L. Master. 1997. Threats to imperiled freshwater fauna. *Conservation Biology* 11:1081-1093.
- Sheldon, A. L. 1968. Species diversity and longitudinal succession in stream fishes. *Ecology* 49:193-198.
- Winemiller, K. O. and M. A. Leslie. 1992. Fish assemblages across a complex tropical freshwater/marine ecotone. *Environmental Biology of Fishes* 34:29-50.

- Wright, K. K. and J. L. Li. 2002. From continua to patches: examining stream community structure over large environmental gradients. *Canadian Journal of Fisheries and Aquatic Sciences* 59:1404-1417.
- Yiming, L. and D. S. Wilcove. 2005. Threats to vertebrate species in China and the United States. *BioScience* 55:147-153.
- Zaroban, D. W., M. P. Mulvey, T. R. Maret, R. M. Hughes, and G. D. Merritt. 1999. Classification of species attributes for Pacific Northwest freshwater fishes. *Northwest Science* 73:81-93.