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Identification and Implementation of Native Fish Conservation Areas in the Upper Colorado River Basin

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ABSTRACT: Freshwater fishes continue to decline at a rapid rate despite substantial conservation efforts. Native fish conservation areas (NFCAs) are a management approach emphasizing persistent native fish communities and healthy watersheds while simultaneously allowing for compatible human uses. We identified potential NFCAs in the Upper Colorado River Basin in Wyoming—focusing on Colorado River cutthroat trout (Oncorhynchus clarkii pleuriticus), flannelmouth sucker (Catostomus latipinnis), bluehead sucker (Catostomus discobolus), and roundtail chub (Gila robusta)—through a process that combined known and modeled species distributions, spatial prioritization analysis, and stakeholder discussions. The network of potential NFCAs is intended to serve as a funding framework for a National Fish and Wildlife Foundation (NFWF) Keystone Initiative focused on Colorado River Basin native fishes. We discuss current opportunities for and impediments to implementing the potential NFCAs we identified for the NFWF Initiative over the long term. NFCAs represent a promising approach to fisheries management that complements existing approaches by focusing on persistent native fish communities.

Identificación e implementación de Áreas para la Conservación de Peces Nativos en la cuenca alta del Río Colorado

RESUMEN: Los peces de agua dulce continúan decreciendo rápidamente pese a los esfuerzos de conservación. Las Áreas para la Conservación de Peces Nativos (ACPN) es un enfoque de manejo en el que se enfatiza la persistencia de comunidades ícticas y de cuencas hidrológicas saludables, mientras se permite hacer uso del sistema de forma compatible con el enfoque. Se identifica una potencial ACPN en la cuenca alta del Río Colorado en Wyoming – particularmente para la trucha degollada (*Oncorhynchus clarkii pleuriticus*), el flannelmouth sucker (*Catostomus latipinnis*), el bluehead sucker (*Catostomus discobolus*) y el charalito de aleta redonda (*Gila robusta*) – mediante un proceso que combina distribuciones observadas y calculadas de las especies, análisis espacial de priorización y discusiones entre los usuarios. La red de potenciales ACPN pretende servir como marco conceptual para una iniciativa de la Fundación Nacional para la Vida Salvaje y la Pesca (FNVSP) enfocada a los peces nativos de la cuenca del Río Colorado. Se discuten las oportunidades para y los impedimentos de la implementación de las ACPN dentro de la iniciativa de largo plazo del FNVSP. Las ACPN representan un enfoque promisorio de manejo de pesquerías que complementa las estrategias existentes, enfocándose en la persistencia de las comunidades ícticas.

Introduction

Despite substantial resources being allocated to conservation of freshwater ecosystems, freshwater fishes in North America are continuing to decline at a much faster rate than their terrestrial counterparts (Master et al. 2000; Jelks et al. 2008). Williams et al. (2011, this issue) discuss how current conservation approaches, such as the National Wildlife Refuge system, have only been moderately successful at protecting riverine ecosystems because rivers are linear in nature and approaches based on terrestrial features and land ownership fail to consider watershed boundaries that are fundamental to aquatic conservation (e.g., Roux et al. 2008).

Though others have proposed protecting watershed-scale areas for aquatic conservation (Saunders et al. 2002), Williams et al. (2011, this issue) proposed the concept of native fish conservation areas (NFCA) where entire watersheds are cooperatively managed for native fish communities. As a complement to existing conservation approaches (e.g., headwater isolation; Novinger and Rahel 2003), implementation of NFCAs would emphasize habitat diversity and connectivity resulting from natural ecosystem processes, care for all life stages of focal species, large watersheds that facilitate long-term community persistence, and sustainable long-term management. The size of watersheds managed as an NFCA would be dependent on the aquatic ecosystem and native fish community rather than jurisdictional boundaries and ownerships.

Although many North American freshwater fishes are declining, the fish fauna native to the Colorado River Basin is especially imperiled (Minckley and Deacon 1968; Minckley et al. 2003). Only 14 fish species are native to the Upper Colorado River Basin (above Glen Canyon Dam), and 10 are endemic (Carlson and Muth 1989). At least 7 of the 10 endemic species are imperiled. Four large-river species are listed as endangered: razorback sucker (*Xyrauchen texanus*), bonytail (*Gila elegans*), humpback chub (*Gila cypha*), and Colorado pikeminnow (*Ptychocheilus lucius*). Over 60 nonnative fishes have been introduced, and some are known to compete and hybridize with or prey upon native fishes (Olden et al. 2006). Substantial resources have been directed toward native fish survival and recovery. Nonnative fish removal programs have been implemented (Mueller 2005), and hatchery programs continue to propagate native fish to supplement wild populations (Schooley and Marsh 2007). In 2008, over US$26 million were spent on recovery of the four endangered species (U.S. Fish and Wildlife Service [USFWS] 2010). Despite these efforts, none have been delisted, and all four remain at a high risk of extinction.

Four other species are not listed but are considered sufficiently at risk to warrant multistate conservation agreements: Colorado River cutthroat trout (*Oncorhynchus clarkii pleuriticus*), flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), and roundtail chub (*Gila robusta*; Colorado River cutthroat trout (CRCT) Coordination Team 2006; Utah Department of Natural Resources [UDNR] 2006). These nonlisted fishes native to the Colorado River Basin have received far less attention and resources compared to the endangered fishes. Although the Colorado River cutthroat trout is a sport fish, only 8% of its historic range is occupied by ecologically significant populations (unhybridized or having migratory life histories), with their decline due to habitat alteration and fragmentation and nonnative trout invasions (brook trout *Salvelinus fontinalis*, brown trout *Salmo trutta*, rainbow trout *Oncorhynchus mykiss*, and nonnative cutthroat trout subspecies; Young 2008). Flannelmouth sucker, bluehead sucker, and roundtail chub now occupy less than half of their historical ranges in the Upper Colorado River Basin (Bezzerides and Bestgen 2002). The native suckers have historically lacked management attention because they were often considered to be habitat generalists tolerant of environmental disturbances and competitors to sport fishes (Cooke et al. 2005). Past efforts were even made to remove them from rivers prior to reservoir impoundment, as was the case when 700 km of the Green River and its tributaries were treated with rotenone prior to the impoundment of Flaming Gorge Reservoir (Holden 1991; Wiley 2008).

Native fish conservation areas provide a useful management approach for the Upper Colorado River Basin because several conservation objectives can be accomplished in NFCAs that are extremely difficult or impossible on large rivers. Though management has emphasized endangered species recovery in the large rivers, NFCAs provide an opportunity to link the conservation of headwater trout populations with the medium-size streams that provide habitat for flannelmouth sucker, bluehead sucker, roundtail chub, and other native species. Most cutthroat trout populations are isolated in small headwater streams. NFCAs are managed to provide interconnected habitats that can increase population persistence by facilitating natural metapopulation processes (Dunham and Rieman 1999; Hilderbrand and Kershner 2000; Compton et al. 2008). At the same time, NFCAs can provide a discrete hydrologic unit in which native fish communities can be isolated, if needed, from nonnative invaders downstream (Novinger and Rahel 2003; Fausch et al. 2009; Clarkson and Marsh 2010). Likewise, watershed-scale control of nonnative fishes would alleviate threats from ongoing hybridization (McDonald et al. 2008; Metcalf et al. 2008). Established NFCAs should be large enough to allow long-term persistence of entire communities yet be small enough to be substantively managed in order to address the needs of a full suite of native species with one set of management actions. By focusing on watersheds encompassing Colorado River cutthroat trout, flannelmouth sucker, bluehead sucker, and roundtail chub, other native species will also benefit, because mountain sucker (*Catostomus platyrhynchus*), speckled dace (*Rhinichthys osculus*), and mottled sculpin (*Cottus bairdi*) often occur sympatric with cutthroat trout—or the three warmwater species—and occur in transitional zones between cold- and warmwater streams.

To this end, we describe a process of identifying watersheds—based on proximate occurrences of Colorado River cutthroat trout, flannelmouth sucker, bluehead sucker, and roundtail chub—in the Upper Colorado River Basin in Wyoming (Upper Green and Yampa subbasins) that have the potential to be managed as NFCAs. We intended to identify NFCAs at the 10-digit hydrologic unit code (HUC) scale (U.S. Geological Survey and U.S. Department of Agriculture [USGS and USDA] 2009) but realized that the exact size would be dependent on specific characteristics of each NFCA. Identification of potential NFCAs is intended to serve as a funding framework for a new National Fish and Wildlife Foundation (NFWF) Keystone Initiative (http://www.nfwf.org) designed to promote conservation of native fishes in the Upper Colorado River Basin under the NFCA concept. Though our goal is to identify one to four watersheds within each major subbasin in the Upper Colorado River Basin (Upper Green, Lower Green, Yampa, Upper Colorado, Gunnison, San Rafael, San Juan, and Dirty Devil-Escalante), we illustrate the identification process and discuss implementation using the Upper Green and Yampa basins in Wyoming as an example.

Identification of Potential NFCAs

We identified potential native fish conservation areas through four steps: (1) determine current and potential distributions of Colorado River cutthroat trout, roundtail chub, flannelmouth sucker, and bluehead sucker; (2) conduct a spatial prioritization analysis; (3) identify sympatric and proximate populations within high priority watersheds; and (4) engage experts and management agencies to discuss and—where appropriate—modify analysis results.

Species Data

We used data on the distribution of Colorado River cutthroat trout populations from a range-wide geographic information system (GIS) database assembled during a 2006 status assessment (Figure 1; Hirsch et al. 2006). The database contains the most recent (up to 2005) spatial information on the extent of each conservation population of cutthroat trout—populations that are 90% genetically pure (by genetic testing or professional judgment by biologists) or were otherwise determined to be important for conservation (e.g., unique life history). Populations are represented as stream segments (digital line graphs), and each population is attributed with categorical information on population density, population extent, genetic purity, disease vulnerability, and life history diversity. Each of these five attributes was scored from 1 (bad) to 5 (good) based on Trout Unlimited's Conservation Success Index (CSI; see Williams et al. 2007 for details). The sum of the five attribute scores (range from 5 to 25) was rescaled to range from 0 to 1.

For our three warmwater target species, we used both known and modeled species occurrences. Known occurrences were based on data from a 2002-2006 Wyoming Game and Fish Department fish survey of the Upper Colorado River Basin in Wyoming (Figure 1; Gelwicks et al. 2009). Stream sites were systematically sampled approximately every 8-16 km on all major streams, and the upstream extent of sampling per stream ceased when the fish community became dominated by salmonids and cottids. Fish sampling occurred most often in 200-m-long stream reaches isolated with block nets or natural barriers (e.g., beaver dams). One or a combination of gear types was used at each site to maximize sampling efficiency. Most sites were sampled with a shore-based electrofisher or a backpack electrofisher, but cataraft and raft electrofishing were used in longer reaches of deeper streams. Seine hauls were made to supplement electrofishing samples. Although the Wyoming Game and Fish Department systematically surveyed streams across the basin, the reaches sampled still represented only a small fraction of total stream length.

To avoid any biases associated with the survey data, and to fill in information gaps, we used spatially explicit predictions of probability of occurrence (sensu Dauwalter and Rahel 2008) for roundtail chub, flannelmouth sucker, and bluehead sucker to estimate likelihood of occurrence in unsampled areas (Figure 2). Spatially explicit predictions were made using artificial neural network models (Olden et al. 2008) developed to model species presence-absence as a function of landscape-scale variables (Dauwalter et al. 2011). Based on the area under the curve (AUC) of a receiver operating plot, the predictive ability of the models was excellent for roundtail chub (AUC = 0.83), outstanding for flannelmouth sucker (AUC = 0.90), and acceptable for bluehead sucker (AUC = 0.71; Hosmer and Lemeshow 2000). Predictions for roundtail chub ranged from 0 to 1 and showed low probabilities of occurrence for many stream segments (mean = 0.05), and a few segments where roundtail chubs occurred—and a few scattered segments in the north—had high predicted probabilities (Figure 2). Predictions for flannelmouth suckers ranged from 0.01 to 0.84 (mean = 0.10) and showed them most likely to occur along the larger, low-gradient stream systems. Predictions for bluehead sucker were never greater than 0.20 (range: 0.001-0.20) and indicated a low probability of occurrence throughout the basin in Wyoming (mean = 0.04). Probabilities of occurrence were set equal to 1 within the sample reaches where species were known to occur based on the survey data and also on extensively studied streams within the basin where each species is known to occur: Upper Muddy Creek (Compton 2007; Compton et al. 2008), Big Sandy River (Sweet 2007), and Little Sandy Creek (Banks 2009).

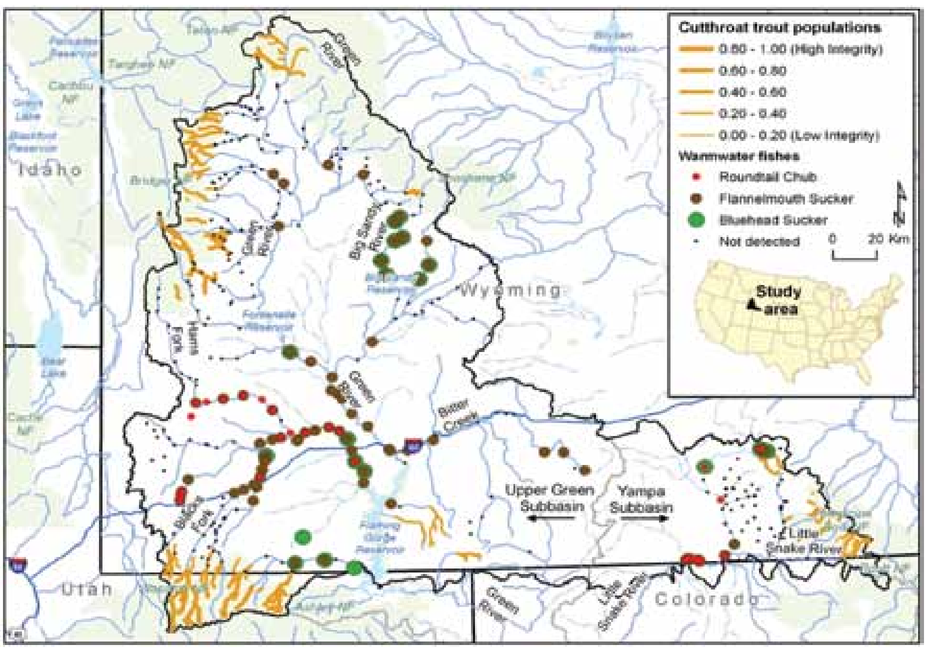

Figure 1. Distributions of Colorado River cutthroat trout, flannelmouth sucker, bluehead sucker, and roundtail chub in the Colorado River Basin in Wyoming. Conservation populations of cutthroat trout are from the most recent status assessment (Hirsch et al. 2006), and the integrity of populations was scaled from 0 (low integrity) to 1 (high integrity) based on Trout Unlimited's Conservation Success Index (Williams et al. 2007). Flannelmouth sucker, bluehead sucker, and roundtail chub distributions are from a 2002-2006 systematic survey by the Wyoming Game and Fish Department; black dots represent sites sampled where flannelmouth sucker, bluehead sucker, and roundtail chub were not detected.

Zonation Analysis

We used the conservation planning software Zonation 2.0 (Moilanen 2008) to prioritize watersheds in the basin in Wyoming to help inform stakeholder discussions (see Stakeholder Discussions below). Zonation uses prioritization algorithms to prioritize landscapes for biodiversity conservation (Moilanen et al. 2005). Within the Zonation analysis we used stream networks attributed with known or potential occurrences of our four target species and information on the costs and risks to conservation to prioritize watersheds. Zonation can implement several landscape removal rules to prioritize watersheds for biodiversity conservation. We used the additive benefit function that iteratively removes landscape units, in our case 12-digit HUC subwatersheds, with the lowest conservation value based on known occurrences or modeled potential occurrences of the target species (Moilanen 2007). We also incorporated upstream-downstream connectivity among subwatersheds, a function that aggregates subwatersheds by explicitly incorporating the connectivity of stream networks (Moilanen et al. 2008). This allows for explicit accounting of the value of tributary watersheds to downstream watersheds when determining their conservation value. We also incorporated information on the costs and risks to focusing conservation in each subwatershed. The costs and risks were based on Trout Unlimited's CSI, which is a broad-scale assessment tool developed for aquatic resource management (Williams et al. 2007).

The CSI summarizes information on current habitat conditions based on land stewardship, watershed connectivity, watershed conditions, water quality, and flow regime at the subwatershed (12-digit HUC) scale (Figure 3A). The CSI also incorporates information on the future security of subwatersheds based on the risks of land conversion, energy development, resource extraction, climate change, and introduced species (Figure 3A). Each of the 10 indicators (5 each for habitat integrity and future security) were scored from 1 (worst condition) to 5 (best condition), weighted based on the perceived relative importance of each indicator by stakeholders during planning meetings (Figure 3B), and then summed. Though higher scores typically indicate high habitat integrity and future security, we inversed the scores so that higher scores indicated higher costs and risks to conservation. The summed index scores ranged from 0 to 50, with a score of 50 indicating that current habitat conditions and the future security of populations and habitats is poor—meaning that the costs and risks for conservation will be high (Figure 3C). These surrogate costs are explicitly incorporated into the additive benefit function along with known or predicted species distributions when determining the value of watersheds in Zonation (Moilanen 2007). We conducted our Zonation analysis at the 12-digit HUC scale but summarized results at the 10-digit HUC scale to meet our objectives. The end result of the Zonation analysis is a nested hierarchy of conservation priorities, defined as watersheds, across the landscape. The top-ranking watersheds are those that contain the highest number of occurrences, or potential occurrences, of the target species while simultaneously considering costs and river connectivity.

We then identified tier I, II, and III watersheds in each subbasin in Wyoming (Upper Green and Yampa) but only within the top 25% of watersheds ranked by Zonation. Tiers are based on proximity of coldwater and warmwater fishes and are based on the assumption that currently sympatric or proximate populations of native species present greater fish community-based conservation potential. Tier I watersheds were defined as those where

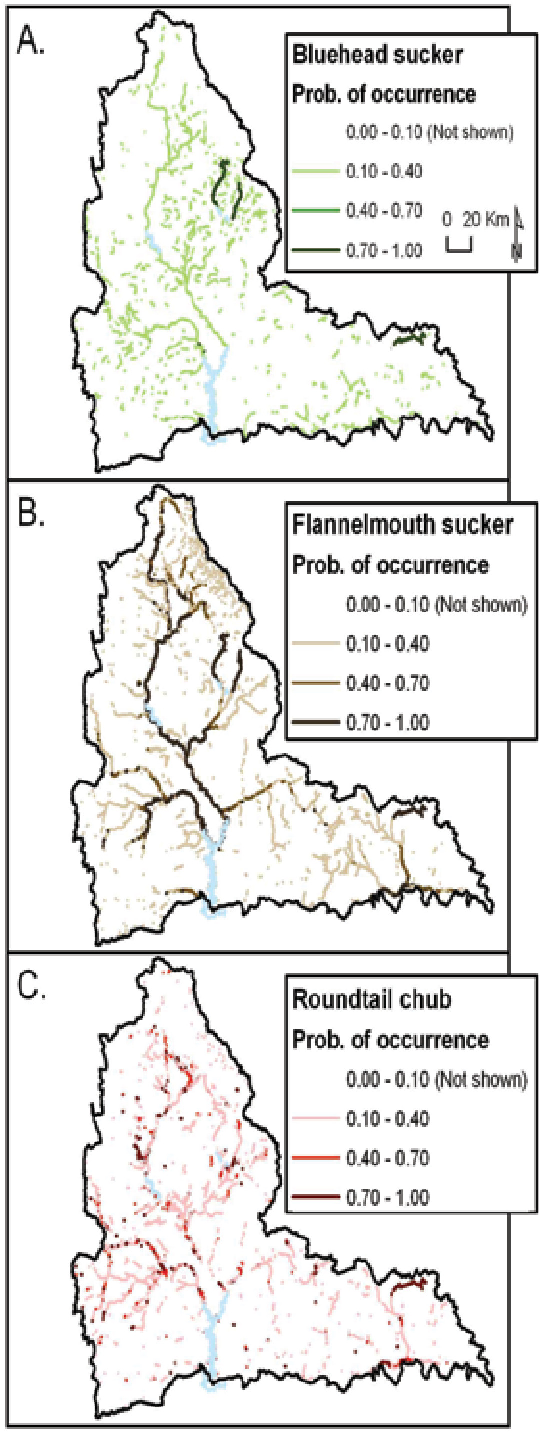

Figure 2. Probability of occurrence predictions from artificial neural network models developed for bluehead sucker (A), flannelmouth sucker (B), and roundtail chub (C) in the Colorado River Basin in Wyoming (from Dauwalter et al. 2011). Predictions were made as a function of variables representing natural landscape features, land uses, and relative abundances of nonnative and hybrid suckers. Probabilities of occurrence were set equal to one in stream reaches were the species are known to occur due to extensive sampling.

Colorado River cutthroat trout and at least one of the three warmwater species—flannelmouth sucker, bluehead sucker, and roundtail chub—are known to occur within the same subwatershed (12-digit HUC). Tier II watersheds were those where Colorado River cutthroat trout and at least one of the three warmwater species occur within the same watershed (10-digit HUC). Tier III watersheds were those that had only cutthroat trout or warmwater species occurring in a watershed (10-digit HUC). Watersheds within each tier were ranked based on the Zonation analysis results.

Very few tier I or II watersheds existed within the top 25% of watersheds ranked by Zonation, indicating that even in the top-ranked watersheds there were few subwatersheds or watersheds with both Colorado River cutthroat trout and one of the three warmwater species. The top 25% of watersheds ranked by Zonation in the Upper Green River Basin represented the entire Blacks Fork Basin due to strong trout populations in the headwaters and occurrences of warmwater fishes in the mainstem, as well as other select watersheds across the study area (Figure 4A). Within the top ranked watersheds, only one tier I and four tier II watersheds existed (Figure 4B). The only tier I watershed, Upper Muddy Creek in the Yampa subbasin, contained sympatric populations of all four species. All four tier II watersheds occurred in the Upper Green subbasin and had different combinations of cutthroat trout and one or two warmwater species in the same watershed (Figure 4B). Remaining highly ranked watersheds represented tier III watersheds (cutthroat trout or warmwater species only) or were tributary to other highly ranked watersheds in the Blacks Fork drainage.

Stakeholder Discussions

The Zonation analysis was based on geographically extensive data sets of species known and potential distributions and landscape-scale variables and therefore cannot capture the details and idiosyncrasies of undertaking conservation in every watershed. Hence, we conferred with agency experts to verify, and modify where appropriate within each tier, watershed rankings of the top 25% of watersheds identified from the Zonation analysis to determine those that could potentially be managed as NFCAs. Stakeholders present were the Wyoming Game and Fish Department, Bureau of Land Management, Forest Service, Trout Unlimited, and The Nature Conservancy. Analysis results were presented to inform the group, and watershed ranks (top 25% identified by the Zonation analysis) were modified within each tier based on discussions of which watersheds could serve best as NFCAs focusing on Colorado River cutthroat trout, roundtail chub, flannelmouth sucker, and bluehead sucker.

Stakeholders generally confirmed the Zonation results in that the top 25% of ranked watersheds represented the best opportunities for cutthroat trout, flannelmouth sucker, bluehead sucker, and roundtail chub conservation under the NFCA concept. They also confirmed the tier I watershed, Upper Muddy Creek (Yampa subbasin). However, on-the-ground familiarity of threats and opportunities in tier II and tier III watersheds indicated the need to rerank some of these watersheds. Though the stakeholders agreed that the top-ranked tier II watershed, Muddy Creek (Blacks Fork), could potentially be managed for native fishes, they thought that land and water uses in the second- and third-ranked watersheds (Upper Blacks Fork and Smiths Fork) would prohibit them from being managed for native fishes. They also thought that the Henrys Fork, the fourth-ranked tier II watershed, represented the best opportunity for native fish management. Hence, the tier II watershed ranks were adjusted due to feasibility of managing them for native fishes and likelihood of conservation success (Table 1), and only the top two stakeholder ranked tier II watersheds appeared to represent potential NFCAs (Figure 5). Likewise, stakeholders thought that tier III watersheds with warmwater fishes should be ranked higher than those with cutthroat trout,

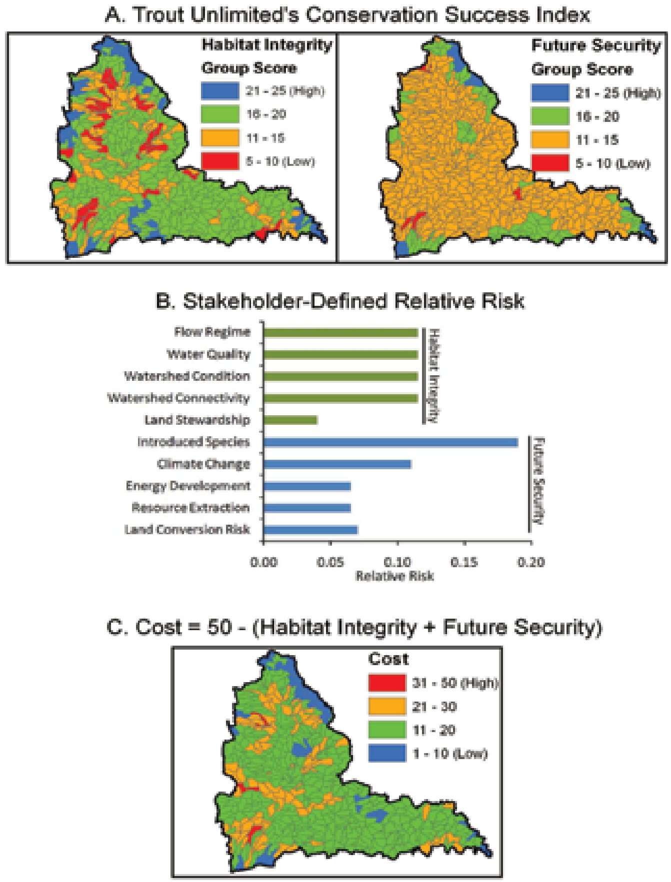

Figure 3. Habitat integrity and future security indicators from Trout Unlimited's Conservation Success Index (12-digit HUC scale) in the Upper Colorado River Basin Wyoming (A) were used in conjunction with stakeholder-defined relative risks (B) to define the relative cost and risk to conservation in each subwatershed (C). The cost layer was used in the Zonation analysis to rank subwatersheds based on the known or potential distributions of the target species along with the costs and risks of conservation.

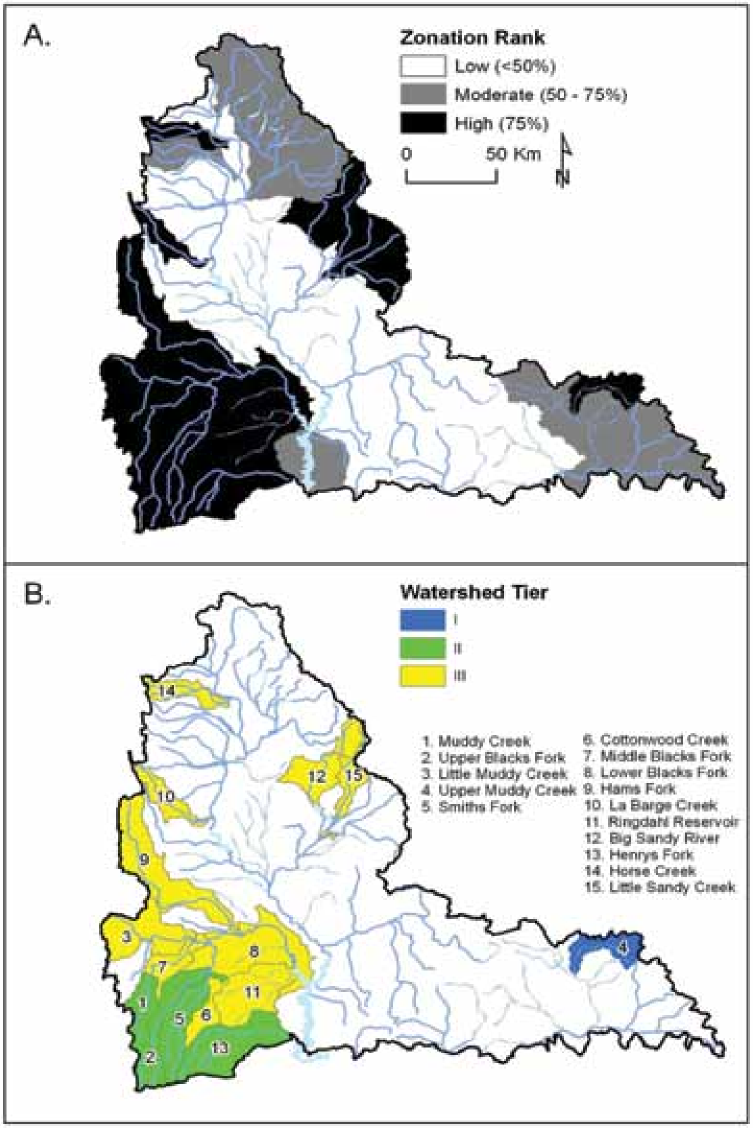

Figure 4. Watershed prioritization ranks for the Upper Colorado River Basin in Wyoming (A) and tiers (I, II, and III) of potential NFCAs within the top-ranked (top 25%) watersheds (B). Tier I watersheds have cutthroat trout and at least one warmwater species (flannelmouth sucker, bluehead sucker, and roundtail chub) in the same subwatershed (12-digit HUC), tier II watersheds have cutthroat trout and at least one warmwater species in the same watershed (10-digit HUC), and tier III watersheds have only cutthroat trout or one or more warmwater species in the watershed (10-digit HUC).

only due to their at-risk status. Tier III watershed rankings were adjusted based on warmwater species presence and abundance (not accounted for explicitly in the Zonation analysis), and the top two stakeholder-ranked tier III watersheds were included as potential NFCAs to reach a total of four watersheds in the Upper Green subbasin (Figure 5). Because only a small fraction of the Yampa subbasin exists in Wyoming (20%), only the top-ranked tier I Upper Muddy Creek was included in the Yampa subbasin in Wyoming (Figure 5). Any remaining potential NFCAs in the Yampa subbasin will be identified as part of an ongoing analysis for Colorado.

Discussion

The continued decline of fishes native to the Colorado River Basin suggests that additional management approaches are needed. Using the native fish conservation area approach outlined by Williams et al. (2011, this issue), we combined a quantitative conservation planning approach with stakeholder experience to identify a set of watersheds in the Basin in Wyoming that can serve as potential NFCAs. We describe how watersheds managed under the NFCA concept can help conserve fishes imperiled in the Upper Colorado River Basin, where similar work is already being done, and how the National Fish and Wildlife Foundation Keystone Initiative can help provide a funding mechanism to initiate management in watersheds not currently receiving management attention. Subsequent analyses, similar to the one described here for Wyoming, have been completed in Utah and are ongoing in Colorado to identify additional watersheds that can potentially serve as NFCAs in the remaining portion of the Upper Colorado River Basin.

The prioritization analysis highlighted areas in Wyoming that have potential as NFCAs. It represented a structured and efficient way to prioritize the basin based on species' known occurrences, potential occurrences, watershed boundaries, and river network connectivity (Sarkar et al. 2006; Nel et al. 2009). The analysis identified a reduced set of watersheds (top 25% of our study area) that then informed discussions with stakeholders about watersheds that could potentially serve as NFCAs. Wenger et al. (2009) used the additive benefit function in Zonation to prioritize the Conasauga River basin in the Southeastern United States for protection and restoration based on occurrences of mussels and fishes. They suggested that quantitative prioritization analyses provide an objective and transparent rationale for conservation programs. Though the additive benefit function in Zonation provided an objective ranking of watersheds in Wyoming based on maximizing the representation of our target species and informed stakeholder discussions, the results required subsequent analysis to get to our tiered endpoint, and discussions with stakeholders highlighted logistical constraints to NFCA implementation and opportunities available not evident from the Zonation analysis. For example, we did not explicitly account for population abundance in the analysis because abundance data were not available for all four species across the entire basin; however, abundance of native suckers was important in stakeholder rankings of tier III watersheds. Though prioritization algorithms and tools are known not to fit perfectly with every application (Ferrier and Wintle 2009; Wenger et al. 2009), we agree that it provided a very useful step in identifying potential NFCAs and informing stakeholder discussions within a spatial framework facilitated by readily available GIS coverages and modeling techniques (Groves et al. 2002; Fisher 2004).

Williams et al. (2011, this issue) suggested that NFCAs be able to maintain processes that create diverse habitats, nurture all life history stages, be large enough to ensure long-term community persistence, and have sustainable long-term management. Ideally, our study area would have had intact watersheds with both Colorado River cutthroat trout and native warmwater fishes, but no tier I or II watersheds were undisturbed or fully protected (e.g., designated wilderness). However, long-term restoration management, such as in Muddy Creek (see Discusion below), can help the watersheds we identified function naturally, and future land management could result in additional protective measures. The watersheds we identified are all likely to be large enough to nurture all life histories stages of cutthroat trout and three warmwater species. Recent research suggests that Upper Muddy Creek (Little Snake River), Big Sandy Creek, and Little Sandy Creek can have self-sustaining native fish populations with strategic restoration and non-native species management (Hilderbrand and Kershner 2000; Sweet 2007; Compton et al. 2008; Banks 2009). Muddy Creek (Blacks Fork) is the smallest of our identified watersheds, but the management boundary need not explicitly follow the 10-digit HUC boundaries and could be extended downstream if additional research suggests that a key habitat is missing. And, as we outline below, stakeholders are already engaged in long-term management in some watersheds, and funding through the NFWF Keystone Initiative can help initiate long-term management in watersheds not currently receiving attention.

Though our analysis highlighted Upper Muddy Creek (Little Snake River) as a priority watershed, it has already been the focus of native fish conservation by the Wyoming Game and Fish Department, Bureau of Land Management, and other stakeholders for some time and suggests that our analysis aligns with the native fish values that were identified previously. In 2001, Colorado River cutthroat trout were restored to Littlefield Creek, a tributary to Muddy Creek, above a temporary rock gabion fish barrier after nonnative brook trout (*Salvelinus fontinalis*) were removed with piscicides (Figure 6). Similar cutthroat trout restoration has been expanded to the Muddy Creek headwaters to result in larger extents of occupied habitat, therefore increasing the species' long-term persistence. Research in Muddy Creek has also led to a better understanding of habitat needs of flannelmouth sucker, bluehead sucker, and roundtail chub (Bower et al. 2008), hybridization with nonnative suckers (McDonald et al. 2008), and how instream structures inhibit fish passage and threaten population persistence (Compton et al. 2008). In 2009, the Rawlins Field Office of the Bureau of Land Management (BLM) proposed Upper Muddy Creek as an Area of Critical Environmental Concern (ACEC) in an attempt to help protect its unique native fish community. The ACEC designation was not adopted by the agency, but a Wildlife Habitat Management Area option was and will afford some protections when compared to other BLM land designations. Mechanical removal of nonnative fishes is ongoing, as is monitoring to evaluate trends of both native and nonnative populations. Future work will include strategic barrier management that reconnects native fish populations in some areas and isolates them from nonnatives in others, chemical removal of nonnative fishes in the lower watershed, channel restoration, livestock management, and community outreach.

TABLE 1. Top-ranked watersheds (10-digit HUC) within each tier from Zonation analysis and revised rankings based on stakeholder discussion. Tier I watersheds have cutthroat trout and at least one warmwater species (flannelmouth sucker, bluehead sucker, and roundtail chub) in the same subwatershed (12-digit HUC), tier II watersheds have cutthroat trout and at least one warmwater species in the same watershed (10-digit HUC), and tier III watersheds have only cutthroat trout or one or more warmwater species in the watershed (10-digit HUC)

Subbasin		Zonation Rank	Stakeholder Rank
Yampa (WY only)	I	1. Upper Muddy Creek (Little Snake River)	1. Upper Muddy Creek (Little Snake River)
	II	None in top 25%	NA
	III	None in top 25%	NA
Upper Green	I	None in top 25%	
	II	1. Muddy Creek (Blacks Fork) 2. Upper Blacks Fork 3. Smiths Fork 4. Henrys Fork	1. Henrys Fork 2. Muddy Creek (Blacks Fork) 3. Upper Blacks Fork[a] 4. Smiths Fork[a]
	III	1. Little Muddy Creek 2. Cottonwood Creek (Blacks Fork) 3. Middle-Lower Blacks Fork 4. Hams Fork 5. La Barge Creek 6. Big Sandy River 7. Little Sandy Creek	1. Big Sandy River[b] 2. Little Sandy Creek[b] 3. Middle-Lower Blacks Fork 4. Bitter Creek[c] 5. Hams Fork 6. La Barge Creek 7. Cottonwood Creek (Blacks Fork) 8. Little Muddy Creek

[a] Stakeholders thought that land and water uses in these watersheds reduced the likelihood of large-scale native fish management and the watersheds were reduced in rank.
[b] Only the top two stakeholder-ranked tier III watersheds were included in the final set of potential NFCAs in the Upper Green subbasin.
[c] Not within top 25% of Zonation rankings but included after stakeholder discussions because it is the only watershed in Wyoming where the flannelmouth sucker has not hybridized with the nonnative white sucker.

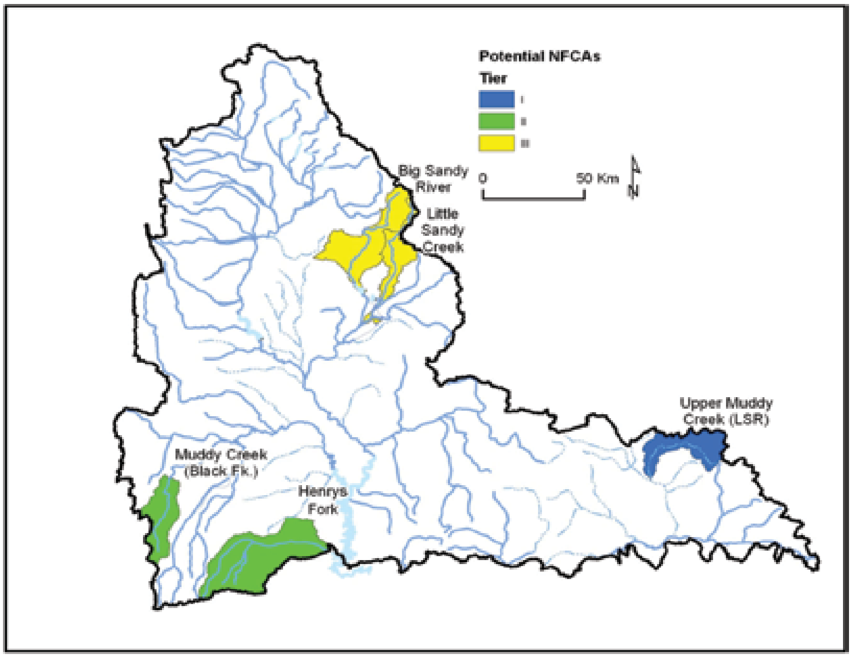

Figure 5. Tier I, II, and III watersheds identified through analysis and stakeholder discussions about potential NFCAs in the Upper Colorado River Basin in Wyoming. Tier I watersheds have cutthroat trout and at least one warmwater species (flannelmouth sucker, bluehead sucker, and roundtail chub) in the same subwatershed (12-digit HUC), tier II watersheds have cutthroat trout and at least one warmwater species in the same watershed (10-digit HUC), and tier III watersheds have only cutthroat trout or one or more warmwater species in the watershed (10-digit HUC).

Big Sandy River and Little Sandy Creek are also being managed for native fishes by the Wyoming Game and Fish Department because flannelmouth sucker and bluehead sucker are more abundant in these watersheds than elsewhere in the Upper Green subbasin. However, native suckers are threatened by predation from burbot (*Lota lota*) that were illegally introduced into Big Sandy Reservoir, hybridization with the white sucker (*Catostomus commersonii*) and longnose sucker (*Catostomus catostomus*), and habitat fragmentation and alteration (Sweet 2007; Gelwicks et al. 2009; Banks 2009). Like Upper Muddy Creek, ongoing work is focused on researching the life history of native fishes in these watersheds, controlling nonnative fishes, and evaluating barrier alternatives to control nonnative species while allowing native fishes to access essential habitats. However, unlike Muddy Creek, the actions needed to minimize threats are not all clear.

Effective implementation of the NFCA concept in the watersheds we identified requires a commitment from all stakeholders and ongoing financial support. Though Upper Muddy Creek has been managed like an NFCA over the past decade, and Big Sandy River and Little Sandy Creek have received significant attention since 2002, additional resources and stakeholder support for native fish conservation in other watersheds, like the Henrys Fork and Muddy Creek (Blacks Fork), will be necessary to achieve long-term conservation goals. This will be difficult given current agency commitments, limited budgets, and conservation priorities in watersheds that do not meet the goals of our analysis for the NFWF Keystone Initiative (i.e., proximate populations of cutthroat trout and warmwater species). For example, the Wyoming Game and Fish Department, in addition to Upper Muddy Creek, Big Sandy River, and Little Sandy Creek, is currently focused on conservation of the flannelmouth sucker in Upper Bitter Creek. Upper Bitter Creek is the only watershed in Wyoming where flannelmouth sucker are not hybridizing with nonnative suckers (Gelwicks et al. 2009). Consequently, Upper Bitter Creek is an agency priority because it contains a genetically pure flannelmouth sucker population important to future conservation efforts. So although it does not represent an ideal NFCA that benefits multiple native species, it is a valid and high priority watershed for native fish management. And though Wyoming Game and Fish Department does recognize Muddy Creek (Blacks Fork) and Henrys Fork as important for native fish conservation, they have given priority to Upper Muddy Creek, Big Sandy River, Little Sandy Creek, and Upper Bitter Creek to ensure that the more abundant or genetically pure populations in those watersheds are stabilized and protected from current threats before shifting management attention to new watersheds where multiple native fish species may occur in close proximity, but current threats are less imminent (D. Miller, Wyoming Game and Fish Department, personal communication). The contrast between Upper Muddy Creek, where abundant populations of cold and warmwater native species are sympatric, and Upper Bitter Creek, where native species richness is low but the flannelmouth sucker population has high genetic value, illustrates well the complementary nature of NFCAs focused on entire native fish communities.

Long-term funding is also needed to ensure that enough resources are available to implement broad-scale native fish conservation. In the Upper Colorado River, the National Fish and Wildlife Foundation committed approximately $5 million over the next 10 years toward native fish restoration under their new Keystone Initiative based on the NFCA concept. The NFWF funding can represent additional resources for watersheds like Upper Muddy Creek, Big Sandy River, and Little Sandy Creek. It can also represent seed money for needed conservation actions in the Henrys Fork, Muddy Creek (Blacks Fork), and other potential NFCAs throughout the Upper Colorado River Basin. For example, NFWF has funded a part-time project manager located in Green River, Wyoming, to help administer NFWF-funded restoration projects in Upper Muddy Creek. Continued funding for project management could help initiate work in watersheds like Muddy Creek (Blacks Fork) and Henrys Fork, despite other stakeholder resources currently being limited. Eventually, however, other funding sources will be needed to leverage NFWF funding and complete the amount of work necessary for large-scale aquatic conservation throughout the Basin.

Through our stakeholder discussions, we also identified factors that compromise ecological integrity and pose future threats in our NFCAs and throughout the Upper Colorado River Basin. Human use of scarce water resources in the West and Colorado River Basin threaten native fishes (Richter et al. 1998; Deacon et al. 2007). The nonnative white sucker now dominates fish assemblages in the Colorado River Basin in Wyoming, and hybridization with native suckers has created genetic bridge between native suckers that were previously reproductively isolated (McDonald et al. 2008; Gelwicks et al. 2009). Fish passage barriers fragment watersheds and fish populations throughout the basin (Hilderbrand and Kershner 2000; Compton et al. 2008). And habitat alteration due to grazing and other land uses is still prevalent (Armour et al. 1991). Though NFCAs can allow for compatible commercial and recreational uses, uses such as grazing or energy development should not adversely impact native fish communities and aquatic ecosystems. If they have negative impacts, proper mitigation should be ensured (Groves 2003; Kiesecker et al. 2010).

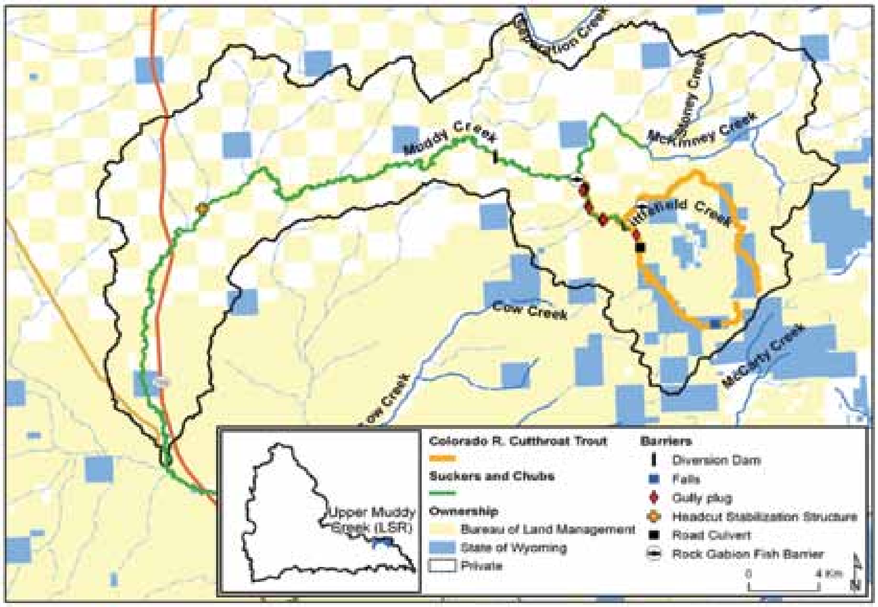

Figure 6. Colorado River cutthroat trout, flannelmouth sucker, bluehead sucker, and roundtail chub distributions relative to fish passage barriers and land ownership in Upper Muddy Creek, tributary to the Little Snake River, south-central Wyoming.

Proactive NFCA-type management can also help protect native fishes from several impending future threats (Clarkson and Marsh 2010). Introduced species, such as burbot, continue to invade new habitats and threaten native fishes (Olden et al. 2006; Sweet 2007). Oil and gas activity has increased substantially in the Intermountain West, and much of Wyoming has a high risk of being developed in the future (Copeland et al. 2009). The impact of development to native fishes is not completely clear (Davis et al. 2009; Farag et al. 2010), but bluehead suckers have been shown to be negatively associated with development (Dauwalter et al. 2011). Trout are threatened by increased temperatures and uncharacteristic wildfires under a warming climate (Williams et al. 2009), disturbances that have caused small, isolated populations to go extinct (Brown et al. 2001). Synergies between these threats could be particularly problematic, because climate change is expected to create new invasion pathways for invasive species (Rahel and Olden 2008). Proactive management under the NFCA concept can alleviate such threats by focusing on nonnative species control, facilitating interconnected fish communities with intact metapopulation dynamics and increased likelihood of persistence, focusing on restoration activities that buffer against climate change impacts, and limiting oil and gas development in key areas.

Native fishes across North America are in decline, and the native fish conservation area concept represents a proactive management approach to native fish conservation that focuses efforts on entire fish communities rather than waiting until individual species require recovery actions. Though similar watershed-scale approaches have been proposed, most have lagged behind marine protected areas (Shipley 2004), and most successful freshwater applications have occurred on isolated springs and lakes (Suski and Cooke 2007). However, the NFCA concept in the Upper Colorado River Basin is gaining inertia and has the potential to complement existing management approaches and benefit entire communities comprised of highly endemic and declining fish species.

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