Fisheries
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t926380646

Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Jack E. Williams[a]; Richard N. Williams[b]; Russell F. Thurow[c]; Leah Elwell[d]; David P. Philipp[e]; Fred A. Harris[f]; Jeffrey L. Kershner[g]; Patrick J. Martinez[h]; Dirk Miller[i]; Gordon H. Reeves[j]; Christopher A. Frissell[k]; James R. Sedell[l]

[a] Trout Unlimited, Arlington, VA, USA [b] Federation of Fly Fishers, Livingston, MT, USA [c] USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA [d] Center for Aquatic Nuisance Species, Invasive Species Action Network, Livingston, MT, USA [e] Illinois Natural History Survey, University of Illinois, Champaign, IL, USA [f] North Carolina Wildlife Resources Commission, Raleigh, NC, USA [g] USGS Northern Rocky Mountain Science Center, Bozeman, MT, USA [h] US Fish and Wildlife Serivce, Grand Junction, CO, USA [i] Wyoming Fish and Game Department, Cheyenne, WY, USA [j] US Forest Service, Pacific NW Research Station, Corvallis, OR, USA [k] Pacific Rivers Council, Portland, OR, USA [l] National Fish and Wildlife Foundation, Portland, OR, USA

Online publication date: 08 June 2011

To cite this Article Williams, Jack E. , Williams, Richard N. , Thurow, Russell F. , Elwell, Leah , Philipp, David P. , Harris, Fred A. , Kershner, Jeffrey L. , Martinez, Patrick J. , Miller, Dirk , Reeves, Gordon H. , Frissell, Christopher A. and Sedell, James R.(2011) 'Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities', Fisheries, 36: 6, 267 — 277

To link to this Article: DOI: 10.1080/03632415.2011.582398

URL: http://dx.doi.org/10.1080/03632415.2011.582398

Native Fish Conservation Areas: A Vision for Large-Scale Conservation of Native Fish Communities

Jack E. Williams, Richard N. Williams, Russell F. Thurow, Leah Elwell, David P. Philipp, Fred A. Harris, Jeffrey L. Kershner, Patrick J. Martinez, Dirk Miller, Gordon H. Reeves, Christopher A. Frissell, and James R. Sedell

Jack Williams is the senior scientist for Trout Unlimited. Rick Williams is the conservation advisor for Federation of Fly Fishers; Thurow is a research fisheries scientist for the USDA Forest Service; Elwell is the program director for the Center for Aquatic Nuisance Species; Philipp is the principal scientist at the Illinois Natural History Survey; Harris is the former chief of inland fisheries for the North Carolina Wildlife Resources Commission; Kershner is the director of the U.S. Geological Survey's Northern Rocky Mountain Science Center; Martinez is a nonnative fish coordinator for the U.S. Fish and Wildlife Service; Miller is the native trout coordinator for the Wyoming Game & Fish Department; Reeves is a research fish biologist for the USDA Forest Service; Frissell is the director of science and conservation for the Pacific Rivers Council; Sedell is the fisheries program director for the National Fish and Wildlife Foundation.

ABSTRACT: *The status of freshwater fishes continues to decline despite substantial conservation efforts to reverse this trend and recover threatened and endangered aquatic species. Lack of success is partially due to working at smaller spatial scales and focusing on habitats and species that are already degraded. Protecting entire watersheds and aquatic communities, which we term "native fish conservation areas" (NFCAs), would complement existing conservation efforts by protecting intact aquatic communities while allowing compatible uses. Four critical elements need to be met within a NFCA: (1) maintain processes that create habitat complexity, diversity, and connectivity; (2) nurture all of the life history stages of the fishes being protected; (3) include a large enough watershed to provide long-term persistence of native fish populations; and (4) provide management that is sustainable over time. We describe how a network of protected watersheds could be created that would anchor aquatic conservation needs in river basins across the country.*

Áreas para la Conservación de Peces Nativos: una visión para la conservación a gran escala de comunidades de peces nativos

RESUMEN: El estado de los peces de agua dulce continúa en deterioro a pesar de los importantes esfuerzos de conservación que se han invertido para revertir esta tendencia y recuperar las especies acuáticas que se encuentran amenazadas y en peligro. La falta de éxito se debe parcialmente a que se ha trabajado en escalas espaciales reducidas y a que los estudios se han enfocado en los hábitats y especies que se encuentran ya degradados. La protección de cuencas enteras y de comunidades acuáticas, que aquí denominamos como Áreas para la Conservación de peces Nativos (ACPN), complementarían los esfuerzos de conservación mediante la protección de comunidades acuáticas prístinas, al mismo tiempo que se permitirían usos compatibles con este enfoque. Cuatro elementos críticos se requieren para la implementación de un ACPN: 1) mantenimiento de los procesos que crean la complejidad, diversidad y conectividad de un hábitat, 2) observancia de todos los estadios de vida de los peces que se piensan proteger, 3) incluir una cuenca lo suficientemente grande como para asegurar la persistencia de largo plazo de poblaciones de peces nativos, y 4) proveer un sistema de manejo que sea sostenible en el tiempo. Se describe cómo pudiera crearse una red de cuencas protegidas que cumplimentaría las necesidades de conservación en los ríos a lo largo del país.

Introduction

The diversity of North American freshwater biota continues to decline at a rapid rate. A recent assessment found that 39% of freshwater and diadromous fishes are at risk of extinction (Jelks et al. 2008). The trend of endangerment appears to be escalating. When comparing the conservation status of fishes included in the status review conducted in 1989 to the review conducted in 2008, 89% of taxa had deteriorated in condition, whereas only 6% had improved (J. E. Williams et al. 1989; Jelks et al. 2008). Declines in native fishes have been attributed to the obstruction of migratory pathways from dams, irrigation diversion, and channel modification; degradation of spawning and rearing habitat; angling mortality; and competition, predation, and hybridization with invasive species (Lee et al. 1997; Jelks et al. 2008).

Declines in freshwater fish status and distribution have continued despite our increased understanding of the life history requirements of these species and the implementation of some of the strongest environmental and species protection laws in the world. For instance, although the number of fish species listed pursuant to the Endangered Species Act has grown over the years, no fish species has been removed from the list due to recovery. To date, all fish delistings have been a result of either taxonomic revisions or extinctions (J. E. Williams et al. 2005). Though the Endangered Species Act has been an effective tool for preventing extinction, it has proven less effective at protecting entire ecosystems or protecting species before they become endangered (Doremus and Pagel 2001).

Collectively, agencies and other conservation entities spend vast monetary resources on endangered fish recovery and aquatic ecosystem restoration but realize relatively little for these efforts. According to the U.S. Fish and Wildlife Service (USFWS 2010), federal and state governments spent more than $1.1 billion on threatened and endangered (T&E) species in the United States during fiscal year 2008. Nine of the top 10 T&E species expenditures are for fishes (including pallid sturgeon, Pacific salmon and steelhead, and bull trout), and 46 of the top 60 T&E species expenditures are for aquatic species (USFWS 2010). An additional $1 billion is spent annually on river restoration in the United States (Bernhardt et al. 2005).

Species declines in aquatic ecosystems are not limited to fishes. More than two of three species of freshwater mussels are at risk of extinction (J. D. Williams et al. 1993), and nearly half of all freshwater crayfishes in the United States and Canada are at risk (Taylor et al. 2007). Extinction rates are five times higher for freshwater fauna in the United States than for mammals, birds, or other terrestrial species (Bernhardt et al. 2005). Additionally, Master et al. (2000) further support the contention that aquatic biodiversity in North America has declined precipitously in recent decades and that aquatic species are at greater risk than their terrestrial counterparts (Figure 1).

Furthermore, threats to aquatic biodiversity appear to be accelerating due to four primary factors: increasing fresh water demand for a growing human population (Postel 2000; Deacon et al. 2007), wildland development and conversion (Hudy et al. 2008), spreading invasive species (U.S. Environmental Protection Agency [USEPA] 2008), and rapid climatic change (Poff et al. 2002; Haak et al. 2010). There is also increasing evidence for a synergy among these factors, especially invasive species and climate change, which would result in new invasion pathways and more rapid spread of invasive species (Rahel and Olden 2008).

Traditional conservation approaches have been only moderately effective at protecting aquatic species for a variety of reasons. Fundamentally, the linear shape of riverine systems and the interconnectedness of drainage systems provide sub-

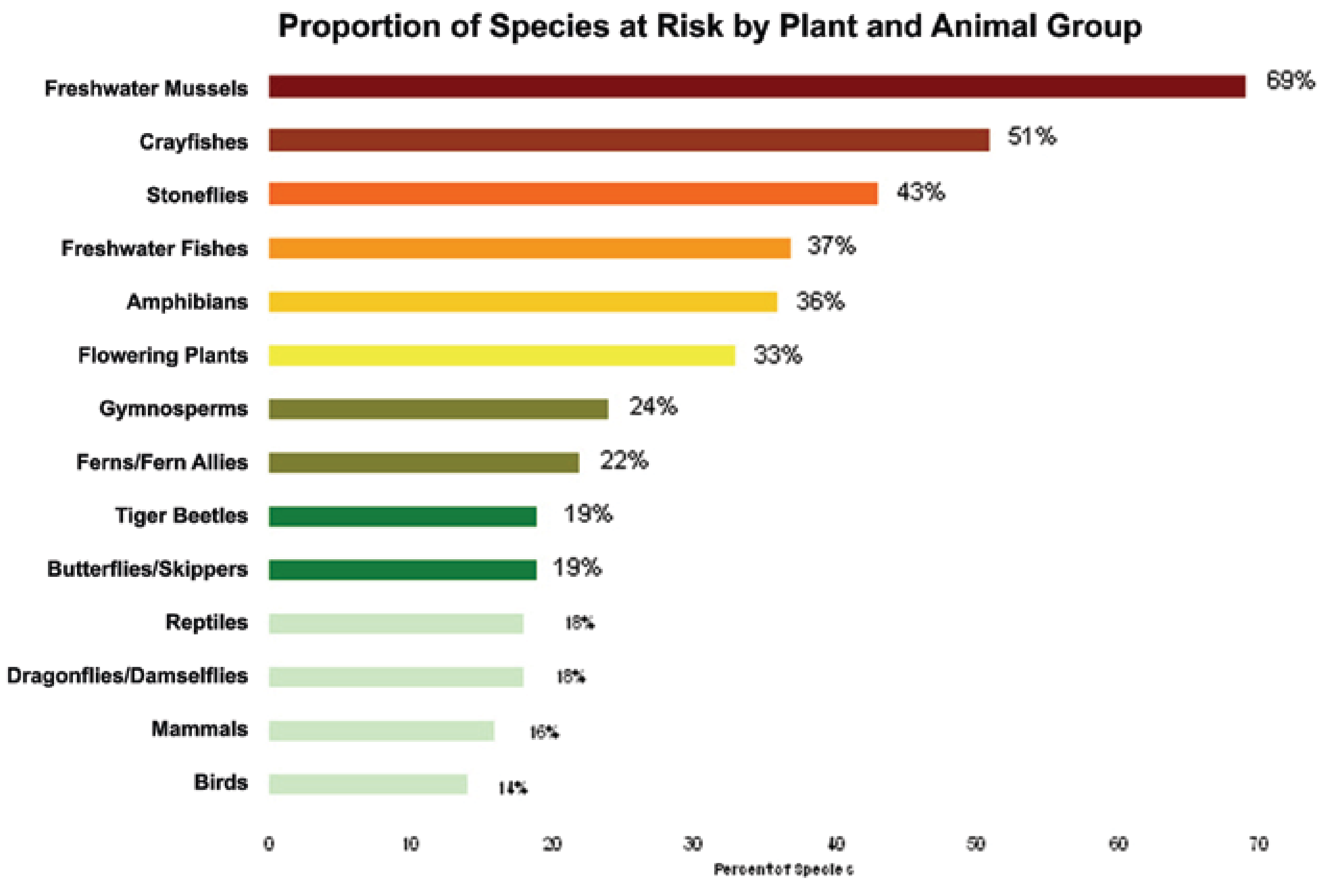

Figure 1. Fragmentation and degradation of aquatic habitat coupled with extensive invasion by large numbers of exotic species into lakes, rivers, and streams have pushed many native species to the brink of extinction. Species that rely on freshwater habitats exhibit a much higher risk of extinction than do terrestrial plants and animals. Data for the United States. Graph modified from Master et al. (2000).

stantial challenges to protection efforts that are usually based on terrestrial features and land ownership boundaries rather than on watershed boundaries. On the other hand, lakes and reservoirs, which in many cases could serve as important aquatic diversity areas, often have been subjected to numerous fish introductions and may be dominated by nonnative species (Li and Moyle 1993; Adams et al. 2001).

Many conservation strategies are more reactive than proactive, focusing on saving individual species or restoring already degraded habitats. Despite being more ecologically and economically effective, we rarely seek to protect intact ecosystems and entire communities before their components become threatened (J. E. Williams et al. 1989).

Existing threats have encouraged fisheries managers to establish small, isolated stream reaches as refuge areas for rare native fishes, especially native trout. These fragmented habitats may be at severe risk in a future likely to be characterized by increasing frequency and severity of stochastic disturbances (J. E. Williams et al. 2009). For example, small population sizes and a lack of connectivity increase extinction risk in these isolated populations (Hilderbrand and Kershner 2000). Indeed, small population size and increasing wildfires already have combined to cause population losses in Gila trout (Brown et al. 2001).

The current status of aquatic species signals the need for additional strategies for conserving and restoring aquatic biodiversity. In response to this need, we propose a new watershed-scale approach, termed "native fish conservation areas" (NFCAs) to conserve and restore aquatic communities. Such an approach would protect existing strongholds of native species diversity and strive to restore a larger network of strongholds in conjunction with existing fish conservation efforts focused on individual species. We revisit the fish refuge concept, describe various alternatives for its implementation, and in a companion paper (Dauwalter et al., 2011), provide examples of how NFCAs can be implemented to integrate the needs of both coldwater and warmwater fishes. We argue that an integrated NFCA approach will provide a more cost-effective and sustainable method for conserving aquatic biodiversity in the face of growing challenges from water demand, land conversion, invasive species, and climate change.

A Brief History of Watershed-Scale Fish Conservation

The concept of large-scale fish refuges dates back to 1892. During that year, President Harrison created the first Pacific salmon refuge on Afognak Island, Alaska. It later served as an egg source for a hatchery, but the refuge was closed in 1923 because fish culturists claimed that hatcheries were more efficient salmon producers than wild rivers (Lichatowich 1999).

Efforts to protect salmon and steelhead stimulated additional watershed-scale fish conservation efforts during development of the Northwest Forest Plan. In 1994, the U.S. Forest Service and U.S. Bureau of Land Management (BLM) established a series of key watersheds and riparian reserves along perennial and intermittent streams on federal lands in the Pacific Northwest. In the 10 years since implementation of protective measures, and despite significant increases in wildfire activity, 64% of 250 watersheds and riparian habitats improved in condition (Reeves et al. 2006). Although private lands were not included in the Northwest Forest Plan, Forest Service and BLM managed lands were sufficiently large and contiguous to facilitate successful efforts at watershed-scale management.

In California, Moyle and Yoshiyama (1994) proposed establishing a system of aquatic diversity management areas (ADMAs) to help reverse the decline of that state's native fish fauna. As part of the Sierra Nevada Ecosystem Project, Moyle (1996) proposed a series of 42 watershed-scale ADMAs, whose primary goal would be the protection of aquatic biodiversity. The criteria for selection were watershed size (>50 km^2), the presence of a natural hydrologic regime, the presence of native fishes and amphibians, and representativeness. Although not formally adopted, the ADMA concept was driven by the realization that some streams in the state still support much of their historic complement of native fishes. Keeping these systems intact would reduce the risk of extirpating aquatic species as California's human population and its demands on water resources continue to grow (Moyle and Yoshiyama 1994; Moyle 1996).

In a similar vein, Suski and Cooke (2007) argued for the establishment of freshwater protected areas as an alternative to current management approaches. These protected areas would provide larger watersheds where ecosystem processes needed to sustain aquatic and riparian habitats would be protected and where disturbances to aquatic systems could be minimized. Re-

TABLE 1. Benefits of implementing conservation strategies at broader watershed scales

Encourages cooperation and coordination across multiple agency jurisdictions
Encourages integration of public and private land management efforts
Encourages a more comprehensive but also adaptive approach to nonnative species control
Focuses on maintaining or restoring ecosystem processes
Reduces dependency on species-specific management programs
Creates larger conservation areas that are more resilient to impacts of climate change
Encourages monitoring and adaptive management to deal with future uncertainty
Encourages development of environmentally sensitive ranching, farming, recreation, and other compatible uses

gardless of the terminology, numerous authors have recognized the failure of current management practices to reverse the rapid decline in aquatic biodiversity and argued for watershed-scale approaches to protect remaining native fish assemblages (J. E. Williams et al. 1989; Moyle and Yoshiyama 1994; Frissell and Bayles 1996; Suski and Cooke 2007).

Defining Native Fish Conservation Areas

In April 2008, a two-day symposium was hosted in Boise, Idaho, by Trout Unlimited, the Federation of Fly Fishers, and the Fisheries Conservation Foundation to gather fisheries scientists, resource managers, policy makers, and nongovernmental conservation organizations to discuss new approaches for conserving native fishes and aquatic ecosystems at watershed scales. Impetus for the symposium came initially from the Federation of Fly Fishers, where Rick Williams and colleagues (Lichatowich and Williams 2004; R. N. Williams and Tabbert 2005) wrote a series of articles exploring the concept of native fish refuges for salmon, steelhead, trout, and warmwater species conservation. The symposium resulted in a consensus definition for a native fish conservation area and development of a four-page prospectus that described the NFCA concept and how it might be implemented (available at http://www.tu.org/science/science-team-csi-reports). The concept is very similar to aquatic diversity management areas, which have been proposed by Peter Moyle and his colleagues as a way to conserve aquatic biodiversity in California (Moyle and Yoshiyama 1994).

We define a native fish conservation area as a watershed-scale (fifth-level, 10-digit HUC or larger) area where management emphasizes conservation and restoration for long-term persistence of native fishes and other native aquatic species while allowing compatible uses. Fifth-level watersheds vary in size from about 16,000 to 101,000 ha (U.S. Geological Survey and U.S. Department of Agriculture Natural Resources Conservation Service 2009). The NFCA concept does not replace more traditional approaches to fisheries conservation but instead complements existing efforts that are often more reactive to existing stressors and focused on single species rather than larger communities. Establishment of watershed-scale conservation areas would conserve the biological integrity of native fish populations as well as the larger aquatic ecosystems upon which those fishes depend. The size of watersheds included in individual NFCAs would be dependent on a variety of factors but should primarily be driven by the needs of the specific aquatic system and its native fish community, rather than extrinsic factors such as jurisdictional boundaries and ownerships.

There are several economic and ecological efficiencies to managing and restoring entire fish communities at watershed scales rather than managing individual species at local streams. As described earlier, agencies in the United States spend billions of dollars annually recovering endangered species and restoring degraded ecosystems but relatively little in protecting species' assemblages that still are intact and habitats that still are healthy. Costs associated with protecting entire communities in a single watershed are likely to be less than the comparative cost of protecting individual species in discrete habitats. There also are likely to be economic efficiencies in conducting restoration at watershed scales. Among the chief causes of aquatic ecosystem restoration failure are the lack of a watershed-scale perspective and a tendency to focus on symptoms of the problem rather than treating the root cause of the problem, which is often related to working at smaller spatial scales (J. E. Williams et al. 1997). Some of the ecological benefits of working at these larger spatial scales are described in Table 1.

Figure 2. Idaho's Middle Fork Salmon River is well known as a wilderness river and native fish stronghold and would have potential as an NFCA. Photo by Rick Williams.

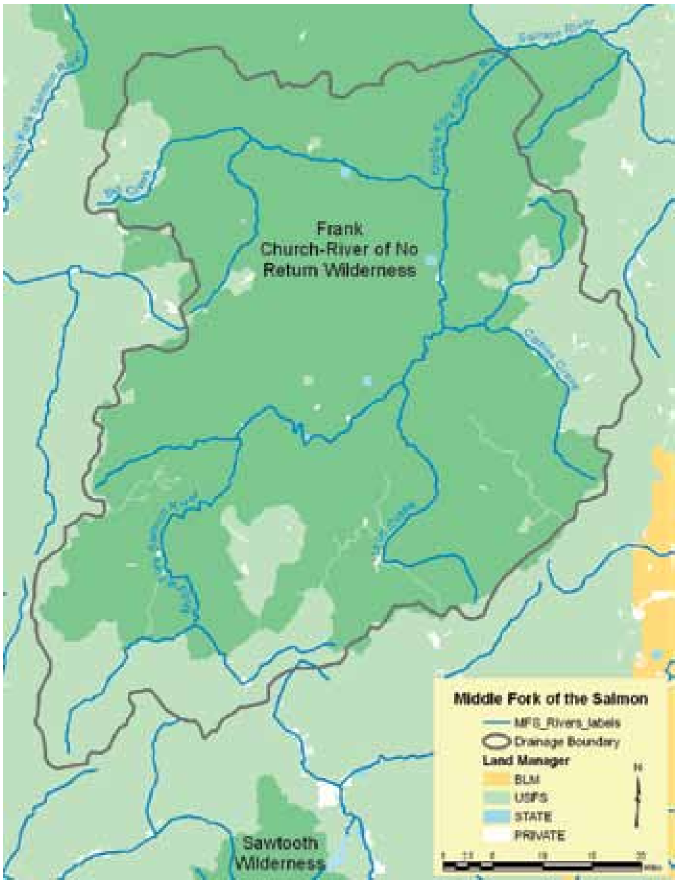

Figure 3. Map of Middle Fork Salmon River drainage.

Our understanding of native fish ecological requirements is incomplete. For some regions, native trout may be appropriate focal species to help define NFCA locations and boundaries. Seven native salmonids were the focus of the assessment of fish status for the Interior Columbia River Basin Ecosystem Management Project (Lee et al. 1997). The authors noted four reasons for focusing on native salmonids: (1) more is known about them compared to other species; (2) they are widely distributed, which enables broad scale comparisons; (3) because they act as predators, competitors, and prey for other aquatic taxa, they are likely to influence the structure and function of aquatic ecosystems; and (4) native salmonids are potentially more sensitive to water quality and disturbance compared to other fishes. Their diverse species and life stages use widely divergent habitats. As a result, salmonids may integrate the cumulative effects of environmental change over broad areas (Lee et al. 1997). In addition, protecting sufficient habitat to support highly mobile fluvial or adfluvial trout life histories often includes well-connected habitat patches that are large enough to support additional native fishes.

In a few notable areas, native fish populations are stable. In these locations, water quality and habitat attributes required by salmonids and other umbrella conservation species often remain intact, human disturbance is limited, and some locations are managed for reduced harvest. As Thurow et al. (1997) observed, native salmonids have generally persisted in the areas least influenced by humans. Within the western United States, the strongest and most intact native salmonid populations occur within a network of federally protected and managed lands, such as roadless areas, wilderness areas, wild and scenic rivers (e.g., westslope cutthroat trout, redband trout, and bull trout in Idaho's Selway and Middle Fork Salmon rivers; Lee et al. 1997), and national parks (e.g., westslope cutthroat trout in Glacier National Park, Yellowstone cutthroat trout in Yellowstone National Park, and greenback cutthroat trout in Rocky Mountain National Park; Young 1995; Figures 2 and 3). Remaining strongholds for native eastern brook trout are found primarily in the Green Mountain and White Mountain National Forest lands and in the large, privately owned northern forest tracts in the upper New England states.

Flexibility and innovation may be key ingredients to establishing NFCAs across lands of mixed ownership. The concept of establishing reserves for native fishes may cause concern that other uses, such as timber harvest, mining, grazing, other agricultural uses, and recreation, would be restricted. A central part of the vision for NFCAs is that recreation and certain other multiple uses can be compatible with native fish conservation efforts. That said, because the primary reason for the NFCA is to protect the native fish populations and their habitats, decisions regarding compatible uses should be made based on their expected effects on the native fish community and the aquatic ecosystem. Local habitat conditions, land ownerships, stakeholder concerns, and other factors will also influence decisions regarding compatible uses. If streams and riparian areas are afforded special management protection and—depending on landscape and hydrologic conditions—numerous activities (including livestock grazing, timber harvest, prescribed burns, and other forms of vegetation), management can be compatible with native fish management.

Working successfully across watersheds containing various agency administrators and landowners will require patience, collaboration, innovation, vision, and strong leadership. Wondolleck and Yaffee (2000) describe the challenges of landscape collaborative conservation efforts across the United States, including some notably successful efforts that focus on rivers and their fisheries, such as Montana's Blackfoot Challenge and Idaho's Henrys Fork. Collaborative efforts work when they are mutually beneficial to all parties. Finding common ground is essential but can take time and effort. Nonetheless, in many parts of the country where large blocks of public lands are limited or lacking entirely, the ability of fisheries managers to forge mutually beneficial relationships with private landowners may prove essential to implementing the NFCA concept.

Essential NFCA Components

Four critical elements need to be met within a NFCA—

three that will ensure its biological effectiveness and one that will ensure that the area is sustainable socially and institutionally—(1) protect and, if necessary, restore watershed-scale processes that create and maintain freshwater habitat complexity, diversity, and connectivity; (2) nurture all of the life history pathways of the fish species being protected; (3) include a large enough watershed to provide for long-term persistence of native fish populations; and (4) provide management that is sustainable over time.

Maintain Natural Processes

Aquatic habitats are dynamic over space and time and are shaped by processes occurring within their immediate stream valleys and upstream watershed. Factors that create habitat complexity, diversity, and connectivity in aquatic systems often originate in headwater streams and intermittent channels far upstream from native fish communities. For example, interactions between stream flow and sediments, substrates, and large woody debris inputs create deep pool habitats and channel complexity. The NFCA should be based on watershed boundaries that include sufficient upslope lands and upstream waters to provide for the continuation of these processes over time.

Disturbances such as floods, drought, and wildfire may substantially alter the condition of streams and their watersheds and should be a consideration in defining the extent of NFCAs (Reeves et al. 1995; Dunham et al. 2002). Therefore, it may be prudent to include a sufficiently large stream network so that the entire NFCA is less likely to be impacted by a single disturbance event, and fish would be more likely to have access to undisturbed habitats.

Include Habitats for Diverse Life Histories and Life Stages

To meet this second critical element, an NFCA must include habitats that are necessary for a species to express all major life history forms that were historically present. Consequently, an important initial step in assessing the suitability of an area as an NFCA might be to assess a species potential historical range, the life history forms that were present, and the current habitat conditions within the historical range. If suitable habitats exist to support all life history forms, an NFCA could be established for fish conservation and restoration even if some life history forms are no longer present. Using a hypothetical example, biologists and managers might determine that an area historically supported fluvial and resident (nonmigratory) forms of native cutthroat trout. Recent fisheries and habitat surveys have documented the persistence of only resident forms; however, the presence of high-quality and connected habitats is deemed sufficient to support both fluvial and resident forms. As a result, the area may be suitable as an NFCA. In this instance, future monitoring might document reemergence of the fluvial life history pattern in cutthroat within the NFCA.

In addition to supporting habitats for all life history forms, an NFCA should support all habitats necessary to complete a species life cycle, including essential habitats for spawning, incubation, rearing, overwintering, and migration. In some cases, wide-ranging species like Chinook salmon may complete such extensive migrations that it may be impractical to include all habitats in a single NFCA. Failure to include all essential habitats in an NFCA, however, may result in inadequate measures to conserve and restore native fishes. For wide-ranging species, conservation and restoration of migratory corridors as well as spawning and rearing areas will be essential.

Support Long-Term Population Persistence

The NFCA should not only be large enough to support all life history stages of the native fishes but also to support sufficiently large populations that have a high likelihood of long-term persistence. At a minimum, Hilderbrand and Kershner (2000) recommend that sufficient habitat is needed to support an effective population size of 500 interbreeding adults to meet persistence needs in trout populations. For cutthroat trout (*Oncorhynchus clarkii*), an effective population of 500 equates to a census population of about 2,500 fish >75 mm total length. Dunham and Rieman's (1999) work on bull trout (*Salvelinus confluentus*) suggested that a minimum habitat patch size of 5,000 ha was necessary for persistence. Trout populations occupying less than 5,000 ha of habitat may still meet persistence criteria if the following combinations of stream habitat availability and population density are available: 9.3–13.9 km stream habitat with high-density fish population (>93 fish/km) or 13.9–27.8 km habitat with moderate density population (31–93 fish/km; Hilderbrand and Kershner 2000). Although these values were derived for western trout populations, they may provide general guidance for other native fishes. If the goal is to support a metapopulation or to provide interconnected habitat patches, a larger amount of habitat would be needed.

Manage in Perpetuity

Management plans or other agreements should be in place to ensure that the NFCA will be managed in a manner that sustains aquatic and riparian habitat integrity over time and across management jurisdictions and land ownerships. Depending on the size and complexity of the watershed, this may require local community commitments, landowner agreements, and local and state government support.

Given variation in ecological value, all lands within the NFCA may not require equal protection or management intensity. If all lands within the watershed are not in some form of protective management, their management should at least be consistent with conservation of the aquatic and riparian habitats and the processes that shape these environments. Public lands, often located in higher elevation headwaters, may be more easily protected and have wider riparian buffers than are valley bottoms, which may be in private ownership.

However, it may be the lower elevation lands that historically harbored the larger and more diverse stream communities. The site-specific and watershed-specific contexts will be crucial in determining management needs and restoration priorities.

Implementing the Concept

A variety of paths exist to implement the NFCA concept. A companion paper in this issue of *Fisheries* describes an approach for implementing the NFCA concept that focuses on cooperative management across diverse land ownerships (Dauwalter et al., 2011). An alternative approach to establishing NFCAs would be through formal refuge designation by a public land management agency. Though we emphasize the importance of implementing the concept over the vehicle of that implementation, it may be helpful to examine some implementation options, constraints, and opportunities.

Some watersheds are protected by existing formal designations but are not necessarily recognized for native fish conservation or specifically managed for these resources. For example, Idaho's Middle Fork Salmon River and its native fish community are protected as part of the larger Frank Church River of No Return Wilderness. The Middle Fork is also designated as a Wild and Scenic River where angling for native cutthroat and bull trout is allowed under catch-and-release regulations.

As part of the Steens Mountain Cooperative Management and Protection Act of 2000, congress created the Donner und Blitzen Redband Trout Reserve on BLM lands in southeastern Oregon. According to the Act, the purposes of the Reserve are "to conserve, protect, and enhance the Donner und Blitzen population of redband trout and the unique ecosystem of plants, fish, and wildlife of a river system" (§302 of the Act). With the headwaters of the Donner und Blitzen River in a designated wilderness area, the drainage serves as an example where conservation efforts effectively protect an intact native fish community (Figures 4 and 5).

In California, the Yurok Tribe is planning a tribal park along Blue Creek, a major tributary of the lower Klamath River that provides habitat for coho salmon, steelhead, coastal cutthroat trout, and other native fishes. The intent of the Yurok Tribal Council is to restore the watershed and its native species "to the richness, diversity, and abundance provided by the Creator" (Yurok Tribe 2005:6). Western Rivers Conservancy recently purchased 10,117 ha in the lower Blue Creek drainage for restoration as part of the tribe's park. These lands, when combined with the headwaters of Blue Creek in the Siskiyou

Figure 4. Oregon's Donner und Blitzen River, which is managed as a native redband trout refuge by the Bureau of Land Management. Photo by Dan Dauwalter.

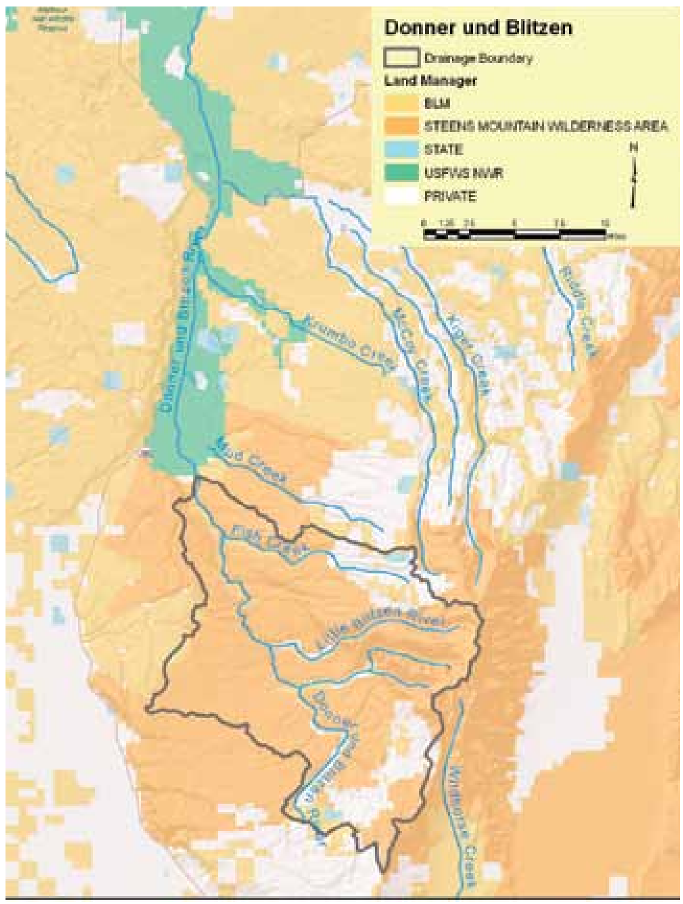

Figure 5. Map of Donner und Blitzen River drainage.

Wilderness Area of the Six Rivers National Forest, will place nearly the entire drainage area in conservation management (Figures 6 and 7).

Of course, mere protection of intact watersheds does not necessarily equate to a flourishing native fish community. Yellowstone Lake and its tributary streams are protected in Yellowstone National Park, yet the formerly robust and diverse populations of native Yellowstone cutthroat trout have been devastated by introduced lake trout and whirling disease (Koel et al. 2007). Even national park status and stewardship by the National Park Service does not ensure that aquatic ecosystems will be secure. A dedicated focus of management and monitoring of aquatic ecosystem integrity is needed in tandem with habitat protection measures.

Figure 6. California's Lower Blue Creek, a tribal salmon park in the Klamath River drainage. Photo by Rick Hiser.

The mission of the National Wildlife Refuge (NWR) System is to protect our nation's fish and wildlife resources, and the system has been remarkably successful for many species and habitats, such as waterfowl and wetlands. Individual refuge parcels, however, often do not cover watershed-scale areas and can be problematic for protection of ecosystems and their diversity (Scott et al. 2004; Herbert et al. 2010). Many NWRs are designed to protect wetland-dependent species or migratory waterfowl that can flourish in disconnected habitat patches. Relative to fish conservation, national wildlife refuges have been more successful in protecting localized spring- or cave-dwelling fishes rather than riverine species that range over larger areas. For instance, Nevada's Ash Meadows NWR was designated to protect a number of rare spring-dwelling species even though managers now realize that additional protection of groundwater aquifers, which extends well beyond refuge boundaries, is also needed (Deacon et al. 2007). Protecting rivers and their native fishes has proven more problematic within NWRs, which are seldom if ever designed around watershed boundaries. Even NWRs established along rivers, such as the Illinois River National Wildlife and Fish Refuge, consist of individual tracts of lands along rivers with little integration of their management to the broader watershed.

Even if NWRs do not provide sufficient lands to protect important watershed processes, they could anchor future NFCAs. The upper Androscoggin River along the Maine–New Hampshire border could be a potential NFCA in the east, where public lands are more scattered and less available to support watershed-scale NFCAs. Umbagog Lake, Rapid River, and the Magalloway River support native fish communities within the upper Androscoggin, and lands around Umbagog Lake are mostly within the Umbagog NWR (Figure 8).

Regardless of the densities of public lands in the region, managing for native fish communities will be particularly difficult if protected lands are scattered along river systems without regard to watershed boundaries and/or the potential for nonnative fish immigration. Even large national parks, such as Canyonlands and the Grand Canyon, which contain large stretches of natural riverine habitats, are not immune from invasion by nonnative species and upstream management practices. The Green and Colorado rivers in Canyonlands National Park, which historically provided excellent habitat for native big river fishes such as razorback sucker and Colorado pikeminnow, are now dominated by carp, channel catfish, and other nonnative aquatic species (J. E. Williams and Davis 1996). Recent studies have shown that up to 95% of the fishes in Canyonlands are nonnatives (http://www.nps.gov/cany/naturescience/fish.htm). Similarly, native fishes in the Colorado River in Grand Canyon National Park declined significantly in abundance because of cold, clear water releases from Glen Canyon Dam, located upstream from park boundaries (Kaeding and Zimmerman 1983).

Negative influences from adjacent lands can be a problem for both large and small reserves. The small size of many NWRs renders their ability to protect species almost entirely dependent upon processes and events occurring on adjacent lands (Czech 2005). Water is a particularly difficult resource to manage, especially if water sources in headwaters are not protected. Pringle (2000) reported that 150 out of 224 western NWRs have conflicts with other water users, and only 98 of 224 reported that their existing water rights assured delivery of adequate water in an average water year.

Designing new NFCAs along watershed boundaries could provide a considerable conservation boost to native aquatic species. Where designation of entire watersheds as protected areas is impractical, management across various land ownerships could be more formally coordinated for the benefit of aquatic ecosystems (Dauwalter et al., 2011). In these cases, protected public lands could anchor conservation needs in critical parts of the watershed and cooperative agreements, easements, or other means could provide management focused on aquatic systems on private lands.

In addition to establishing new NFCAs, effort should be focused on restoring native fish communities in areas that are already protected. The National Park Service, for example, is emphasizing control of nonnative lake trout and rainbow trout in their efforts to reestablish native trout and graying in Yellowstone National Park. If lake trout can be controlled in Yellowstone Lake, myriad aquatic and terrestrial species would benefit by restoration of Yellowstone cutthroat trout that historically numbered in the millions and ascended dozens of tributary streams from the lake each spring. Similar opportunities exist in other national parks and monuments where lands already are protected.

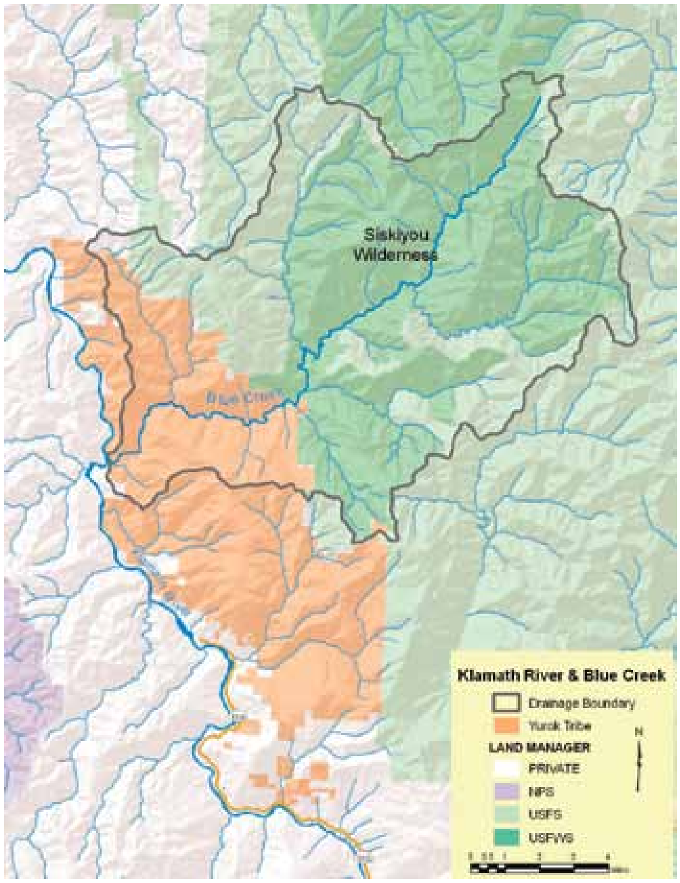

Figure 7. Map of the Blue Creek drainage.

Protection of large tracts of land has been a cornerstone in the efforts to conserve terrestrial species, but has seldom been utilized to conserve aquatic species. Establishing a network of protected watersheds in river basins across the country will be challenging because of diverse patterns of land ownership, as well as land use, water allocation, and aquatic invasive species that dominate many areas. Nonetheless, the task will only become more difficult in the future as human population growth and associated demands on resources proceed. Conserving a network of functional aquatic communities across the country using the native


Figure 8. The Rapid River, part of the wild upper Androscoggin River drainage along the New Hampshire–Maine border region. Photo by Shelby Rousseau of the Rangeley Lakes Heritage Trust.

fish conservation area strategy would provide an economically and ecologically viable complement to current approaches to fish conservation.

Acknowledgments

We thank Peter Moyle for his pioneering efforts to promote the conservation of larger aquatic communities. Many of the participants in the Boise workshop are authors of this article. Several others participated in the workshop and provided guidance to this effort, including John Epifanio (Illinois Natural History Survey), Chris Wood (Trout Unlimited), and Amy Haak (Trout Unlimited). Sabrina Beus kindly created the maps of potential NFCAs. We also appreciate comments from Dan Dauwalter (Trout Unlimited) and John Sanderson (The Nature Conservancy). Support for the workshop and subsequent efforts to promote Native Fish Conservation Areas have been provided by Trout Unlimited's Coldwater Conservation Fund, the Fisheries Conservation Foundation, Federation of Fly Fishers, and the National Fish and Wildlife Foundation. The authors also thank three anonymous reviewers for their helpful comments and suggestions.

References

Adams, S. B., C. A. Frissell, and B. E. Rieman. 2001. Geography of invasion in mountain streams: consequences of headwater lake fish introductions. Ecosystems 4(4):296–307.

Bernhardt, E. S., et al. 2005. Synthesizing U.S. river restoration efforts. Science 308(5722):636–637.

Brown, D. L., A. A. Echelle, D. L. Propst, J. E. Brooks, and W. L. Fisher. 2001. Catastrophic wildfire and number of populations as factors influencing risk of extinction for Gila trout (*Oncorhynchus gilae*). Western North American Naturalist 61(2):139–148.

Czech, B. 2005. The capacity of the National Wildlife Refuge System to conserve threatened and endangered animal species in the United States. Conservation Biology 19:1246–1253.

Dauwalter, D. C., J. S. Sanderson, J. E. Williams, and J. R. Sedell. 2011. Identification and implementation of native fish conservation areas in the Upper Colorado River Basin. Fisheries 36:278-288.

Deacon, J. E., A. E. Williams, C. Deacon Williams, and J. E. Williams. 2007. Fueling population growth in Las Vegas: how large-scale groundwater withdrawal could burn regional biodiversity. BioScience 57:688–698.

Doremus, H., and J. E. Pagel. 2001. Why listing may be forever: perspectives on delisting under the U.S. Endangered Species Act. Conservation Biology 15:1258–1268.

Dunham, J. B., and B. E. Rieman. 1999. Metapopulation structure of bull trout: influences of physical, biotic, and geometrical landscape characteristics. Ecological Applications 9:642–655.

Dunham, J. B., B. E. Rieman, and J. T. Peterson. 2002. Patch-based models to predict species occurrence: lessons from salmonid fishes in streams. Pages 327–334 *in* J. M. Scott, P. Heglund, M. Morrison, J. Haufler, and B. Wall, editors. Predicting species occurrences: issues of scale and accuracy. Island Press, Washington, D.C.

Frissell, C. A., and D. Bayles. 1996. Ecosystem management and the conservation of aquatic biodiversity and aquatic integrity. Water Resources Bulletin 32:229–240.

Haak, A. L., J. E. Williams, D. Isaak, A. Todd, C. C. Muhlfeld, J. L. Kershner, R. E. Gresswell, S. W. Hostetler, and H. M. Neville. 2010. The potential influence of changing climate on the persistence of salmonids of the inland West. U.S. Geological Survey Open-File Report 2010-1236, Reston, Virginia.

Herbert, M. E., P. B. McIntyre, P. J. Doran, J. D. Allan, and R. Abell. 2010. Terrestrial reserve networks do not adequately represent aquatic ecosystems. Conservation Biology 24:1002–1011.

Hilderbrand, R. H., and J. L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much habitat is enough? North American Journal of Fisheries Management 20:513–520.

Hudy, M., T. M. Thieling, N. Gillespie, and E. P. Smith. 2008. Distribution, status, and land use characteristics of subwatersheds within the native range of brook trout in the eastern United States. North American Journal of Fisheries Management 28:1069–1085.

Jelks, H. L., et al. 2008. Conservation status of imperiled North American freshwater and diadromous fishes. Fisheries 33:372–407.

Kaeding, L. R., and M. A. Zimmerman. 1983. Life history and ecology of the humpback chub in the Little Colorado and Colorado rivers of the Grand Canyon. Transactions of the American Fisheries Society 112:577–594.

Koel, T. M., J. L. Arnold, P. E. Bigelow, P. D. Doepke, B. D. Ertel, and M. E. Ruhl. 2007. Yellowstone fisheries and aquatic sciences: annual report 2007. National Park Service, Yellowstone, Wyoming.

Lee, D. C., J. R. Sedell, B. E. Rieman, R. F. Thurow, and J. E. Williams. 1997. Broadscale assessment of aquatic species and habitats. Pages 1058–1496 *in* T. M. Quigley, et al., editors. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins. U.S. Department of Agriculture Forest Service, PNW-GTR-405, Portland, Oregon.

Li, H. W., and P. B. Moyle. 1993. Management of introduced fishes. Pages 287–307 *in* C. K. Kohler and W. A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Lichatowich, J. 1999. Salmon without rivers: a history of the Pacific salmon crisis. Island Press, Washington, D.C.

Lichatowich, J., and R. N. Williams. 2004. Needed: salmon and steelhead refuges in the Pacific Northwest. Flyfisher 37(4):28–31.

Master, L. L., B. A. Stein, L. S. Kutner, and G. A. Hammerson. 2000. Vanishing assets: conservation status of U.S. species. Pages 93–118 *in* B. A. Stein, et al., editors. Precious heritage: the status of biodiversity in the United States. Oxford University Press, New York.

Moyle, P. B. 1996. Potential aquatic diversity management areas. *in* Sierra Nevada Ecosystem Project, volume 2, pp. 1493-1502 in Assessments and scientific basis for management options. University of California, Davis, Centers for Water and Wildland Resources.

Moyle, P. B., and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. Fisheries 19:6–18.

Poff, N. L., M. M. Brinson, and J. W. Day, Jr. 2002. Aquatic ecosystems and global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Pew Center on Global Climate Change, Arlington, Virginia.

Postel, S. L. 2000. Entering an era of water scarcity: the challenges ahead. Ecological Applications 10(4):941–948.

Pringle, C. M. 2000. Threats to U.S. public lands from cumulative hydrologic alterations outside of their boundaries. Ecological Applications 10:971–989.

Rahel, F. J., and J. D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. Conservation Biology 22:521–533.

Reeves, G. H., L. E. Benda, K. M. Burnett, P. A. Bisson, and J. R. Sedell. 1995. A disturbance-based approach to maintaining and restoring freshwater habitats of evolutionarily significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334–349.

Reeves, G. H., J. E. Williams, K. M. Burnett, and K. Gallo. 2006. The aquatic conservation strategy of the Northwest Forest Plan. Conservation Biology 20:319–329.

Scott, J. M., T. Loveland, K. Gergely, J. Strittholt, and N. Staus. 2004. National Wildlife Refuge System: ecological context and integrity. National Resources Journal 44:1041–1066.

Suski, C. D., and S. J. Cooke. 2007. Conservation of aquatic resources through the use of freshwater protected areas: opportunities and challenges. Biodiversity Conservation 16:2015–2029.

Taylor, C. A., G. A. Schuster, J. E. Cooper, R. J. DiStefano, A. G. Eversole, P. Hamr, H. H. Hobbs III, H. W. Robison, C. E. Skelton, and R. F. Thoma. 2007. A reassessment of the conservation status of crayfishes of the United States and Canada after 10+ years of increased awareness. Fisheries 32:372–389.

Thurow, R. F., D. C. Lee, and B. E. Rieman. 1997. Distribution and status of seven native salmonids in the interior Columbia River basin and portions of the Klamath River and Great basins. North American Journal of Fisheries Management 17:1094–1110.

USEPA (U.S. Environmental Protection Agency). 2008. Effects of climate change for aquatic invasive species and implications for management and research. U.S. EPA National Center for Environmental Assessment, EPA/600/R-08/014, Washington, D.C.

USFWS (U.S. Fish and Wildlife Service). 2010. Federal and state endangered species expenditures: fiscal year 2008. U.S. Fish and Wildlife Service, Washington, D.C.

USGS and USDA NRCS (U.S. Geological Survey and U.S. Department of Agriculture Natural Resources Conservation Service). 2009. Federal guidelines, requirements, and procedures for the national watershed boundary dataset. U.S. Geological Survey Techniques and Methods Report 11-A3.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. S. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18(9):6–22.

Williams, J. E., and G. E. Davis. 1996. Strategies for ecosystem-based conservation of fish communities. Pages 347–358 *in* R. C. Szaro and D. W. Johnston, editors. Biodiversity in managed landscapes: theory and practice. Oxford University Press, New York.

Williams, J. E., A. L. Haak, H. M. Neville, and W. T. Colyer. 2009. Potential consequences of climate change to persistence of cutthroat trout populations. North American Journal of Fisheries Management 29:533–548.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14(6):2–20.

Williams, J. E., C. A. Macdonald, C. Deacon Williams, H. Weeks, G. Lampman, and D. W. Sada. 2005. Prospects for recovering endemic fishes pursuant to the U.S. Endangered Species Act. Fisheries 30:24–29.

Williams, J. E., C. A. Wood, and M. P. Dombeck. 1997. Understanding watershed-scale restoration. Pages 1–13 *in* J. E. Williams, C. A. Wood, and M. P. Dombeck, editors. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland.

Williams, R. N., and R. Tabbert. 2005. Protecting resident native trout: a case for a national refuge system. Flyfisher 38(1):30–34.

Wondolleck, J. M., and S. L. Yaffee. 2000. Making collaboration work: lessons from innovation in natural resource management. Island Press, Washington, DC.

Young, M. K., tech. editor. 1995. Conservation assessment for inland cutthroat trout. U.S. Department of Agriculture Forest Service, General Technical Report RM-GTR-256.

Yurok Tribe. 2005. Tribal park concept plan. The Yurok Tribe, Klamath, California.