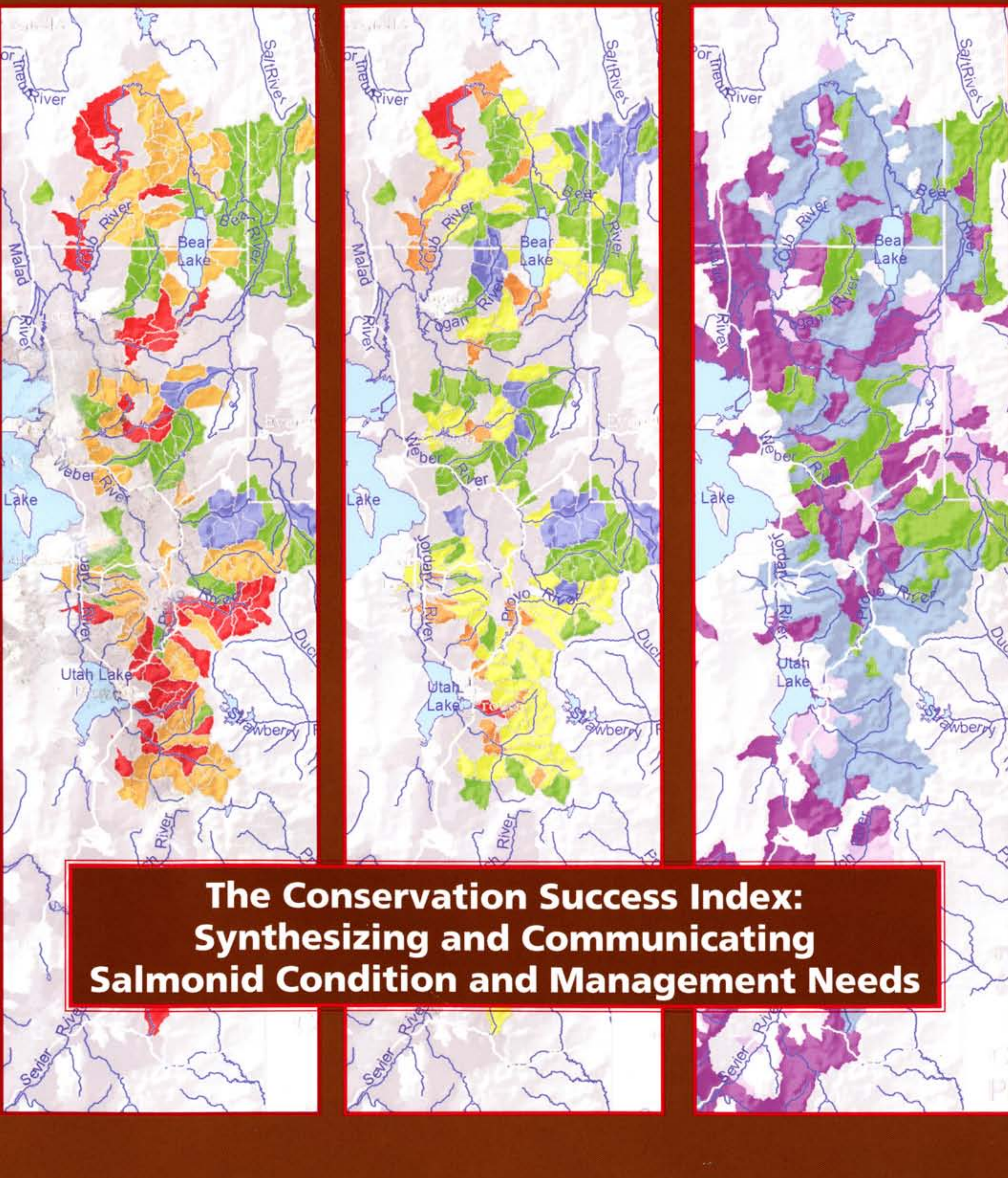
Fisheries

VOL 32 NO 10
OCTOBER 2007

AFS

American Fisheries Society • www.fisheries.org

Fish News
Legislative Update
Journal Highlights
Calendar
Job Center



The Conservation Success Index: Synthesizing and Communicating Salmonid Condition and Management Needs

FEATURE:
CONSERVATION

**Jack E. Williams,
Amy L. Haak,
Nathaniel G. Gillespie,
and Warren T. Colyer**

Williams is the senior scientist for Trout Unlimited and is located in Medford, Oregon. He can be contacted at jwilliams@tu.org. Haak is the information resource director for TU located in Boise, Idaho. Gillespie is a fisheries scientist for TU located in Arlington, Virginia. Colyer is a restoration ecologist for TU located in Logan, Utah

The Conservation Success Index: Synthesizing and Communicating Salmonid Condition and Management Needs

ABSTRACT: Increasing our ability to synthesize and compare fisheries assessment data among species and across geographic boundaries should facilitate a better understanding of the broad-scale condition of fish resources and necessary management strategies. We describe the Conservation Success Index (CSI), a new tool to analyze the status of native salmonids and facilitate protection, restoration, reintroduction, and monitoring efforts. The CSI provides a framework to evaluate indicators of population integrity, habitat integrity, and future security within native salmonids across all subwatersheds within their historic range. To date, the CSI has been completed for seven native trout and char species with summary status maps, data sheets, spatial analyses of management needs, and analysis of climate change and energy development impacts available at http://tucsi.spatialdynamics.com. Additional species are added annually. Case studies using Bonneville cutthroat trout and brook trout illustrate how the CSI provides a multi-scaled description of management priorities that can be combined with site-specific data to design needed restoration. Although specifically developed by Trout Unlimited to prioritize the organization's conservation work and to assist our members in understanding broad-scale conservation needs, the CSI may be useful to other organizations as a fisheries management or environmental education tool.

Índice de Éxito de la Conservación: síntesis y comunicación de la condición actual de los salmónidos y necesidades para su manejo

RESUMEN: El incremento de nuestras habilidades para sintetizar y comparar información de evaluaciones pesqueras entre especies y a través de fronteras geográficas, debiera facilitar el entendimiento acerca de la condición general de los recursos pesqueros y las consecuentes estrategias de manejo. En la presente contribución se describe el Índice de Éxito de la Conservación (IEC) una nueva herramienta para analizar el estado de los salmónidos autóctonos de los Estados Unidos de Norteamérica y facilitar su protección, recuperación, reintroducción y esfuerzos de monitoreo. El IEC provee un marco de referencia para evaluar los indicadores de integridad poblacional, integridad del hábitat y aseguramiento del futuro de los salmónidos nativos a lo largo de todas las cuencas hidrográficas comprendidas en su rango histórico de distribución. Hasta el momento se ha completado el IEC para siete especies de truchas y "chars" que incluye mapas de su estado actual, datos, análisis espaciales, necesidades de manejo, análisis de cambio climático y análisis de impactos asociados al desarrollo energético; la información está disponible en: http://tucsi.spatialdynamics.com. A esta lista, se agregan más especies cada año. Los casos de estudio de las truchas Oncorhynchus clarkii utah y Salvelinus fontinalis muestran cómo el IEC ofrece una descripción "multi-escalar" de las prioridades de manejo que puede combinarse con datos puntuales para dar como resultado un diseño adecuado de recuperación. Si bien el índice fue desarrollado originalmente por "Trout Unlimited" con la finalidad de priorizar su trabajo y ayudar a nuestros propios miembros a comprender las necesidades más generales de conservación, el IEC puede resultar muy útil para otras organizaciones como herramienta de manejo pesquero y educacional.

INTRODUCTION

"How do we best conserve trout and salmon?" This fundamental and seemingly simple question underlies the conservation work to protect and restore our coldwater fishes. Before strategies can be developed to conserve trout and salmon, fisheries agencies must first synthesize a myriad of population and habitat information collected at various temporal and spatial scales. Developing a proper understanding of these data may take years given the natural variation of watershed conditions, disturbance events, and patterns of cause and effect. The broad geographic range of many species, coupled with a complex mix of agency priorities, jurisdictions, and data availability, make tracking the health of salmonid populations and habitat a difficult but essential task.

Despite these challenges, state, federal, and tribal agencies have produced numerous conservation status assessments (e.g., Young 1995; Slaney et al. 1996; May and Albeke 2005), recovery plans (e.g., Greenback Cutthroat Trout Recovery Team 1998), and broader landscape assessments that use salmonids as indicator species (e.g., Lee et al. 1997). These studies have generated considerable data on status, trends, and habitat conditions. Additional data on stream and watershed conditions can be obtained from government publications and web sites (e.g., U.S. Geological Survey, Idaho National Laboratory). In order to answer the question of how best to conserve trout and salmon, all of these disparate data sets must be synthesized into a consistent and informative framework that takes into account the variability in spatial and temporal scales as well as methodologies.

Maintaining the inherent diversity of native salmonid species, subspecies, and life history forms is critical to achieving a future where robust populations of trout and salmon will provide the ecological, economic, evolutionary, aesthetical, and spiritual values for which they are known. The Conservation Success Index (CSI) is a tool developed by Trout Unlimited (TU) to help conserve and restore trout and salmon through the characterization and synthesis of native salmonid status across the United States. Fisheries biologists, land managers, and other agency personnel can use the CSI to answer the following questions and thereby inform future management and restoration efforts:

- What is the range-wide status of each species?
- What are the primary existing threats to populations and habitats?
- How secure are populations and habitats from likely future threats?
- Where, from a broad-scale perspective, should we focus our limited conservation resources?
- How do we measure the success of our conservation investments?
- How does the status of multiple taxa compare and contrast across their respective ranges?

Our intent in this article is to describe the CSI and its potential application to the conservation of coldwater fishes and their habitats, from brook trout in the East to cutthroat trout in the West. The CSI provides a framework to direct TU's volunteer members and other organizational resources towards areas in greatest need of protection and restoration and where the greatest conservation benefits can be achieved, both locally and within a larger landscape context. We also utilize CSI to better understand impacts of climate change, energy development, and other processes that operate at broad spatial scales.

The CSI is designed to make results available and applicable to a wide range of user technology and conservation interests. This includes, but is not limited to, TU's 150,000 members, agency personnel, research biologists, ecologists, and the interested public. Results are available on the TU website http://tucsi.spatialdynamics.com and may be viewed in numerous formats as described below.

BENEFITS OF USING NATIVE SALMONIDS AS ASSESSMENT SPECIES

Salmonids are among the most valued and well-known native fishes in North America (Behnke 2002). Many native trout and char species are good indicators of stream and watershed conditions and are often selected as key indicators of broader habitat conditions in regional assessments (Lee et al. 1997). In addition, their renowned sporting and culinary qualities, cultural significance, and beauty resonate with the general public, making these salmonids among the most widely recognized and popular freshwater fishes.

Native trout and char are often used as indicators of local and broad-scale environmental conditions. They are sensitive to habitat degradation, reduced stream flows, and poor water quality. Therefore, the presence of wild, naturally-produced trout and char is usually a sign of good habitat conditions both locally and in the upstream contributing area. Conversely, local population declines are often indicative of larger ecological problems. Further, the high degree of diversity and plasticity of life history forms among these salmonids enables them to survive across a range of geographic environments, fluctuating seasonal and annual conditions, and long-term environmental changes (Gharrett and Smoker 1993), and has allowed for their widespread distribution across North America. Habitat requirements of salmonids are better understood than those of many other aquatic taxa, due in large part to their broad public appeal and the requirements of the Endangered Species Act (ESA), which have driven numerous scientific studies on population viability, habitat requirements, behavior, and limiting factors. With seven trout species and subspecies and numerous Evolutionarily Significant Units of anadromous salmonids listed under the Endangered Species Act (USFWS 2006), and many more considered sensitive, there is a strong impetus for state, federal, tribal, and non-governmental agencies to work together in the development and implementation of effective recovery plans based on credible science.

CONSERVATION SUCCESS INDEX: FRAMEWORK AND METHODOLOGY

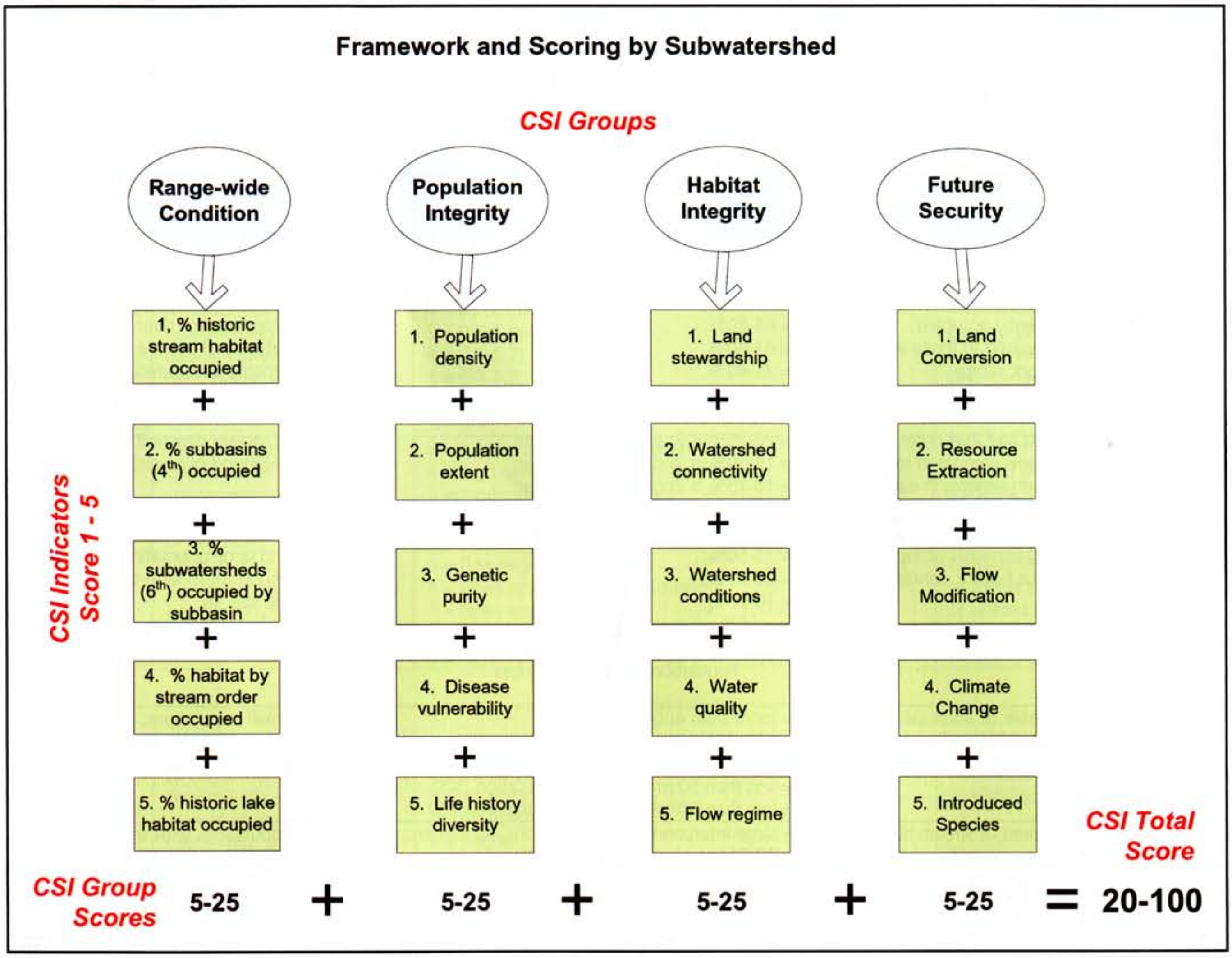
Status Evaluation

The Conservation Success Index assesses the status of coldwater fishes based on current distribution, population, and habitat conditions, and security from future threats at various geographic scales from the local subwatershed to the broader historic range. It uses a geographic information system (GIS) to integrate existing biological data gathered by state and federal agencies with spatial information about natural and anthropogenic landscape features and displays results using Google Earth™ and Google Map™ imagery. Results identify subwatersheds (6^{th} Hydrologic Unit Code: approximately 10,000 to 40,000 acres each) where populations remain strong, have become weakened, or have been extirpated, and help determine priority areas for protection, monitoring, restoration, and reintroduction. Assessment results can be used to identify gaps in current protection and restoration strategies and to inform future management decisions.

The CSI includes an analytical framework consisting of 20 indicators (grouped into 4 categories: range-wide condition, population integrity, habitat integrity, and future security) that supports comparisons among taxa and across administrative boundaries (Figure 1). Each indicator is scored from 1 to 5 based on a general CSI ruleset, which may be modified by a species-specific ruleset determined by data availability and species ecology (Table 1). To date, the CSI has been used for native trout and char. We anticipate some additions to the CSI framework as anadromous salmonids are incorporated into the analysis.

The range-wide condition indicators measure changes between historical (pre-colonial) and current distribution. Definitions of "current distribution" vary somewhat among assessments and species but generally correspond to the period of 1990 to 2005. The population integrity indicators are based primarily on population data collected and compiled in federal, state, and tribal status assessments and recovery plans. Habitat integrity indicators use publicly available spatial data sets to characterize in-stream and watershed conditions. When data for a specific metric, such as flow, are not available, appropriate

Figure 1. Status and trends of each salmonid are examined by a suite of 20 CSI indicators, which are divided into 4 categories of range-wide condition, population integrity, habitat integrity, and future security. Each indicator is scored from 1 (poor) – 5 (very good) for every subwatershed that the target fish occurs in, resulting in 100 possible points.



surrogates, such as dams and diversions, are used. Future security indicators evaluate potential threats to both population and habitat and are critical to prioritizing subwatersheds, watersheds, and subbasins for conservation strategies. Thresholds used in scoring individual metrics are based on relevant scientific research and, when available, follow categories defined in range-wide assessments.

Our choice of indicators was intended to include major factors influencing salmonid persistence as described in recent literature (e.g., Rieman et al. 1993; Hilderbrand and Kershner 2000; Young et al. 2005; Fausch et al. 2006) but also was affected by data commonly collected in range-wide species assessments. McElhany et al. (2000) recognize four factors as key to determine salmonid population persistence: abundance, population growth rate, population spatial structure, and diversity. CSI indicators for population density and population extent relate to abundance and the fact that small populations are at greater risk of extinction. Population spatial structure is indicated by habitat connectivity, watershed conditions, and life history diversity. Genetic diversity is important for populations to respond to environmental change and may be indicated by the range of habitats and geography occupied (range-wide condition factors) and the degree to which the native gene pool has been altered by hybridization (genetic purity indicator). Measures of population growth rate are more problematic because data in most range-wide species assessments are gathered over longer time frames and summarized as if they were collected at a single point in time.

Management Prioritization

CSI analyses are conducted at the subwatershed scale, which maximizes flexibility because data can be aggregated into larger hydrologic watersheds or river basins. Aggregating results into larger geographic areas, up to the entire species range, provides ecological context for interpreting the findings while highlighting the broader conservation issue of species persistence (Ziemer 1997). For finer scale applications, such as stream reach projects, CSI data need to be augmented with more local information. Completion of the CSI for a species is dependant upon availability of a comprehensive assessment and data layers that provides biological data on existing populations and spatial data on habitat conditions and barriers. Varying assessment methodologies can be accommodated in

Table 1. Twenty CSI indicators, definitions, general scoring rules, and their relevance to salmonid conservation. Each subwatershed is scored from 1-5 for each indicator, resulting in a total possible score of 100.

Indicator	Definition	General Scoring Rules[1]	Relevance to Conservation
Range-wide Condition Indicators			
% Historic stream habitat occupied	% historic stream habitat currently occupied (km) versus historic conditions	5 = >50% historic range occupied; 4 = 35-49%; 3 = 20-34%; 2 = 10-19%; 1 = < 10%	Species that occupy a larger proportion of their historic range will have an increased likelihood of persistence.
% Subbasins (4th level HUC) occupied	% 4th level hydrologic units currently occupied versus those within historic range	5 = 90-100% historic subbasins occupied; 4 = 80-89%; 3 = 70-79%; 2 = 50-69%; 1 = < 50%	Larger river basins often correspond with Distinct Population Segments or Geographic Management Units that may have distinct genetic or evolutionary legacies for the species.
% Subwatersheds (6th level HUC) occupied within subbasin	% 6th level hydrologic units currently occupied compared to those within historic range	5 = 81-100% historic subwatersheds occupied; 4 = 61-80%; 3 = 41-60%; 2 = 21-40%; 1 = 1-20%	Species that occupy a larger proportion of their historic subwatersheds are likely to be more broadly distributed and have an increased likelihood of persistence.
% Habitat by stream order occupied	% current habitat occupied in 1st and 2nd order streams compared to larger stream systems in each subwatershed	5 = > 25% of stream habitat is 2nd order or greater; 4 = 20-25% is 2nd order or greater; 3 = 15-20% is 2nd order of greater; 2 = 10-15% is 2nd order or greater; 1 = < 10% is 2nd order or greater	Species that occupy a broader range of stream sizes will have an increased likelihood of persistence.
% Historic lake habitat occupied	% lake habitat (surface area) currently occupied versus historic condition	5 = > 50% historic lake habitat occupied; 4 = 35-50%; 3 = 20-35%; 2 = 10-20%; 1 = < 10%	Lakes often harbor unique life histories and large populations that are important to long-term persistence of the species.
Population Integrity Indicators			
Population density	Number of adult salmonids per habitat unit area	5 = more than 400/mile; 4 = 151-400/mile; 3 = 50-50/mile; 2 = less than 50 /mile, overall population 500; 1 = less than 50/mile, overall population < 500	Small populations, particularly those below 500 effective population size, are more vulnerable to extirpation.
Population extent	Amount of stream habitat (km or mi) or lake habitat (surface acres) available to population	5 = large interconnected populations, no barriers; 4 = 30-50 km of connected habitat; 3 = 20-30 km connected habitat; 2 =10-20 km connected habitat; 1 = < 10 km connected habitat	Populations with smaller available habitats are more vulnerable to extirpation.
Genetic purity	Measured as percent of fish known or suspected to be hybridized with non-native salmonids, including hatchery fish	5 = no hybridization; 4 = no hybridization known but proximity to non-native trout causes concern; 3 = hybridization < 10%; 2 = hybridization 10-20%; 1 = hybridization > 20%	Hybridization and loss of the native genome via introgression with non-native salmonids are among the leading factors in declines of native salmonids.
Disease vulnerability	Measured as presence of non-native diseases or parasites and/or accessibility of vectors of disease or parasites	5 = no diseases/pathogens; 4 = none present but proximity >10km; 3 = disease/pathogens present but not in target fish; 2 = disease/pathogens present in habitat but not target fish; 1 = disease/pathogens in target fish	Non-native pathogens and parasites, including the myxozoan parasite that causes whirling disease, can infect native trout and reduce their populations.
Life history diversity	Number of life history forms present as compared to presumed historic condition	5 = all life history forms present; 3 = two or more life histories present but at least one absent; 1 = one life history present, others absent	Loss of life history forms, particularly migratory forms, increases risk of extirpation; loss of migratory forms may reduce genetic diversity.

[1] General scoring rules are abbreviated. More detailed descriptions and any species-specific rules are available at http://tucsi@spatialdynamics.com.

Indicator	Definition	General Scoring Rules[1]	Relevance to Conservation
		Habitat Integrity Indicators	
Land stewardship	Amount (acres or ha) of federal or state lands with regulatory or congressionally-established habitat protections	5 = 30% or more of subwatershed in protected status; 4 = 20-29% protected; 3 = 10-19% protected; 2 = 1-10% protected; 1 = no protected habitat	Subwatersheds with higher proportions of protected federal and state lands typically support higher quality habitat than do other lands.
Watershed connectivity	Measured by instream barriers, water diversions, and dewatered segments	5 = all streams connected; 4 = streams connected but fragmented at watershed scale; 3 = minor fragmentation within subwatershed; 2 = moderate fragmentation; 1 = high fragmentation	Increased hydrologic connectivity provides more habitat area and facilitates development of multiple life histories, which increase likelihood of persistence.
Watershed conditions	Measured by road density, riparian function, stream habitat complexity, and/or deep pools	if road density is used: 5 = 0-0.1 density; 4 = 0.1-0.7; 3 = 0.7-1.7; 2 = 1.7-4.7; 1 = > 4.7	Habitat conditions as indicated by road density, presence of deep pools, or riparian vegetation, are the primary determinant on persistence of most populations.
Water quality	Measured by presence of 303(d) water quality limited stream segments; number of mines, and point sources of pollution.	5 = high quality, no 303(d) segments; 4 = high quality, minor pollution sources; 3 = moderate to high quality; 2 = moderate quality with significant sources of pollution; 1 = poor quality	Decreases in water quality, including reduced dissolved oxygen, increased turbidity, increased temperature, and the presence of pollutants, reduces habitat suitability for salmonids.
Flow regime	Measured by seasonal fluctuations and total flows, compared to historic regime	5 = flow regime unaltered; 4 = flows approx. 90% of historic; 3 = flows approx. 75%; 2 = flows approx. 50%; 1 = flows highly modified, < 50% of historic	Natural flow regimes are critical to proper ecosystem function. Reduced or altered flows reduce capability of watershed to support native biodiversity.
		Future Security Indicators	
Land conversion	Amount of land vulnerable to conversion based on proximity to population centers, slope, land ownership, and road density	5 = amount of land vulnerable to conversion < 20%; 4 = 20-40%; 3 = 40-60%; 2 = 60-80%; 1 = >80%	Conversion of lands from natural habitats will reduce habitat quality and availability.
Resource extraction	Amount of land vulnerable to resource extraction based on energy leases, undeveloped mineral resources, oil, and gas deposits	5 = no potential development; 4 = no active development; low potential; 3 = no active development but recoverable deposits present; 2 = recoverable deposits present, moderate likelihood of active development; 1 = high likelihood of active development	Increased mining and energy development will increase road densities, modify natural hydrology, and increase likelihood of pollution.
Flow modification	Amount of water vulnerable to future diversion, impoundment, or other development	5 = no known vulnerability; 4 = one site or application; 3 = 2 or 3 sites or applications; 2 = multiple sites or applications indicatelikely modifications in significant portion of subwatershed; 1 = multiple applications indicat likely modifications throughout subwatershed	Changes in natural flow regimes are likely to reduce habitat suitability for native salmonids and increase the likelihood of invasion by non-native species.
Climate change	Resistance to climate change impacts as a function of watershed connectivity, habitat conditions, and elevational gradient	5 = high condition; high connectivity; 4 = moderate condition; moderate connectivity; 3 = moderate conditions but low connectivity; 2 = low conditions, low connectivity; 1 = very low conditions	Climate change is likely to threaten most salmonid populations because of warmer water temperatures, changes in peak flows, and increased frequency and intensity of disturbances such as flood and wildlife.
Introduced species	Future vulnerability to introduced species determined as a function of roads in riparian corridors, human population density, and occurrences of introduced species	5 = threats minor or nonexistent; 4 = nonnatives present in larger watershed, chance of spread low; 3 = nonnatives present in watershed, chance of spread moderate; 2 = nonnatives in watershed, chance of spread high; 1 = nonnatives present in subwatershed, chance of spread high	Introduced species are likely to reduce native salmonid populations through predation, competition, hybridization, and the introduction of non-native parasites and pathogens.

the CSI framework as long as they provide data appropriate to all, or nearly all, 20 indicators.

One of the primary purposes of the CSI analysis is to prioritize management strategies for protection, monitoring, restoration, and reintroduction for a species of interest based on accepted conservation principles. Trout Unlimited supports the concept of protecting remaining population and habitat strongholds, actively restoring degraded habitat that retains high potential, and allowing natural, long-term processes to heal the most damaged areas (see Frissell 1997; Ziemer 1997). It is widely recognized that in terms of investment return, it is much less expensive to protect an intact, functioning aquatic system than altering that system and mitigating for resulting impacts (NRC 1992). In addition, especially in the arid West, the strategy of protecting the best remaining higher quality habitats until they can be reconnected to lower elevation areas through instream flow and watershed restoration may represent the best opportunity for salmonids to persist in an era of rapidly changing climates (Battin et al. 2007). These conservation priorities are rooted in fundamental principles of conservation biology that are further described in Williams et al. (2006). They are defined at the subwatershed level and require further refinement with site-specific data to determine stream reach priorities. Local knowledge and private landowner relationships are critical to making strategic and informed decisions about the most appropriate and cost-effective locations for these respective conservation strategies.

Management priorities for protection, restoration, reintroductions, and monitoring are established at the subwatershed scale by comparing scores for habitat and population integrity with scores for future security. For a subwatershed to rank "highest for protection," it must score high for both population and habitat integrity (indicating a stronghold) but low for future security (indicating the high likelihood of a future threat). For a subwatershed to rank "high for protection," it must score high for both population and habitat integrity but also high for future security. For a subwatershed to rank "highest for restoration," it must score moderate to high for population and habitat integrity, and high for future security (indicating a highly restorable population at low future risk). For a subwatershed to rank "high for restoration," it must score moderate to high for population and habitat integrity, but low for future security.

Subwatersheds where the target species are absent or severely limited but habitat integrity remains high and security is high or moderate are targeted as high priority for reintroduction of native fish. Because monitoring should be an inherent part of all high-priority protection, restoration, and reintroduction efforts (Kershner 1997), subwatersheds that are ranked as the highest priority for these management efforts also are indicated as the highest priority for monitoring. The CSI website provides more details on ranking subwatersheds for management actions.

CONSERVATION SUCCESS INDEX: APPLICATION

Trout Unlimited will apply CSI results in a number of ways. First, we will use the results to strategically direct protection, restoration, reintroduction, and monitoring efforts in collaboration with relevant agencies, organizations, and stakeholders. Second, we will use the CSI to identify previously overlooked areas that represent timely conservation opportunities. Third, we will be more strategic in our Embrace-a-Stream grant award programs, one of our primary funding sources for local chapter restoration efforts. Fourth, the CSI will help focus TU chapter resources and prioritize TU's ongoing scientific monitoring and restoration efforts. This is not to imply that CSI results alone will be sufficient for these tasks. For CSI results to be useful in on-the-ground projects, they must be paired with finer-scale knowledge. Assessments utilizing subwatersheds as their unit of analysis are best for broader scale applications and benefit from additions of local data in finer scale decisions (Dunham et al. 2002).

As of 2007, CSI analyses have been completed for the following seven taxa: brook trout (*Salvelinus fontinalis*), greenback cutthroat trout (*Oncorhynchus clarkii stomias*), Bonneville cutthroat trout (*O. clarkii utah*), westslope cutthroat trout (*O. clarkii lewisi*), Yellowstone cutthroat trout (*O. clarkii bouvieri*), Snake River finespotted cutthroat trout (*O. clarkii* ssp.), and Colorado River cutthroat trout (*O. clarkii pleuriticus*). Our goal is to apply the CSI methodology to all native salmonid species across the United States and report the findings in a variety of formats suitable for diverse agency and public audiences with a broad range of technological expertise and biological knowledge.

In the following case studies, we briefly describe CSI applications for two native trout, Bonneville cutthroat trout and brook trout. Although our presentation here provides only a small portion of CSI analyses that are available online for these two taxa, they are intended to provide the reader with insight on data availability and analysis.

In addition to understanding the usefulness of CSI analyses, it is important that the user also appreciate limitations inherent in our data and methodologies. Generally, CSI scoring is completed only for taxa in which broad-scale assessments and databases provide adequate information to score all 20 indicators. Like any analysis process that combines large and diverse data sets, the CSI can suffer from unevenness of data and important gaps in some data sets. Occasionally, however, one or more indicators will not be scored for a subset of populations (e.g., data on lake-dwelling populations of cutthroat trout often are lacking), resulting in maximum possible scores of less than 100. In such cases we indicate on maps and supporting spreadsheets on our website those data that are lacking. In other cases where data may be lacking, we have used the best surrogates available. Rarely, this has resulted in some interdependence or redundancy of indicators. For example, road density could be used to indicate both watershed condition and land conversion. Readers can refer to species-specific rulesets (provided at http://tucsi.spatialdynamics.com) to determine which data were used to score each indicator for a species of interest.

Relative to scoring, we have chosen to weigh all 20 indicators equally. For certain species it can be argued that one or more indicators are more important. For example, genetic purity may be of more importance for the population integrity of a certain species than is disease vulnerability and could arguably be weighted higher. Nonetheless, we believed that with the large number of species that the CSI will potentially deal with and the need to compare one species against another, that it would be best to weigh indicators equally and remove the enigmatic decisions about which factor is more important and under which circumstances. Constraints and opportunities for applying broader scale results from CSI analyses are compared in Table 2.

Case Study of Bonneville Cutthroat Trout CSI

Bonneville cutthroat trout (BCT) evolved in ancient Lake Bonneville and its tributaries during the Pleistocene period, after the Bear River was rerouted from the Snake River drainage into the Great Basin by a massive lava flow. The subspecies now occupies roughly 35% of its historic range in the states of Utah, Idaho, Wyoming, and Nevada. BCT provide an excellent test case for the CSI due to the availability of data in the comprehensive status assessment database that was recently compiled by the Range-Wide Bonneville Cutthroat Trout Conservation Team (May and Albeke 2005).

As an example of one of the four major factors considered in the CSI, Figure 2 shows CSI scores for BCT population integrity by subwatershed. Subwatershed scores are based on a maximum of 25 points and comprise individual scores (5 points maximum each) for population density (average fish per mile), population extent (number of occupied connected streams), genetic purity, disease vulnerability, and life history diversity (number of life history strategies present versus historic potential). Scores for BCT population integrity reflect a pattern of range constriction towards higher elevations and northern latitudes that has been relatively common among cutthroat trout subspecies across the West. In fact, the only subwatersheds that scored in the highest category (blue; 21-25 points) were low-order tributaries in the upper reaches of the Weber and Bear River watersheds. The relatively high population integrity at the upper ends of these two systems reflects the fact that the Weber and Bear river drainages comprise the most connected populations and greatest life history diversities within the subspecies' range. Conversely, most of the historically occupied habitat throughout the southern range of BCT no longer supports extant populations following widespread extirpations during the past century. It is important to note, however, that several of the southern subwatersheds that do support BCT populations score in the second highest category (green), thanks in large part to the extensive restoration and protection efforts by managers, and suggesting that the few remaining southern populations may exhibit better chances at survival. Nevertheless, many fail to meet minimum habitat requirements for long-term persistence in stream-dwelling cutthroat trout as defined by Hilderbrand and Kershner (2000).

The next step in the CSI process is to combine the population integrity rankings with scores for range-wide conditions, habitat integrity, and future security to derive a total CSI score for BCT by subwatershed (Figure 3). This score is based on a maximum value of 100 points (although no subwatershed scored above 90) and incorporates existing habitat and population conditions as well as future threats. The total CSI score for BCT tracks the habitat integrity rankings closely, with the highest scoring subwatersheds again located in the upper Weber and Bear river drainages where connected habitats and populations support multiple life history strategies. Also scoring relatively high in total CSI are a few subwatersheds in western Utah and eastern Nevada. Many of these populations have been reestablished through extensive translocation and reintroduction projects. Until recently, BCT were thought to have been extirpated completely from the western range. Owing to collaborative efforts by tribal, state, and federal agencies, Trout Unlimited, and private landowners, BCT have been reestablished in streams throughout the Deep Creek Mountains and Great Basin National Park where they once flourished. Many of the high total CSI scores for subwatersheds in the southern range reflect similar translocation and reintroduction efforts. Other subwatersheds in the southern region, along with many in central Utah (Provo area), score in middle to low categories for total CSI. These low scores reflect existing impaired habitat and population conditions, as well as future threats due to disease, water storage and irrigation development, and introductions of non-native salmonids. Both the central and southern regions of Utah highlight the interface where limited water supplies and urban development in arid landscapes increasingly threaten aquatic habitats.

A critical application of the CSI will be to use the derived scores to direct future management activities to maximize benefits to BCT. To that end, the CSI also assigns management priorities by subwatershed (Figure 4). Subwatersheds with high CSI scores remain largely intact in terms of populations and habitats, and therefore rank high for protection and monitoring. Subwatersheds that have high potential for reconnecting or otherwise expanding population strongholds but currently harbor depressed populations or

Table 2. Constraints and opportunities for implementing strategies using the Conservation Success Index.

Application	Opportunities	Constraints
Tracking trends over time	Limited application; only useful for long-terms and if methodologies at different times are very similar	Unsuitable for detecting trends over short to mid- time frames (< 10 years)
Comparing status among species	Designed primarily for trout and char	Dependent upon availability of broad-scale species and habitat data
Comparing status within a species	Highlights differences among river basins or other larger geographic management units	Dependent upon regional data availability and compatibility
Dealing with data uncertainty	General and species-specific CSI rulesets attempt to reduce personal bias	Subjectivity and personal bias may occur in assessments and be integrated into CSI scores; surrogates may be needed for habitat factors
Spatial scale applications	Can aggregate subwatershed scores into larger watersheds and river basins	Inappropriate at scales finer than subwatershed
Determining management and conservation priorities	Appropriate for subwatershed scales or broader applications; places management into range-wide context	Inappropriate for stream-reach management; requires site-specific knowledge
Increasing public awareness of conservation issues	Synthesizes assessment data into readily understood scoring system and imagery	Scoring may overly simplify complex issues and encourage inappropriate comparisons across broad areas

Figure 2. Map of population integrity CSI scores for Bonneville cutthroat trout by subwatershed. The total population integrity score for each subwatershed is based on a maximum of 25 points, with up to 5 points each for population density, population extent, genetic stability, disease risk, and life history diversity. Dark gray shaded areas represent historically occupied subwatersheds that no longer support extant populations.

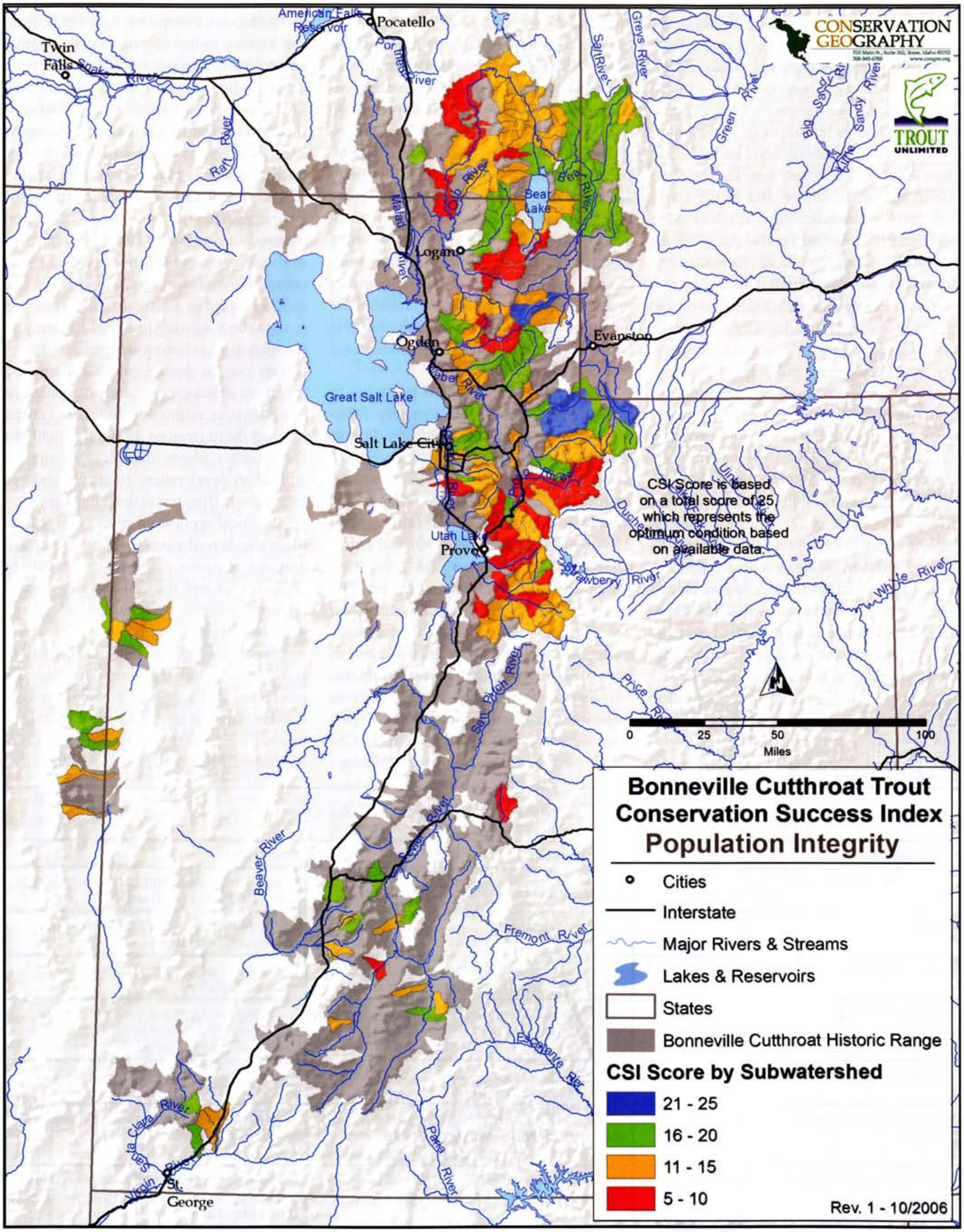


Figure 3. Map of total CSI scores for Bonneville cutthroat trout by subwatershed. The total CSI score for each subwatershed is based on a maximum of 100 points, with up to 25 points each for range-wide conditions, population integrity, habitat integrity, and future security. Dark gray shaded areas represent historically occupied subwatersheds that no longer support extant populations.

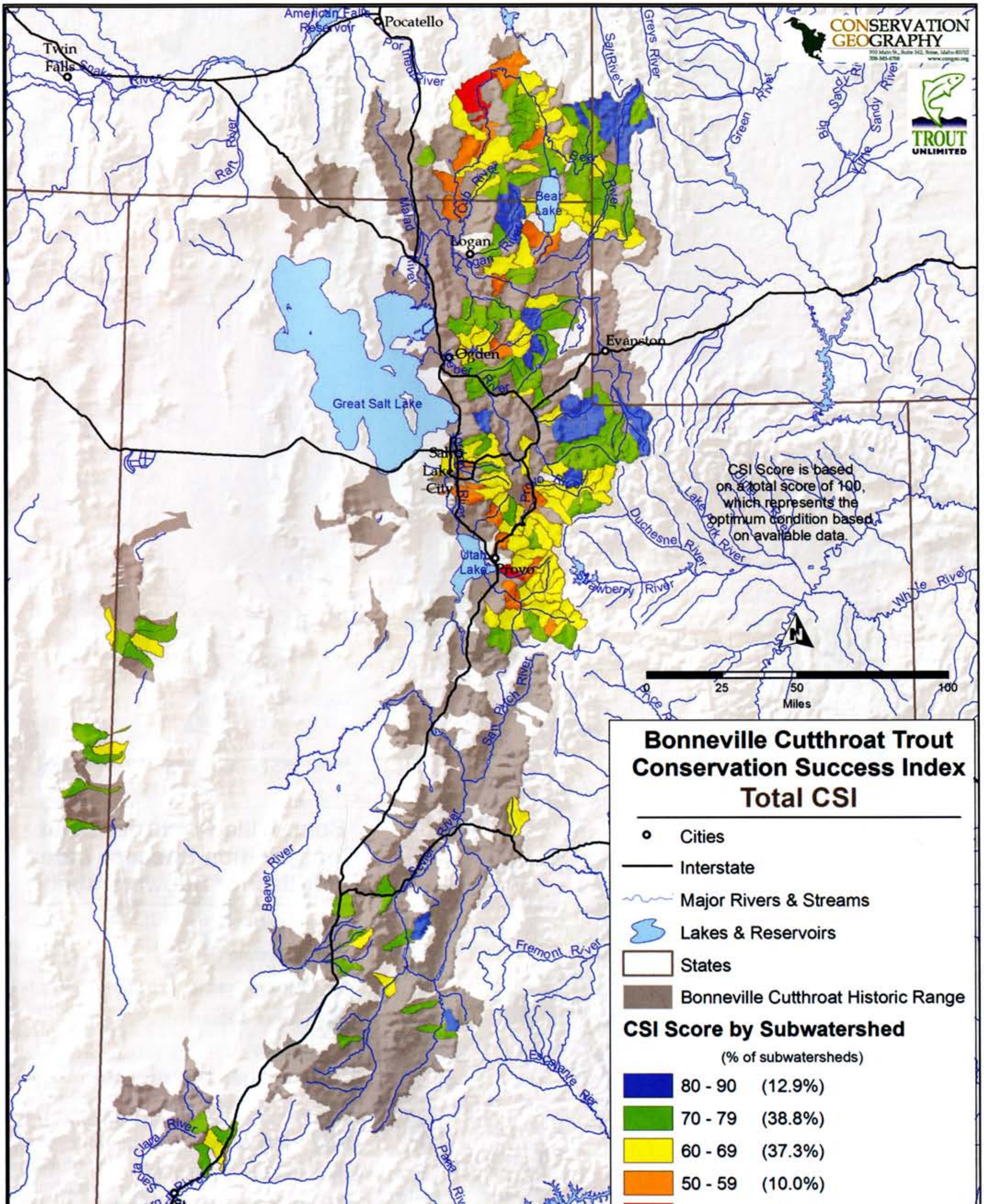
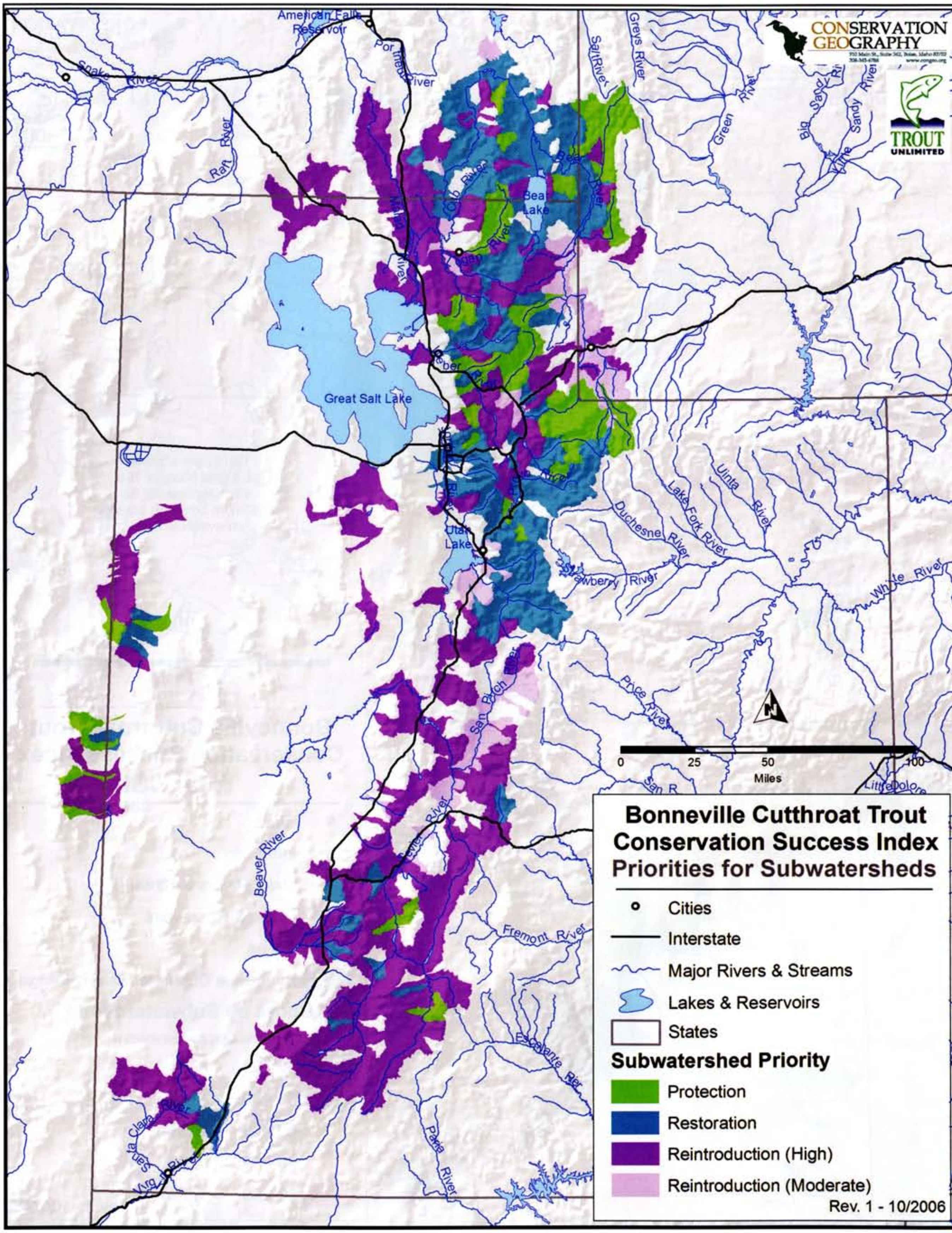
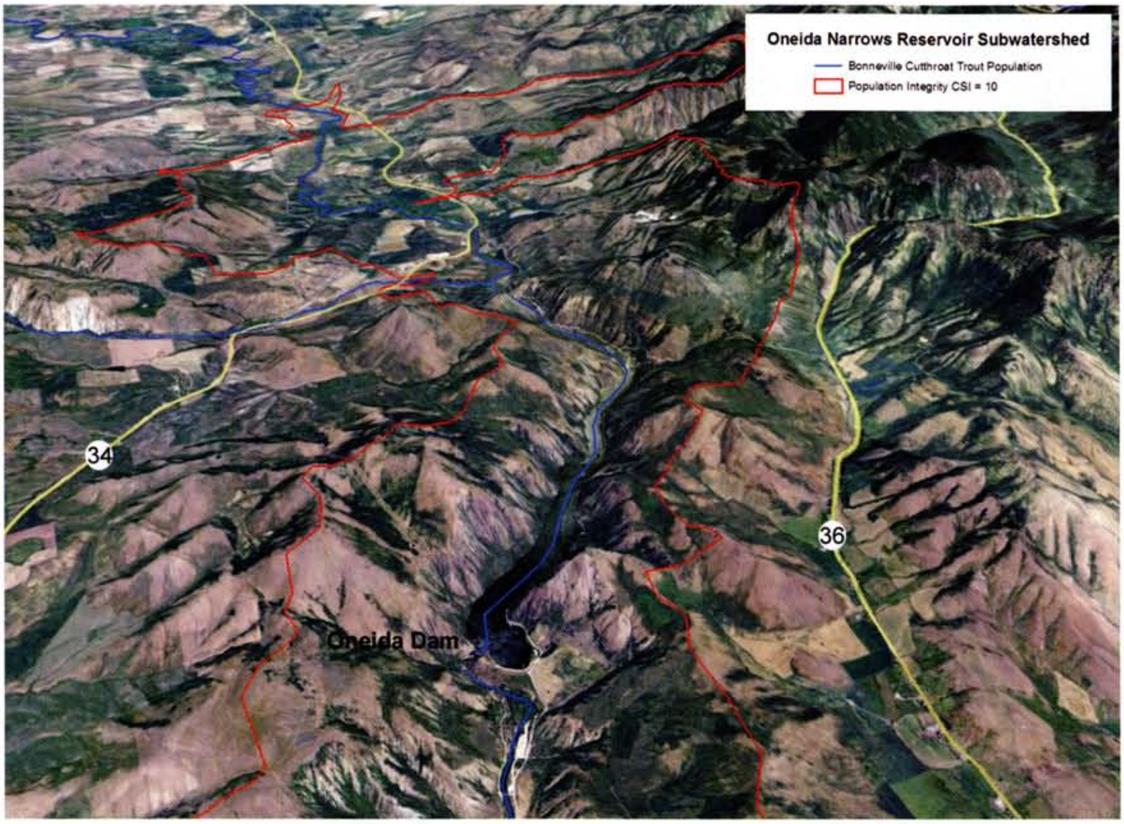


Figure 4. Map of CSI conservation priorities for Bonneville cutthroat trout by subwatershed. Subwatersheds that score high in habitat and population integrity generally are priorities for protection, and those that score moderate to low for habitat and population integrity are priorities for restoration. Subwatersheds that currently do not support BCT populations are either high or moderate priorities for reintroduction depending on existing conditions and security from future threats.



habitat conditions are priorities for active restoration. Unoccupied subwatersheds that historically supported BCT and currently have higher scores for habitat integrity are top candidates for reintroductions to benefit the subspecies. Reintroduction priority is further broken down into moderate and high based on existing habitat conditions and security from future threats. In the northern range of BCT, CSI management priorities scores reflect research that suggests conservation efforts should focus on protecting habitats and populations in higher elevation tributaries on public land, and restoring habitats and populations on mainstem rivers lower in the watersheds, which usually are located on privately owned lands (Colyer et al. 2005). In the southern range, BCT management priorities should focus on restoration in the isolated subwatersheds where populations currently exist, and reintroductions to expand BCT throughout unoccupied portions of the historic range where habitat conditions warrant.

Figure 5. CSI Google Earth™ image of Oneida Narrows Reservoir subwatershed on the Bear River in southeastern Idaho. Subwatershed boundaries are delineated by red lines, streams and rivers by blue lines, and roads by yellow lines. Note the Oneida Narrows Dam near the bottom of the image.



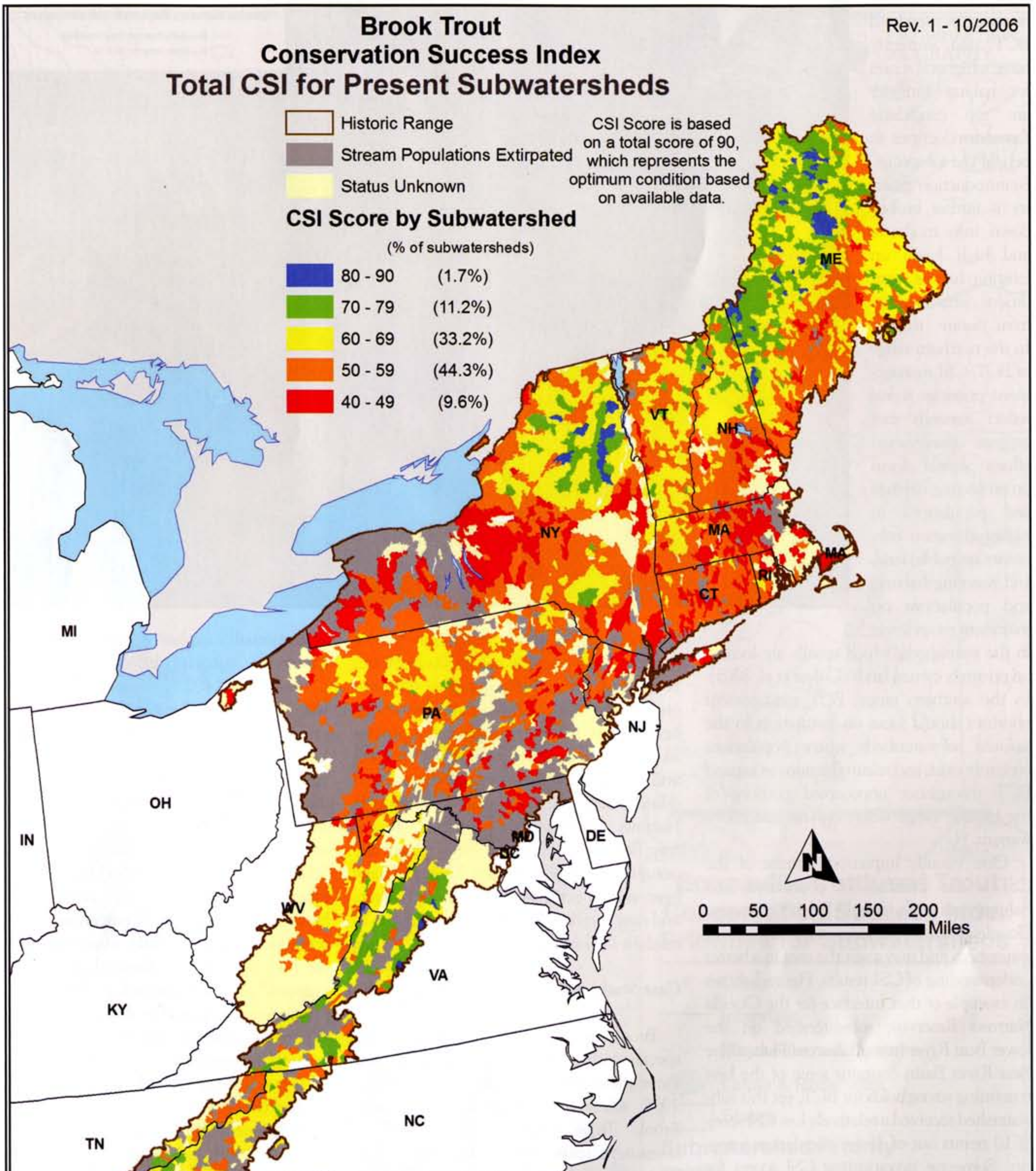
One visually impressive feature of the CSI is the interface of population and habitat data with Google Earth™ imagery. Google Earth™ enables visualization of watersheds and may assist the user in a better understanding of CSI results. Figure 5 shows an example of that interface for the Oneida Narrows Reservoir subwatershed on the lower Bear River in southeastern Idaho. The Bear River Basin contains some of the best remaining strongholds for BCT, yet this subwatershed received a relatively low CSI score of 10 points out of 25 for population integrity. Someone investigating CSI scores for BCT in this subwatershed could use Google Earth™ to associate CSI scores with specific habitat features. In this case, a user would immediately see the Oneida Narrows Dam that is visible near the bottom of the image. The fact that this subwatershed received low individual scores for population density, genetic purity, and life history diversity can be at least partially attributed to the presence of the dam. Native trout rarely thrive below dams, where non-native competitors like brown trout and rainbow trout compete and interbreed with native populations and dilute gene pools. In the case of the Oneida Narrows Reservoir subwatershed, migratory Bonneville cutthroat trout historically occupied the mainstem Bear River, but have been nearly extirpated from these habitats and now thrive only in isolated tributaries as resident life history forms.

Case Study of Brook Trout CSI

Brook trout provide an example of a species with a large geographic range and incomplete assessment data. In 2004 and 2005, scientists working for the Eastern Brook Trout Joint Venture (EBTJV) assessment team collaborated with fisheries biologists from 17 states and the U.S. Forest Service, National Park Service, U.S. Geological Survey, and Trout Unlimited to summarize existing knowledge on the distribution and status of naturally-reproducing populations of eastern brook trout (EBTJV 2006). Using a consistent method of 8 mutually exclusive population status categories, fisheries biologists evaluated a total of 11,400 subwatersheds located within the native United States range east of Ohio (as delineated in MacCrimmon and Campbell 1969). Population status was based on the percentage of naturally-reproducing populations of brook trout within historically-occupied lotic and lentic habitats. The assessment determined that of the 5,563 subwatersheds within the historic range that were historically occupied by brook trout, only a small percentage (5%) remained "intact," while over one-quarter had populations classified as "greatly reduced," and over one-fifth had extirpated populations. Regional biologists used their expert knowledge to list the greatest local impacts or perturbations to wild brook trout and their habitat for each occupied subwatershed (Hudy et al. 2006).

Assessment data from the EBTJV were integrated with other spatial datasets to score each subwatershed for the 20 CSI indicators (Figure 6). The map highlights those areas where there is insufficient data about brook trout populations in large portions of West Virginia, pockets of Pennsylvania, and major metropolitan areas in Virginia, New York, Massachusetts, and New Hampshire.

Figure 6. Total CSI scores out of 100 possible for eastern brook trout subwatersheds. Less than 2% of 5,563 subwatersheds that still have extant populations scored 80 or greater. Data gathered in conjunction with EBTJV.



A range-wide perspective shows relatively small clusters of high scoring subwatersheds in Virginia, New York's Adirondack region, Vermont, New Hampshire, and western and northern Maine where high quality habitat and relatively intact populations still remain. In contrast, regional extirpations are found in western New York, across the mid-Atlantic, and much of the Southeast. Although populations still exist throughout the remainder of the historic range, the relatively low CSI scores reflect their reduced status and degraded habitat. Aggregate CSI information was used to prioritize subwatersheds for protection, restoration, reintroduction, and monitoring to facilitate development of future restoration strategies by the EBTJV and other stakeholders.

Figure 7 shows the management priorities for each subwatershed within the South Branch Potomac subbasin, which encompasses the Potomac Headwaters Project. This general area was identified as a high priority brook trout restoration project by Trout Unlimited, Dominion Power, and West Virginia, Maryland, and Virginia natural resource agencies, as well as numerous federal agencies. Based on CSI scores plus input from local TU staff, the analysis recommends 5 subwatersheds for protection, 18 for restoration, and 15 for reintroduction at varying degrees of prioritization. Highest priority subwatersheds for protection, restoration, and reintroduction also rank as high priority for monitoring. This management strategy is consistent with local conditions where populations are depressed but the rural, mountainous landscape provides moderate to high habitat integrity and high to moderate future security, therefore making restoration a reasonable conservation strategy.

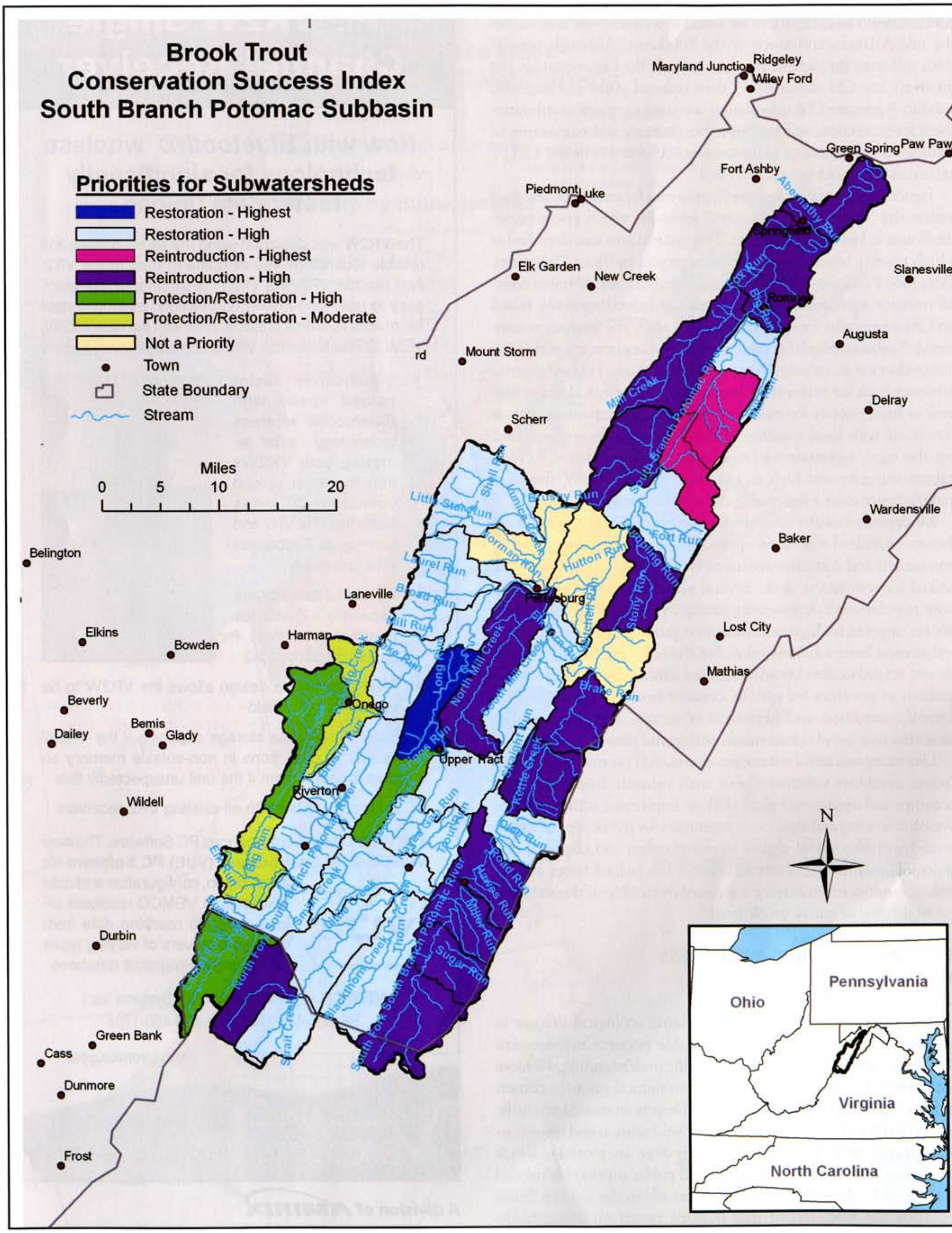
Moderately healthy subwatersheds with high security to future threats provide the greatest opportunity for long-term conservation success and cost-effective investments, and so these areas were ranked for restoration work. Several subwatersheds lacking brook trout populations but possessing strong to excellent habitat integrity are targeted for high reintroduction priority. All subwatersheds and streams have inherent value, but the CSI helps decision-makers and scientists develop an integrated strategy by ranking subwatersheds as priorities for specific conservation strategies based on scientific condition and likelihood of success, thus ensuring the most effective use of conservation dollars and time.

Like many successful restoration efforts, the Potomac Headwaters Project combines volunteer labor with valuable landowner relationships and agency technical skills to implement actions such as livestock fencing and riparian revegetation for the benefit of native trout. Involving school classes in tree-planting and chemical and biological monitoring of stream reaches has helped foster a long-term commitment and create a sense of ownership of the sites and the well-being of native brook trout.

INCREASING PUBLIC AWARENESS AND PARTICIPATION

Scientists widely believe that increasing ecological literacy in our society is a prerequisite to sustainable resource management (Orr 1992; Speth 2004) and that scientific understanding is seldom the limiting factor in achieving effective natural resource conservation (Deacon and Minckley 1991). Despite increased scientific data on what is needed for recovery, our wild salmon and trout continue to decline. Conservation problems often are rooted in a lack of political will that results from limited public support for needed changes. Polls show that only 63% of people in the United States recognize the basic tenant that humans negatively affect biodi-

Figure 7. CSI management priorities for brook trout in a targeted subbasin in the Potomac River drainage showing subwatershed priorities for restoration, protection, reintroduction and monitoring.



versity (Orr and Ehrenfeld 2002). That percentage was the lowest response among citizens of 20 countries surveyed. Even our lifestyle decisions, including the everyday choices we make as consumers, affect the status of natural resources but are under appreciated as a root cause of fisheries declines (Williams and Pister 2006). Clearly, an improved public awareness of current conditions, trends, and causes of declines would be helpful for increasing our ecological literacy.

One of the primary goals of the CSI is to communicate complex assessment data and conservation opportunities to the TU membership and broader public. Our ability to successfully restore coldwater fisheries requires knowledge of disturbance events and ecological processes that operate across multiple scales (Rieman et al. 2006). Yet, much of the angling public has a greater appreciation for the condition of their home waters than more distant watersheds. Through the synthesis and display of broad-scale salmonid assessment data, we hope to increase knowledge among TU membership and others to (1) foster a better understanding of the health of rivers and watersheds that support native salmonids, (2) increase awareness of threats facing these systems, and (3) encourage support for and participation in needed management efforts.

While the CSI helps shape conservation strategies across various spatial scales, local knowledge of individual streams and stream reaches is equally essential to developing effective on-the-ground strategies for improving subwatershed conditions and restoring trout populations and habitat. As with any project, effective partnerships and leadership are key ingredients for project success. Trout Unlimited staff, volunteers, and agency personnel offer these less tangible but nonetheless essential components for success, providing critical answers to relevant questions such as: what types of restoration projects can mitigate or eliminate existing threats, which techniques and approaches may be embraced or spurned by the community, which major landowners might be amenable to conservation practices, and which local leaders would help generate acceptance and momentum within the community if convinced to partner in the project.

Grass-roots participation in habitat protection, restoration, species reintroduction, and monitoring is critical to successful long-term management of coldwater resources. Each year, local angler and conservation groups participate in hundreds of on-the-ground restoration activities and engage in policy debates on such items as protecting National Forest roadless areas, curtailing oil and gas development on sensitive public lands, and overturning unnecessary bans on the use of piscicides. For TU, the CSI is another valuable tool in our efforts to mobilize our members for conservation and assist our partner organizations with their conservation missions.

ACKNOWLEDGMENTS

States participating in the Eastern Brook Trout Joint Venture as well as the states of Colorado, Idaho, Montana, Utah, and Wyoming kindly provided status data utilized in the CSI. We also gratefully acknowledge the diligent efforts of Matt Barney and Matt Mayfield of Conservation Geography for assistance in spatial analysis of the various data sets. Reviews of earlier drafts of this manuscript by Bill Bakke, Jason Dunham, Bob Gresswell, Mark Hudy, Steven Leider, Helen Neville, Joe McGurrin, Kevin Reilly, Bruce Rieman, Chris Wood, and an anonymous reviewer are greatly appreciated. Major support for development of the CSI was kindly provided by the Curtis and Edith Munson Foundation, TU's Coldwater Conservation Fund, and Kenneth Woodcock.

REFERENCES

Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K.K. Bartz, and **H. Imaki.** 2007. Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences 104:6720-6725.

Behnke, R. J. 2002. Trout and salmon of North America. The Free Press, New York.

Colyer, W. T., J. L. Kershner, and **R. H. Hilderbrand.** 2005. Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho—Wyoming. North American Journal of Fisheries Management 25:954-963.

Deacon, J. E., and **W. L. Minckley.** 1991. Western fishes and the real world: the enigma of "endangered species" revisited. Pages 405-413 *in* W. L. Minckley and J. E. Deacon, eds. Battle against extinction: native fish management in the American West. University of Arizona Press, Tucson.

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. Scott, P. Hegland, M. Morrison, M. Raphael, J. Hauffer, and B. Wall, eds. Predicting species occurrences: issues of accuracy and scale. Island Press, Washington, D.C.

EBTJV (Eastern Brook Trout Joint Venture). 2006. Eastern brook trout: status and trends. Available online at www.brookie.org.

Fausch, K. D., B. E. Rieman, M. K. Young, and **J. B. Dunham.** 2006. Strategies for conserving native salmonid populations at risk from nonnative fish invasions: tradeoffs in using barriers to upstream movement. USDA Forest Service General Technical Report RMRS-GTR-174, Fort Collins, Colorado.

Frissell, C. A. 1997. Ecological principles. Pages 96-115 *in* J. E. Williams, C.A. Wood and M.P. Dombeck, eds. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland.

Gharrett, A. J., and **W. W. Smoker.** 1993. Genetic components in life history traits contribute to population structure. Pages 197-202 *in* J. G. Cloud and G. H. Thorgaard, eds. Genetic conservation of salmonid fishes. Plenum Press, New York.

Greenback Cutthroat Trout Recovery Team. 1998. Greenback cutthroat trout recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado.

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

Hudy, M., T. M. Thieling, N. Gillespie, and **E. P. Smith.** 2006. Distribution, status and threats to brook trout within the eastern United States. Report submitted to the Eastern Brook Trout Joint Venture, International Association of Fish and Wildlife Agencies, Washington, D.C.

Kershner, J. L. 1997. Monitoring and adaptive management. Pages 116-131 *in* J. E. Williams, C.A. Wood, and M.P. Dombeck, eds. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland.

Lee, D. C., J. R. Sedell, B. E. Rieman, R. F. Thurow, and **J. E. Williams.** 1997. Broadscale assessment of aquatic species and habitats, Volume 3. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon PNW-GTR-405.

MacCrimmon, H. R., and **J. C. Campbell.** 1969. World distribution of brook trout (*Salvelinus fontinalis*). Journal of the Fisheries Research Board of Canada 26:1699-1725.

May, B. E., and **S. Albeke.** 2005. Range-wide status of Bonneville cutthroat trout (*Oncorhynchus clarki utah*): 2004. Utah Division of Wildlife Resources, Salt Lake City. Publication Number 05-02.

McElhany, P., M. H. Ruckleshaus, M. J. Ford, T. C. Wainwright, and **E. P. Bjorkstedt.** 2000. Viable salmonid populations and the recovery of Evolutionarily Significant Units. NOAA Technical Memorandum NMFS-NWFSC-42.

NRC (National Research Council). 1992. Restoration of aquatic ecosystems: science, technology, and public policy. National Academy Press, Washington, D.C.

Orr, D.W. 1992. Ecological literacy: education and the transition to a postmodern world. State University of New York Press, Albany.

Orr, D. W., and **D. Ehrenfeld.** 2002. None so blind: the problem of ecological denial. Pages 85-90 *in* The nature of design: ecology, culture, and human intention. Oxford University Press, New York.

Rieman, B., D. Lee, J. McIntyre, K. Overton, and **R. Thurow.** 1993. Consideration of extinction risks for salmonids. Fish Habitat Relationships Technical Bulletin 14. USDA Forest Service, Logan, Utah.

Rieman, B., J. Dunham, and **J. Clayton.** 2006. Emerging concepts for management of river ecosystems and challenges to applied integration and biological sciences in the Pacific Northwest, USA. International Journal River Basin Management 4(2):85-97.

Slaney, T. L., K. D Hyatt, T. G. Northcote, and **R. J. Fielden.** 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21(10):20-35.

Speth, J. G. 2004. Red sky at morning: America and the crisis of the global environment. Yale University Press, New Haven, Connecticut.

USFWS (U.S. Fish and Wildlife Service). 2006. Species information threatened and endangered animals and plants. Available online at www.fws.gov/endangered/wildlife.html. Accessed 20 November 2006.

Williams, J. E., and **E. P. Pister.** 2006. Lifestyles and ethical values to sustain salmon and ourselves. Pages 577-596 *in* R. T. Lackey, D. H. Lach, and S. L. Duncan, eds. Salmon 2100: the future of wild Pacific salmon. American Fisheries Society, Bethesda, Maryland.

Williams, J. E., W. Colyer, N. Gillespie, A. Harig, D. Degraaf, and **J. McGurrin.** 2006. A guide to native trout restoration. Trout Unlimited, Arlington, Virginia.

Young, M. K. 1995. Conservation assessment for inland cutthroat trout. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado RM-GTR-256.

Young, M. K., P. M. Guenther-Gloss, and **A. D. Ficke.** 2005. Predicting cutthroat trout (*Oncorhynchus clarkii*) abundance in high-elevation streams: revisiting a model of translocation success. Canadian Journal of Fisheries and Aquatic Sciences 62:2399-2408.

Ziemer, R. R. 1997. Temporal and spatial scales. Pages 80-95 *in* J. E. Williams, C. A. Wood and M. P. Dombeck, eds. Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland.