



## The Role of Government in Building Civic Capacity at the Watershed Scale: A Case Study of the White River in Vermont

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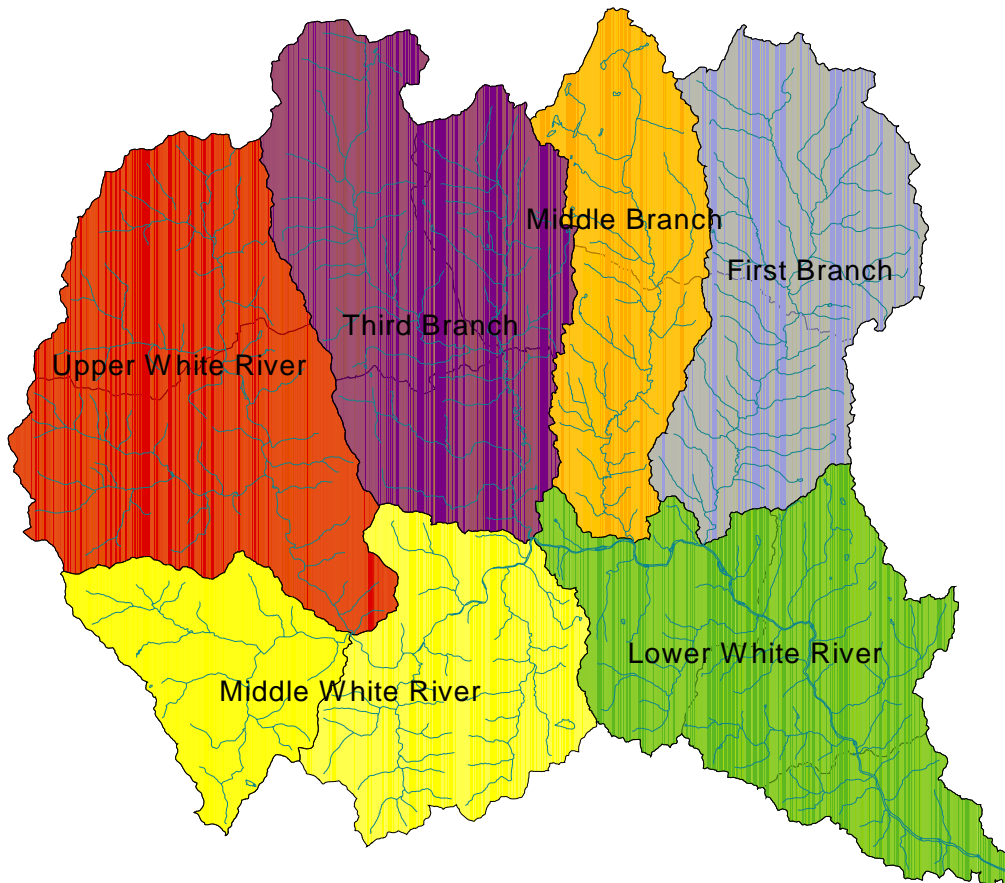
**ABSTRACT**—Collaboration between conservation groups and government is recognized as a necessity at every scale of aquatic restoration and stewardship, from backyard riparian buffers to watershed-wide fish passage. However, community-based watershed groups are often missing from the collaborative equation. This may be a serious flaw as ultimately it is the community's relationship to its streams and rivers that must change in order for long-term stewardship to occur. Infusions of government resources have resulted in significant outputs and outcomes addressing non-point source pollution and trout habitat where community-based watershed organizations have high levels of civic capacity. Conversely, a lack of civic capacity infused into government-led watershed-scale efforts creates a barrier to lasting change. The importance of civic capacity, defined as the network of relationships among individuals and institutions, and the potential role of government in its development cannot be overstated. Presented here is a case study and chronology of civic capacity-building in the White River Watershed in central Vermont. The White River Partnership, a grass roots watershed group, came into existence in 1995. By 1999, the watershed was a U.S. EPA National Showcase Watershed and one of 16 Community-Based Watershed Restoration Projects nation-wide to receive generous funding from the USDA Forest Service. State and Federal financial and technical resources have been critical to the development of this strong non-profit watershed organization that now serves as the link between more than 20 organizations and 21 communities within the White River watershed. Resource management agencies and other grantors should consider the long-term benefits of investing in capacity building activities in addition to tangible restoration projects.

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### Introduction

The White River is Vermont's fourth largest watershed, draining an area of 710 square miles and encompassing all or part of 21 towns. The river flows southeast for 56 miles, with its headwaters in the Green Mountain National Forest at an elevation of 3,700 feet and enters the Connecticut River at an elevation of 330 feet. It is the longest un-dammed tributary of the Connecticut River. Land ownership is 84% private, 11% National Forest and 5% municipal and state land. Land use is 84% forested, 7% agriculture and only 5% developed. Figure 1 shows the White River watershed and its six sub-watersheds.

The White River is part of the Connecticut River Atlantic Salmon Restoration Program and a Special Focus Area of the Conte National Fish and Wildlife Refuge. The main stem and its tributaries support populations of native wild brook trout and naturalized brown and rainbow trout. The Vermont Fish and Wildlife Department augments the fishery in the main stem and some tributaries by stocking catchable-size brook and rainbow trout. Thirty-seven percent of the 125 sites monitored over the past 50 years had only brook trout and 19% had all three trout species.



**Figure 1. White River watershed with six sub-watersheds.**

The White River watershed has tremendous human, cultural and natural resources, but faces many challenges on the journey to sustainable communities and natural resource stewardship. Large-scale in-stream gravel extraction was common on the main stem and tributaries until 1986. River morphologists believe the watershed is still experiencing instability due to decades-old gravel extraction. The straightening of stream channels and removal of riparian vegetation to facilitate transportation and agriculture had also had lasting watershed-wide impacts. Sedimentation from eroding banks, elevated water temperatures and the loss of riparian functions have reduced aquatic habitat quality for trout and salmon in many reaches of the watershed.

Presently the watershed is 84% forested, however, at the turn of the 20<sup>th</sup> century it was only 20% forested.

### **Collaborating on the Watershed Scale**

#### **Milestone #1: The ground work is laid for Forest Service to engage in community-based watershed collaborative.**

The USDA Forest Service (Forest Service), and specifically the Green Mountain National Forest, is no stranger to working in partnership to accomplish management goals. Recreational, fishery and wildlife resources on national forests are important enough to both local and national conservation

organizations to spend vast amounts of volunteer and financial resources to implement on-the-ground projects on public lands. What was new to the agency in the early 1990's was clear direction from Congress emphasizing an expanded role outside National Forest boundaries within the communities that are linked culturally, economically and environmentally to public lands (McAllister and Zimet 1994). McAllister and Zimet (1994) reported on 12 case studies across the country where the Forest Service had turned outward to work with forest-dependent communities. Although the case studies they presented focused on areas that were more dependent on national forest timber than the White River watershed, the groundwork had been laid for collaborating with local communities across political boundaries on the watershed-scale.

In the Forest Service's report on its 1993 national workshop on collaborative planning (Forest Service 1993), they recognized that most in the agency "*were accustomed to top-down planning, in which few decide for the many, and change comes from outside*". The report went on to describe collaborative planning as emerging from the community, honoring a full spectrum of values and assumes everyone is responsible for the community's success. "*There is no one leader and no one is excluded from the table.*" To the Service's credit, it realized that with this newfound role and shift in thinking came the need for new skills not previously valued or nurtured in the organization. Fortunately, for the White River watershed, the skills required were well honed and highly accessible at the George D. Aiken Resource Conservation and Development Council (RC&D Council) and the Regional Planning Commission (RPC).

### **Milestone #2: A project-level partnership provides the vision for a watershed-scale collaborative.**

In 1993, a geographically small but complex issue along the banks of the White River brought together private landowners, the Forest Service, Vermont Agency of Natural Resources (Vermont ANR), the RPC, town and state highway managers, and the local RC&D Council. The project involved fish migration, riverbank erosion, road damage and a small piece of National Forest sandwiched between private lands. Resolution clearly called for the participation of multiple agencies and landowners as well as creative financing. A seemingly over-sized group of would-be stakeholders mulled over the project in fog of jurisdictional uncertainty for some time before progress was made. In the end, three years later, the fish still could not navigate the barrier; the partners raised enough funding to study the cause of road failure but not fix it; and only one of the two private landowners found resources to stop their bank erosion. The project was hardly a glowing example of collaborative planning, partnerships and civic capacity. Yet, it was not a complete failure in that some goals were met and the seed of collaboration was planted.

### **Milestone #3: Adopting a community-based and locally led model—a shift from government led to government participant.**

Under the leadership of the RC&D Council, the RPC, the Vermont ANR and the Forest Service recognized the potential for collaboration to address a growing number of river related issues. Local, state and federal government representatives and local and national conservation groups struggled for more than a year to define their roles and goals in a 710 square mile watershed that was 84% privately owned. A break through occurred in 1994 when staff from the Green Mountain National Forest, Vermont ANR and the RC&D Council took

advantage of a Forest Service Collaborative Planning Workshop—a spin off from the 1993 National Workshop. The training event provided the critical thrust and momentum needed to kick off a watershed event. Using the collaborative planning approach, the initiative quickly transformed from an agency-led initiative to an agency-facilitated initiative being locally led by the people who lived, worked, recreated, and did business in the White River watershed. In affect, there was a paradigm shift where government took a seat at the table as one of the participants, joining the circle instead of being at the head of the table.

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## **Birth of the White River Partnership**

### **Milestone #4: Hiring a Watershed Coordinator to assure steady forward movement and continued enthusiasm.**

In January 1995, an organizing body was expanded to include more local groups and community leaders with interests not only in the well being of the natural resources but also the quality of life in their communities. Extensive brainstorming and lengthy discussions by the fledgling group resulted in an aggressive plan to involve community members in a locally led initiative encompassing 21 towns within the watershed. It quickly became evident that a labor intensive and complex planning project was in the making. The RC&D Council and the RPC had the technical expertise to help guide the process but neither had the necessary human resources to see it through. Practitioners and observers of community-based collaborative efforts generally agree that chances for success are increased when an individual can be charged with doggedly pursuing the organizing body's vision for planning and implementation (McAllister and Zimet 1993; Doppelt et al. 2002). The process is often messy and protracted, requiring more time and energy than a volunteer project coordinator can typically offer. In the summer of 1995, the RC&D Council received a rural development grant from the Forest Service and a partnership grant from the Silvio Conte National Fish & Wildlife Refuge to create a half-time Watershed Coordinator position.

### **Milestone #5: Residents of the watershed provide the framework for the White River Partnership's plan of action.**

As the initiative gathered steam and participants planned a series of community forums, it took on the name White River Partnership (WRP) with the initial goal of forming a grass roots organization to actively promote the social, economic, and environmental health of the White River. The Partnership adopted two principles in its pursuit of a community-based collaborative: 1) The initiative must be developed by the residents of the White River watershed; and 2) the initiative must be developed collaboratively whereby all interested persons and parties may take part.

In October and November 1995, the Partnership conducted six public forums. Over 150 people from communities throughout the watershed came together to express their views on: what they wanted for the future; what issues and opportunities needed to be addressed; and what were the next steps to be taken by the citizens, communities, conservation groups, local governments, and resource management agencies to achieve their shared vision.

## Organizing for Action

### **Milestone #6: Organizational structure creating community-based, locally led Stream Teams to identify and implement projects with technical and financial assistance from partners.**

A prioritized list of issues and next steps was compiled from the six public forums. Of particular interest is the variation in prioritization by the different geographic regions of the watershed. While all the forums identified stream bank erosion and public awareness as priorities, only the communities at the lower end of the main stem identified pollution as a priority, and only the upper portion of the main stem made gravel removal a priority issue. Clearly, a one-size fits all approach on a regional or whole watershed scale would not suffice.

The diversity of community interests led the White River Partnership to look towards a decentralized organization model. A single centralized steering committee or board of directors could not adequately represent and serve the entire watershed. The ridge and valley topography of the watershed created obvious ecologically significant subwatershed boundaries. The geography has also influenced early settlement patterns, socially and economically linking communities within the subwatersheds. Hence, the watershed was well suited to creating local groups, called Stream Teams, to implement the partnerships mission in each of six subwatersheds under the guidance of a WRP Steering Committee. This model has served many watershed groups well throughout the country.

## Building Local Civic Capacity

### **Milestone #7: The WRP established its first Stream Team to provide local leadership while government agencies and conservation groups form an inter-agency technical team.**

In 1996, the WRP began building the capacity to implement the “Next Steps” identified by community members. Human, technical, and financial resources were needed to transform the energy and enthusiasm created by the forums into real action. Once again, under the leadership of the RC&D Council and continued seed money from the Forest Service, Conte Refuge and Trout Unlimited (TU) for the paid coordinator, the WRP received a two-year, \$35,000 grant from VT Department of Environmental Conservation (VT DEC). The funding was to address non-point source pollution from stream bank erosion in the upper White River watershed. A state government partner had met the need for financial resources with remarkably few strings attached. The WRP initiated the development of a technical team made up of partners from state and federal agencies and TU. The Forest Service agreed to provide the staff time to coordinate the technical team’s involvement in the project. Again, partners met the need. The Forest Service, USDA Natural Resource Conservation Service, U.S. Fish & Wildlife Service, VT Fish & Wildlife Department, VT DEC and Trout Unlimited formed a Stream Restoration Technical Team to advise the WRP on fish and wildlife-friendly techniques to slow erosion on privately owned streambanks. The final step in the initial capacity building effort was to pull together local leaders, citizens and landowners in the upper portion of the watershed to help identify and prioritize project sites. The Upper River Stream Team was born and the network of individuals and institutions was formed. After

two years, the project restored nearly a mile of stream bank and riparian habitat at six sites on the White River.

**Milestone #8: Environmental Protection Agency's (EPA) National Showcase Watershed web site up and running and development of inter-agency training programs.**

In 1998, as a direct result of the projects completed by the Upper River Stream Team and partners, the WRP was selected as one of 12 National Showcase Watersheds demonstrating the “principles, processes, and practices of stream corridor restoration.” While the showcase designation did not come with additional resources, it did provide important recognition for the WRP and further increased capacity—people like to join a successful cause. By the time the U.S. Environmental Protection Agency's National Showcase Watershed web site was up and running: the Partnership had formed an additional Stream Team; and the Technical Team had embraced a natural channel design approach and began developing inter-agency training programs. In addition, the WRP established itself as a membership organization with well-articulated mission, vision, and guiding principles.

**Milestone #9: Community-based Watershed Restoration Partnership grant from the Forest Service allows WRP to hire a full-time Watershed Coordinator and an Outreach and Education Coordinator.**

In 1999, the stars aligned to bring the WRP a tremendous opportunity that few non-profit watershed groups experience—a large multi-year grant to fund both staff and stream corridor restoration projects. The early 1990s had brought focus to working on the watershed scale in communities highly dependent on National Forest timber. Now the focus had broadened with the realization that “solutions to watershed issues required working collectively across mixed ownerships within a watershed” (USDA Forest Service 2003). To this end, the Service selected 16 projects from a nation-wide request for proposals to receive five-year grants to develop Community-Based Watershed Restoration Partnerships. The partnership projects selected averaged only 46% national forest lands. The White River was one of those watersheds with only 11% national forest ownership. The grant was for approximately \$1.4 million.

The infusion of financial resources immediately opened doors for the Partnership. Activities that are typically difficult to fund, such as full-time staff, collecting base-line data, river morphology assessments, and publications, came within reach. In addition, the grant included funds to implement stream restoration projects on private lands. Without the need to do almost continuous fund raising the organization focused on increasing partnerships, engaging communities and building and supporting the local Stream Teams.

Once grant funding was in place and a full-time coordinator was hired, the WRP took off. A comprehensive business plan, required by the Forest Service, helped the Partnership focus its efforts and develop a strategy to grow the organization into a self-supporting non-profit watershed group while it was actively pursuing balancing the cultural, economic and environmental health of the watershed.

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**Measuring Success in Terms of Capacity Building and Outputs**

Following the community-based watershed restoration grant the WRP grew considerably in civic capacity and tangible outputs. As of 2004, the six Stream

Teams are in operation and the Partnership has contracted with the National Wildlife Federation to coordinate and manage restoration projects. In addition, a water quality internship program was started. Accomplishments that will benefit wild trout include:

- Approximately 5 miles of stream restoration
- 10 miles of riparian planting.

Between 2000 and 2003 the Partnership spent \$1.8 million. Approximately 66% (\$1.2 million) came from the Forest Service. The question will invariably be asked, “was this a good investment?” Using a modest estimate of \$100,000/mile for natural channel design restoration and \$12,000/mile for riparian reforestation, the agency could theoretically have accomplished 10.7 miles of habitat restoration for wild trout over that 4-year period on their own. However, it would likely have ended there in 2003.

Whereas government programs can often deliver expedient and cost efficient technical and financial services to riparian landowners, developing collaboration and consensus is complex and time consuming. The advantage is that the collaborative lives on after project money is gone. Following is a partial list of WRP activities and accomplishments that the typical grantor does not fund but were important capacity building factors funded all or in part by the Forest Service grant:

- Weekly water quality monitoring at 23 sites throughout the watershed
- Remote sensing of stream corridor conditions throughout the watershed
- 145 miles of stream assessment involving rapid geomorphic and habitat assessments
- Annual river cleanup events
- Approximately 800 volunteers planting trees
- Coordinated water quality monitoring protocol for schools/teachers in the watershed
- Development of watershed map focusing on cultural, economic and environmental assets
- Stream Teams established in each of the six sub-watersheds
- Over 420 individual landowners informed about state and federal buffer programs.
- Nine of 21 towns in the watershed made modest contributions of financial support
- Contributing membership reached 240 individuals and businesses
- Application of Vermont DEC Stream Corridor Management Framework
- Forestry working group assisted by university of Vermont to develop forestry framework.

Engaging communities to allow leadership and capacity to develop requires a different way of thinking about accomplishments and timeframes. Measuring the success and long-term benefits of community engagement does not fall neatly into the typical natural resource agency’s metrics of cost/mile, miles/year, and

fish/mile. In an extensive evaluation of the successes and failures of the Forest Service's community-based watershed restoration partnerships, researchers from Portland State University recognized that the strongest partnerships were found in areas where civic capacity was high (Doppelt et al. 2002). The researchers described civic capacity as having three components: social capital (networks of individuals and institutions); community competence (knowledge, skills and abilities within the community); and civic enterprise (history of collective action). In their report, several observations specific to the White River Partnership clearly point to a strengthening of civic capacity:

- Outreach and education projects are changing the public's view of the river
- The WRP feels empowered to take responsibility for projects
- The WRP provides a forum for all agencies to come together and develop better communications
- Public knowledge about the WRP is starting to snowball due to community outreach and getting projects on the ground
- The WRP has gained broad support from several groups around the State including the agricultural community, local towns and counties and federal agencies.

The WRP business plan (White River partnership 2003) contains an excellent section on outcomes and measures related to stream restoration goals. The plan also lists several measures associated with education, outreach, and capacity building. Their measures include: (1) Dollars raised annually from membership; (2) Grant writing success; (3) Number of schools with watershed curriculum; (4) Number of towns providing funding, materials, etc.; and (5) Number of active sub-watershed groups.

These measures track significant accomplishments gained through painstaking communications and relationship building. Of particular interest in the Forest Service community-based grants is grantor expectations. Most restoration grants are tied to tangible outputs and outcomes. While on-the-ground results were extremely important to the success of the community-based partnerships, softer targets, such as capacity building, were valued as well.

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## Conclusions

The White River Partnership is a success because of the commitment and hard work contributed by the citizens of the watershed. More than 20 partner organizations also make important contributions. However, were it not for local citizens, the initiative pondered by the government agencies back in 1993 would have been a very different creature. The turning point of the initiative came with the shift from government-led to a locally led, independent organization. Government agencies can take a seat at the table as just another partner with resources to bear. To do so takes a different mindset and skill set than a top down planning approach where a few decide for the many.

When a government grants program measures success in acres and miles of treatments over the life of a one or two year grant the return on investment is rapid. This is an effective model when civic capacity is high. Public-private partnerships can flourish because communities have the networks, skills and history to work collaboratively. Where it is low, government agencies have a role

to play in building capacity in addition to putting projects on the ground. The Forest Service community-based partnership grants were a much more risky investment with long-term paybacks anticipated from: building networks; developing knowledge, skills and abilities in communities; and creating a history of collective action. The wheels are in motion and what remain to be seen are the accomplishments in 2005 and beyond.

The real fruit of the White River partnership's labor will be the slow change in communities' relationships to their rivers and streams. An awareness and understanding of how 225 years of land use has changed the character of their watershed will eventually inform community decisions. Knowledge of how rivers function to provide habitat will begin to inform how communities interact with their river channels, riparian forests, and flood planes. These changes will likely play a greater role in the future of wild trout habitat in the White River than all the government programs combined.

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### Acknowledgements

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### References

- Doppelt, B., C. Shinn, and M.O. Hatfield. 2002. Review of USDA Forest Service Community-Based Watershed Restoration Partnerships. USDA Forest Service Report. Unpublished.
- McAllister, W.K. and D. Zimet. 1994. Collaborative Planning: Cases in Economic and Community Diversification. USDA Forest Service Report, FS-575.
- USDA Forest Service. 1993. The Power Of Collaborative Planning: Report of the National Workshop. USDA Forest Service, Report FS-553.
- USDA Forest Service. 1993. Community-Based Watershed Restoration Partnerships: Accomplishments for FY 2000—2002. Report FS-770.
- White River Partnership. 2003. White River partnership Watershed Restoration Business Plan. Unpublished.

## Trout Unlimited and the Pennsylvania Mennonite Community—A Partnership to Enhance a Stream

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**ABSTRACT**—1995 and 2001 assessment reports of the Sacony Creek by the Pennsylvania Fish and Boat Commission (PFBC) (section 2, stations 0201 and 0202) were compared to the Berks County Conservation District's June 2004 study of the same stations. The PFBC conducted their 2001 assessment up to and including Station 0201 to examine potential effects of a newly installed sewer discharge. Compared to the 1995 study, we found that there was an increase in sensitive macroinvertebrate taxa at station 0202 and a decrease in the amount of coldwater fish species. There was an increase in sensitive macroinvertebrate taxa at station 0201 compared to the 2001 PFBC study and the same amount of pollution intolerant taxa compared to the 1995 PFBC study. Comparing both PFBC 1995 and 2001 studies, there was a decrease in the amount of coldwater fish species at station 0201. Stream restoration work implemented by the Tulpehocken Chapter of Trout Unlimited along this section of the Sacony Creek in conjunction with the cooperation of landowners has helped protect the stream. This has led to the development of moderate aquatic ecological improvements and valuable education and outreach to participating landowners.

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### Introduction

Few studies address the long-term effects of stream restoration on aquatic ecosystems in a specific watershed. Here, the biological water quality improvements of stream restoration projects implemented by the Tulpehocken Chapter of Trout Unlimited (TCTU) on the Sacony Creek from June 1999 to June 2004 are examined. Additionally, stream enhancements through unique community partnerships are analyzed. The Sacony Creek originates in the forested mountains of the Reading Prong, a few miles south of Kutztown, PA. At this point, the stream is classified as Exceptional Value (EV) (Chapter 93 - 2003), a designation given to streams in Pennsylvania with optimum water quality. Additionally, the headwaters are awarded a Class A Wild Brown Trout Stream designation. After running off the mountain, the creek meanders through the small town of Bowers and a large agriculture community that is populated by Mennonites. Land use in this community changes from a forested canopy-covered ecosystem to a dense agricultural ecosystem. Here, the creek loses its Wild Trout designation and drops from an EV stream to a Cold Water Fishery (CWF) (Chapter 93—2003).

In the 1995 study, Mike Kaufmann, PFBC, specifically recommended, "If an interested sportsmen's group can be found, habitat improvement projects, including streambank fencing, tree planting, and some in-stream work should be implemented in Section 02 in an effort to extend wild trout population downstream and provide cooler water temperatures for stocked trout." Because of the creek's exceptional headwater classification and the potential of habitat improvement downstream of this area, the TCTU became interested in restoring the stream, improving trout habitat and encouraging landowner participation in

the lower classified sections. By using creative techniques such as speaking Pennsylvania German to establish a rapport with the Mennonite landowners and partnering with the summer youth of the Berks County Juvenile Probation Office, TCTU successfully implemented numerous best management practices in this CWF region. With the recommendations from the PFBC, the Tulpehocken Chapter of Trout Unlimited started to gather partners to plan their restoration efforts in the Sacony Creek.

In 1999, the Tulpehocken Chapter of Trout Unlimited commenced the implementation of eight stream restoration projects along a 2.3-mile stretch of the Sacony Creek. During a five-year span, the group worked with seven Mennonite farmer landowners and one municipality. TCTU started at Bowers Park and worked their way downstream towards Kutztown. They installed a total of 13,681 feet of animal exclusionary fencing, ten cattle crossings for pasture access and water sources using 120 tons of 2A modified stone, and planted 4,050 native shrubs and 325 native trees. 1,577 tons of R-4 rock, 25,790 square feet of coir matting, 8,750 wire staples, 325 pounds of grass seed and 950 feet of biologs were used to stabilize the stream banks. To enhance trout habitat, 30 log deflectors were installed in the streambed.

TCTU secured funds from multiple sources to execute these best management practices: William Penn Foundation, \$23,490, administered by the Berks County Conservancy, the Pennsylvania Department of Environmental Protection's Growing Greener Grant Program, \$58,374.26, local Mennonite farmers, \$7,122 and in-kind services valued at \$15,000 were provided by TCTU and their summer youth program. TCTU works with the Berks County Juvenile Probation Office, which allows troubled youth to volunteer their time to these stream restoration projects. The summer youth program volunteered 1,912 total hours during the entire project.

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## Methods

The PFBC's 1995 and 2001 assessments of the Sacony Creek were compared to our June 2004 study of the same stations. Sampling in the 1995 and 2001 assessments also occurred in June. The goal was to take data from the 2004 study and correlate improvements with the projects completed by TCTU.

Two different types of organisms were assessed in the June 2004 study, benthic macroinvertebrates and fish. Macroinvertebrate sampling was conducted Monday, June 14, 2004 using methodologies modified from the U.S. Environmental Protection Agency's Rapid Bioassessment Protocols, or RBP (USEPA, 1989), and the Volunteer Stream Monitoring Methods Manual (USEPA, 1997). Delaware Riverkeeper Network and Berks County Conservation District staff used a Surber sampler (500 micron mesh) and a D-frame net (500 micron mesh) to sample riffle areas as well as Course Particulate Organic Material, or CPOM (e.g. submerged logs, submerged aquatic vegetation, leaf packs). Riffle and CPOM habitats were selected for sampling because both are recognized as productive habitats for macroinvertebrates and typically contain a high diversity of benthic organisms.

The macroinvertebrates collected at each site were transferred from the Surber and D-frame net into one container. The sample was "picked" and individual organisms were sorted into separate containers. All macroinvertebrates collected were identified, most to order level, with a few aquatic insects identified to family level. This identification was completed in the field based on

previous training, simple pictures and identification keys. All macroinvertebrates collected were counted streamside and returned unharmed to the stream. A standardized datasheet was used to record results.

Fish species were collected on Friday, June 18, 2004 using a Smith-Root, Inc. Model #12-B POW Electrofisher 400-600 Watts on a Cathode/Anode system. Data was collected using the U.S Environmental Protection Agency's RBP (USEPA, 1989). The sites selected were approximately 300 meters in length and correlated with the PFBC stations 0202 and 0201.

Stunned organisms were captured using dip nets and were temporarily held in buckets. The identification was completed in the field based on previous training and simple identification keys. All fish species were measured using a metric wooden measuring board, counted and recorded streamside, and returned to the creek. Because some trout were captured at stressful stream conditions (e.g. warm water temperatures), we observed these organisms in the net, estimated and recorded their measurement and released them immediately. A Fish Sampling Field Data Sheet from the EPA Rapid Bioassessment Protocol was used to record data.

Site 0202, which correlates with the PFBC Station 0202 assessment in 1995, was located at a farm southeast of Kutztown (Figure 1). The riffles selected for macroinvertebrate sampling were located downstream from a fenced cattle crossing. The dominant substrate in the riffle areas was cobble with gravel as the subdominant substrate. Riffle areas demonstrated moderate consolidation. Limited algal growth was observed on some rocks in the center of the stream. Fish sampling began at the downstream corner of the property adjacent to a fenced-off horse pasture and ended at the cattle crossing. The riparian buffer was well established with multiple overhanging trees and shrubs; we observed minimal bank erosion. It was difficult to stand up straight while conducting electrofishing in the streambed, due to a low hanging canopy. Adjacent to the sampling site, approximately 75% of the stream was shaded by riparian buffer habitat. Approximate buffer width on both sides of the stream was 15 feet. The land used on either side of the stream was utilized as open pasture. Habitat types at this location were about 10% riffles, 40% pools and 50% runs.

Site 0201, which correlates with the PFBC Station 0201 assessed in 1995 and 2001, was located at a farm northwest of Bowers (Figure 1). The riffles selected for sampling were located downstream from a farm lane bridge. The dominant substrate in the riffle areas was cobble with gravel as the subdominant substrate. Riffle areas demonstrated moderate consolidation. Some algal growth was observed on some rocks in the center of the stream. Fish sampling began approximately 30 meters upstream of the farm lane bridge and ended on the upstream side of the railroad tracks at Bowers Park. Land use adjacent to the stream includes, riparian buffers, row crops and a fenced off pasture. The riparian buffer width was approximately 15 feet on both left and right banks. Approximately 70% of the stream was shaded due to a dense riparian buffer. Though the water appeared low in turbidity, a slight sewage odor was present while walking in the streambed. Habitat types at this location were about 30% riffles, 31% pools, 35% runs and 4% snags.

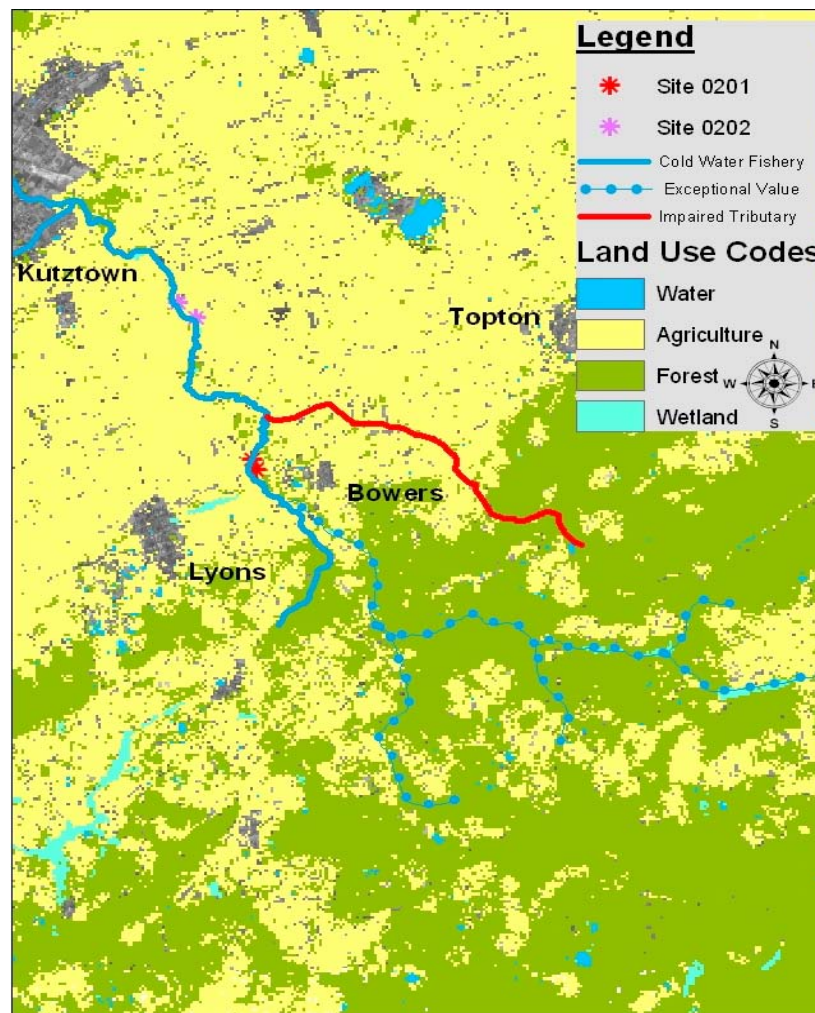


Figure 1. Land use surrounding the two study locations along the Sacony Creek and stream classification changes in the watershed.

## Results

The Sacony Creek macroinvertebrate sampling data were analyzed using metrics recommended by Virginia Save Our Streams (VA SOS), the USEPA, and the Pennsylvania Department of Environmental Protection (PADEP):

- VA SOS examines a number of individual metrics (mayflies+stoneflies+caddisflies, common net-spinners, lunged snails, beetles, percent tolerant, and percent non-insects) then calculates a water quality score using a multimetric index. The VA SOS multimetric index identifies a numerical threshold that distinguishes between acceptable (7-12) and unacceptable ecological condition (0-6).
- The USEPA assigns tolerances (sensitive, somewhat sensitive, and tolerant) to taxa as well as codes based on the abundance of individual species present (Rare equals 1-9 organisms; Common equals 10-99 organisms; Dominant equals 100 plus organisms). Index values are calculated for each group. The total of all index values equals the water quality score (Poor = <20; Fair = 20-40; Good = >40).

- PADEP’s Watershed Snapshot incorporates both a presence/absence rating and pollution tolerances. Taxa are assigned tolerances (S,F,T) and then a score is calculated for each group based on the number of taxa present. The site ranking is based upon the total of all group values or the number of sensitive taxa present (Poor = no S taxa or <11 points; Fair = 1 S taxa or 11-16 points; Good = 2 or 3 S taxa or 17-21 points; Very Good = 4 S taxa or 22-26; points; Excellent = 5+ S taxa or a score <27+).
- The PFBC rated their data according to present or abundant, where X = Present and \* = Abundant.

Using the VA SOS system, Stations 0202 and 0201 both received ratings of Acceptable Ecological Condition. The same data used with USEPA tolerance criteria resulted in scores considered “Good”. With the PA DEP Watershed Snapshot criteria the same data resulted in “Excellent” rankings for both sites. Each site exhibited a diversity of organisms. Sixteen (16) taxa were found at Site 1 including organisms from all three tolerance groupings: Group I, Sensitive, Group II, Somewhat Sensitive and Group III, Tolerant. Nineteen (19) taxa were found at Site 2, again including organisms from all three tolerance groupings (Table 1).

**Table 1. Macroinvertebrate Composition**

Aquatic organisms (Family/Order/Class)		2004 Station 0202	1995 Station 0202	2004 Station 0201	2001 Station 0201	1995 Station 0201
Group 1: sensitive to pollution and will quickly disappear if water quality is degraded	Water penny larvae, <i>Psephenidae</i>	2	*	27	X	X
	Mayfly nymphs, <i>Ephemeroptera</i>	21	X	74	X	X
	Stonefly nymphs, <i>Plecoptera</i>		X	9	X	X
	Non-netspinning caddisfly, <i>Trichoptera</i>	3	X	11	X	X
	Fingernet caddisfly larvae, <i>Philopotamidae</i>	2	X	4	X	X
	Free-living caddisfly larvae, <i>Rhyacophilidae</i>			2	X	X
Group 2: tolerate moderate amounts of pollution	Other beetle larvae, <i>Coleoptera</i>	34		3		
	Riffle beetle adult, <i>Coleoptera</i>	98	*	11		X
	Other beetle adult, <i>Coleoptera</i>	1				
	Cranefly larvae, <i>Tipulidae</i>	19	X	1		X
	Damselfly larvae, <i>Odonata</i>	2		2		
	Dragonfly larvae, <i>Odonata</i>			1	x	
	Scuds, <i>Amphipoda</i>	4	x	3		
	Aquatic sowbugs, <i>Isopoda</i>					
Group 3: pollution tolerant	Net-spinning caddisfly larvae, <i>Hydropsychidae</i>	40	*	81	X	*
	Water Mites, <i>Acariformes</i>	1		1		
	Aquatic worms, <i>Oligocheta</i>	6		7	X	X
	Blackfly larvae, <i>Simuliidae</i>	100 <sup>+</sup>	X	2		
	Leeches, <i>Hirudinea</i>	1			X	
	Midge larvae, <i>Chironimidae</i>	12	X	14	X	X
	Water striders, <i>Hemiptera</i>			5	X	
<b>Total Individuals</b>	<b>346</b>		<b>309</b>			

The Sacony Creek fish sampling data was analyzed using the Tolerance Designation metric (relevant to non-specific stressors) recommended by USEPA RBP (Appendix C), where I = Intolerant; M = Intermediate; T = Tolerant to pollution. Each organism was classified according to the above-mentioned levels.

River Chub are not commonly found in small headwater streams so Group 1 was recorded, but will not count in the overall results. Our collection was strictly based on the number of species captured. The PFBC recorded their data based on a subjective abundance index where: A = Abundant (> 100); C = Common (26-100); P = Present (3-25); R= Rare (< 3). Only the species captured by the PFBC and the Conservation District are charted. According to our data, there were 26 more Group 2 (Intolerant/Intermediate) fish species at station 0201 then at 0202 (Table 2).

Inaccuracies regarding macroinvertebrate collection were minimized because the technicians were more experienced in collecting macroinvertebrates and that these organisms are easier to capture than fish. Due to the technical field experience of the PFBC more fish species were captured at the 1995 and 2001 sites than in our 2004 sites. We felt we had a 60% capture rate when detaining the fish, compared to a much larger capture rate from the PFBC.

The fish that were captured and identified were identified to the best of our ability. Although we determined that all of the trout captured were wild, there are stocked trout in the creek. It is important to mention this to maintain quality assurance/quality control measures in this data.

**Table 2. Composition of Fish Species**

Fish Organisms (common name/genus/species)	2004 Station 0202	1995 Station 0202	2004 Station 0201	2001 Station 0201	1995 Station 0201		
Group 1: <b>I</b> = Intolerant to pollution and will quickly disappear if water quality is degraded		*River Chub, <i>Nocomis micropogon</i>	2		1		
Group 2: <b>I, M</b> —Intolerant and Intermediate; sensitive to tolerant to moderate amounts of pollution		Brown Trout, <i>Salmo trutta</i>	3	P	10	C	C
		Northern Hogsucker, <i>Hypentelium nigricans</i>	6		11		
		Rock Bass, <i>Ambloplites rupestris</i>	5	P	5	P	
		Longnose Dace, <i>Rhinichthys cataractae</i>			14	C	P
Group 3: <b>M</b> = Intermediate—tolerate moderate amounts of pollution		Redbeast Sunfish, <i>Lepomis auritus</i>	11	P	4	R	
		Common Shiner, <i>Luxilus cornutus</i>	9	P	2	C	A
		Tessellated Darter, <i>Etheostoma olmestedi</i>	8	P	7	P	P
Group 4: <b>M, T</b> = Intermediate and Tolerant—tolerate more than moderate amounts of pollution		Banded Killifish, <i>fundulus, diaphanus</i>	2	A			
Group 5: <b>T</b> = Tolerant—pollution tolerant		Blacknose Dace, <i>Rhinichthys atratulus</i>		P	4	A	A
		Creek Chub, <i>Semotilus atromaculatus</i>	3	C		P	C
<b>Total organisms</b>			<b>49</b>		<b>58</b>		

\* species is very uncommon in this ecosystem, could have been mistaken for a creek chub or a cutlips minnow

## Discussion

The purpose of the June 2004 study was to examine the downstream migration of cold-water aquatic organisms, compare the three studies and see if the affects could be attributed to TCTU restoration efforts. Based on the results from the 2004 study, it was determined that the stream restoration work implemented by the TCTU has led to moderately positive ecological improvements and valuable education and outreach to participating landowners. In five years, noticeable physical changes have occurred to the riparian buffer and habitat structures in the stream (Figures 2 - 4).

Though stations 0201 and 0202 have thick riparian buffers, it may be too early to see the effects of riparian buffer plantings on macroinvertebrates and fish along the entire 2.3 mile stretch. Once the newly planted trees establish a thick canopy cover, they should decrease stream temperature, enabling the stream to host more coldwater fish species.

According to the Pennsylvania's 2003 303(d) list of impaired streams, the small tributary that flows into the Sacony Creek downstream of Site 0201 and upstream of Site 0202 (Figure 1), is listed as impaired due to habitat and sediment. This tributary has not been rehabilitated by TCTU, and suffers from a degraded riparian buffer. The tributary is influenced by decreasing habitat and increasing thermal pollution, potentially affecting Station 0202 and other downstream sections of the Sacony Creek.

The eight projects took place along a transitional topographic point. The upper reaches of the project area are in medium gradient slopes, flowing off large hills and mountains. The downstream reaches are at lower gradients, which interrupt the stream's pool-riffle-run sequence. This sequence of pools, riffles and runs provides a heterogeneous physical environment that is utilized by many different types of organisms. Pools, riffles and runs provide refuge from stream velocity and extreme temperatures, spawning sites for cold-water fish, and habitat sites for benthic invertebrates and



**Figure 2. Severely eroded stream banks at a location in between stations 0201 and 0202. Notice pine trees in background for reference.**



**Figure 3. This after picture shows streambank fencing excluding cattle from the stream, stabilized stream banks and improved in-stream habitat. This shot was taken immediately after the restoration.**



**Figure 4. Shot of the same site taken 2 years after restoration. Notice lush riparian buffer and stabilized stream banks.**

plants (Gore and Shields 1995). The complexity of pool-riffle-run sequences offers a wide variety of habitat types necessary to support a diverse lotic community. Site 0201 (the higher gradient site) supported more coldwater fish and more pollution intolerant macroinvertebrate taxa than Site 0202 (the lower gradient site) because it has a more consistent pool-riffle-run regime.

Through their restoration efforts, TCTU formed numerous partnerships to accomplish their goal of improving the Sacony Creek. These partnerships were the driving force behind the stream improvement projects. Partnerships are crucial to providing effective watershed management schemes. Through a partnership, different people and organizations work together to address common interests and concerns (Conservation Technology Information Center, 2004). Through landowner cooperation and environmental responsibility projects of this nature continue to be possible.

Although reduction of non-point source pollution and downstream migration of coldwater fish may be difficult to quantify, it can be concluded that the best management practice implementation efforts conducted by TCTU and their partners have had a positive impact on the water quality in the Sacony Creek Watershed.

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## Acknowledgements

The Berks County Conservation District would like to thank the following individuals: Chari Towne with the Delaware RiverKeeper Network for providing technical assistance with the aquatic macroinvertebrate monitoring; Matthew Kofroth with the Lancaster County Conservation District for the use of the electrofisher, data collection and providing technical assistance; Rick Bell and Leonard Good with the Tulpehocken Chapter of Trout Unlimited for their project knowledge and data collection efforts; Kristie Reccek with the Berks County Conservancy for sharing data; Mike Kaufmann and Vincent Dick with the Pennsylvania Fish and Boat Commission for their information about past stream conditions in the Sacony Creek and allowing us to assess the watershed; Rebecca Seidel, intern with the Berks County Conservation District, for providing macroinvertebrate identification and editorial assistance; James Spayd with Pennsylvania Spatial Data Assess (PASDA) for providing maps; Karl Shellenberger for providing the fish measuring equipment and all of the landowners along the Sacony Creek who have participated in these restoration projects.

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## References

- Commonwealth of Pennsylvania. Department of Environmental Protection. PA Code. Title 25. Chapter 93. Harrisburg: Department of Environmental Protection, 2003. 53.
- “Conservation Technology Information Center: Building Local Partnerships- A Guide for Watershed Partnerships.” Know Your Watershed. June 29, 2004. < <http://www.ctic.purdue.edu/KYW/Brochures/BuildingLocal.html> >
- Gore, J.A. and F.D. Shields, Jr. “Can Large Rivers Be Restored?” *BioScience*: 1995. Vol. 45, 142-152.
- Miko, D. and Kaufmann, M. et al. “PA Fish and Boat Commission Sacony Creek Fisheries Management Report.” June-July 2001. (603B): 1-17.
- “Rapid Bioassessment Protocols.” United States Environmental Protection Agency. 1989. < <http://www.epa.gov/owow/monitoring/rbp/> >
- “Volunteer Stream Monitoring: A Methods Manual.” United States Environmental Protection Agency. 1997. < <http://www.epa.gov/owow/monitoring/volunteer/stream/> >
- Wnuk, R. and Kauffman, M. et al. “PA Fish and Boat Commission Sacony Creek Fisheries Management Report.” June 1995. (603B): 1-37.

## Elwha River Dam Removal—A Public/Private Partnership in Ecosystem Restoration

### B.D. Winter

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**ABSTRACT**—The Elwha River Ecosystem and Fisheries Restoration Act of 1992 authorized the Secretary of the Interior to acquire and remove the Elwha and Glines Canyon Dams in Washington State to “fully restore the Elwha River ecosystem and native anadromous fisheries.” Funding for the restoration project is by annual appropriations, the initiation of which was stimulated by the efforts of non-profit organizations and members of the local community. Acquisition of the dams was accomplished in February 2000 with their removal scheduled for 2007. Restoration of the ecosystem will result in anadromous fisheries run sizes increasing from about 3-5,000 fish annually to over 390,000 fish in odd years (when pink salmon return). Resident rainbow trout and bull trout and searun cutthroat trout will benefit from the influx of salmon eggs, juvenile salmon, and adult carcasses, as well as habitat recovery. Over 70 miles of mainstem and tributary habitat as well as nearshore marine areas will be restored. The public will be able to assist in revegetation and fish restoration efforts.

### Introduction

The Elwha River historically supported spring- and summer/fall-run chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), pink salmon, (*O. gorbuscha*), chum salmon (*O. keta*), sockeye salmon (*O. nerka*), winter- and summer-run steelhead trout (*O. mykiss*), sea run cutthroat trout (*O. clarki*), bull trout (*Salvelinus malma*), and resident rainbow trout (*O. mykiss*). Estimates of the historic production of salmon and steelhead suggest that about 392,000 were produced from the Elwha River, Washington system in odd years when pink salmon returned from the sea (ONP 1996). These runs would have contributed about 820,000 pounds of carcass biomass to the Elwha River ecosystem during those return years (ONP 1995).

Construction of two hydroelectric dams on the Elwha River in the early 1900s drastically reduced salmon and steelhead runs by eliminating access to over 70 miles of mainstem and tributary habitat (Figure 1). In addition to the immediate cessation of migration to about 93% of the once available habitat, the reservoirs trapped gravels which eliminated the replacement of spawning gravels eroded downstream of the dams, blocked the transport of large woody debris downstream and nutrients both upstream and downstream, and inundated about 5.3 miles of important low gradient river habitat. Operation of the projects caused the stranding of both juvenile and adult fish in the 1930s and 1940s, although operation approximating run-of-river largely eliminated the extreme unnatural river fluctuations downstream. Water temperatures downstream of the dams are increased about 4 degrees Celsius during the summer low flow period because of the absorption of solar radiation within the reservoirs. This temperature increase contributed to the pre-spawning mortality of about two-thirds of the 1992 chinook salmon return (Wunderlich et al. 1994).

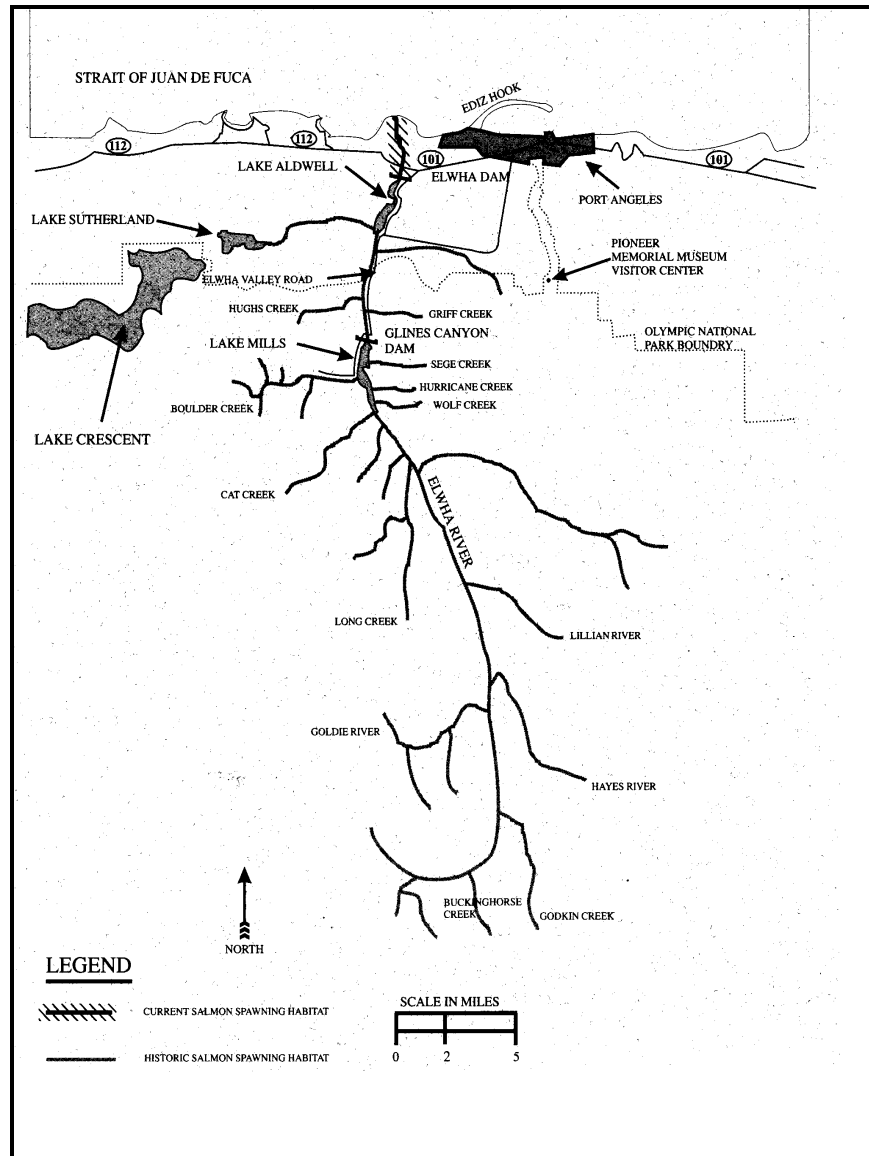


Figure 1. Location of the Elwha River, Elwha Dam, Glines Canyon Dam, and existing accessible area to anadromous fish (from ONP 1994).

The previous owner of the dams filed a first time license application for Elwha Dam with the Federal Power Commission (FPC) in 1968. Glines Canyon Dam had been licensed by the FPC in 1925 for a period of 50 years, so the owner filed a relicense application in 1973 (see [www.nps.gov/olym/elwha/home.htm](http://www.nps.gov/olym/elwha/home.htm)). These applications were consolidated in the Federal Energy Regulatory Commission’s (FERC, previously the FPC) licensing process for these two projects.

In the early 1980’s, the Lower Elwha Klallam Tribe (Tribe) and a coalition of four environmental groups submitted filings to FERC calling for the removal of both dams as mitigation for the adverse effect of the dams up to that point. FERC actually considered dam removal in its environmental impact statement for the licensing process, but of course also evaluated retention of the dams with the

inclusion of fish passage facilities. It quickly became obvious that FERC's process was going to be mired in litigation for years to come.

Congressional representatives offered to draft legislation that could resolve existing and pending litigation over these dams. Their efforts resulted in a negotiated settlement among the parties to the FERC proceeding that became the Elwha River Ecosystem and Fisheries Restoration Act of 1992 (Public Law 102-495). This Act authorized the Secretary of the Interior to acquire and remove both dams to fully restore the Elwha River ecosystem and native anadromous fisheries.

However, this law might never have occurred were it not for the efforts of environmental groups and some Port Angeles residents. In particular, 13 individuals formed what they called the Elwha Citizens' Advisory Committee. This group was composed of people that opposed dam removal, supported dam removal, or were not strongly swayed one way or the other. They considered the pros and cons of dam removal, listened to presentations by groups and agencies in opposition and those in favor and ultimately concluded that dam removal was the best alternative for Port Angeles and Clallam County. This effort eliminated the opposition to dam removal by a U.S. Senator from Washington that opposed dam removal because it was not a "community based plan". Federal appropriations in support of project acquisition and removal also benefited from the continual support of citizens, environmental groups, and the Tribe. Federal acquisition of the two dams occurred on February 29, 2000.

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## Dam Removal

The Elwha Hydroelectric Project was constructed at RM 4.9 from 1910 to 1912. It has a central concrete gravity-type section that is 105 feet in height with a span of 450 feet at its crest and two sets of spillways. The original powerhouse contains two horizontal Francis turbines. A second powerhouse was constructed about ten years later and it contains two vertical Francis turbines (Figure 2). The total installed capacity of this project is 14.8 MW (FERC 1993). Lake Aldwell, the reservoir created by Elwha Dam, has a storage capacity of about 8,100 acre-feet with a maximum drawdown capacity of about seven feet—there is no low-level water outlet at Elwha Dam.

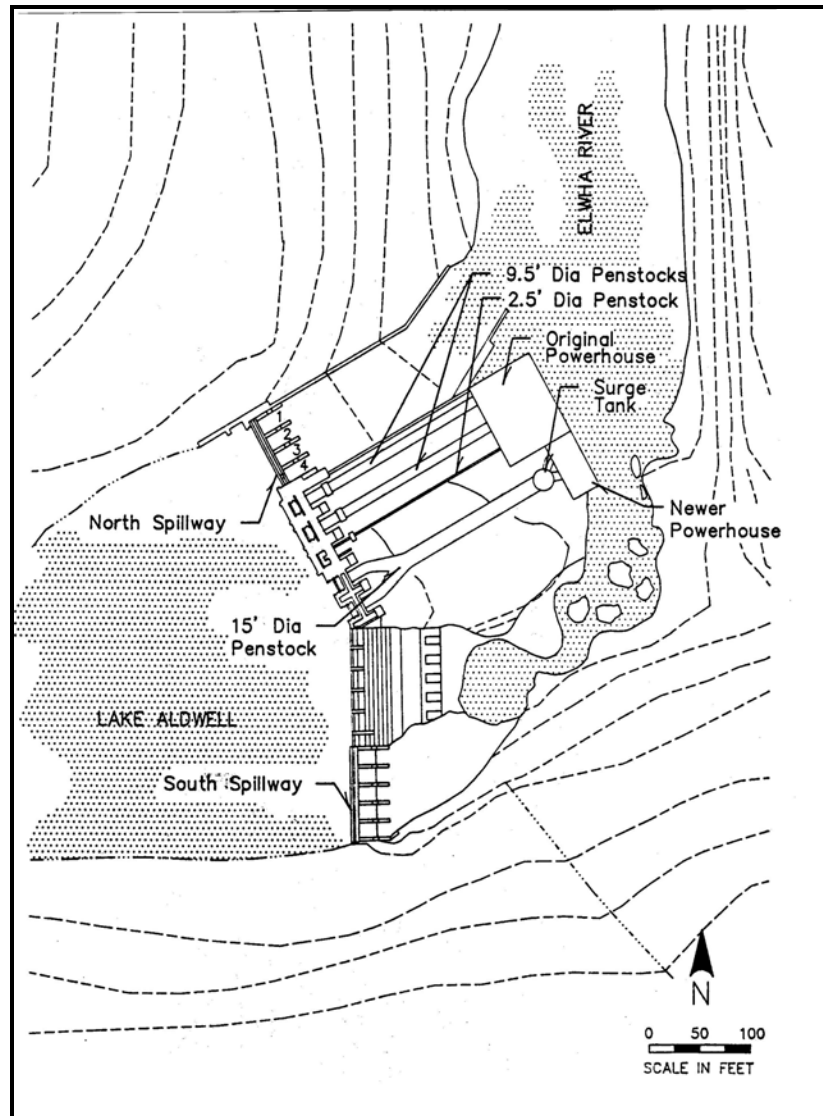


Figure 2. Site plan for Elwha Dam and powerhouses (from FERC 1993).

The Glines Canyon Hydroelectric Project was built from 1925-1927 at RM 13.1. The dam is a varied radius, single arch concrete structure that is 210 feet high and 270 feet at its crest. It has a single spillway on the left bank and there is only one vertical Francis turbine in the powerhouse (Figure 3). The installed capacity of this project is 13.1 MW (FERC 1993). The associated reservoir, Lake Mills, has about 30,000 acre-feet of active storage. The dam has a small low-level outlet, but it has not been used since construction of the dam.

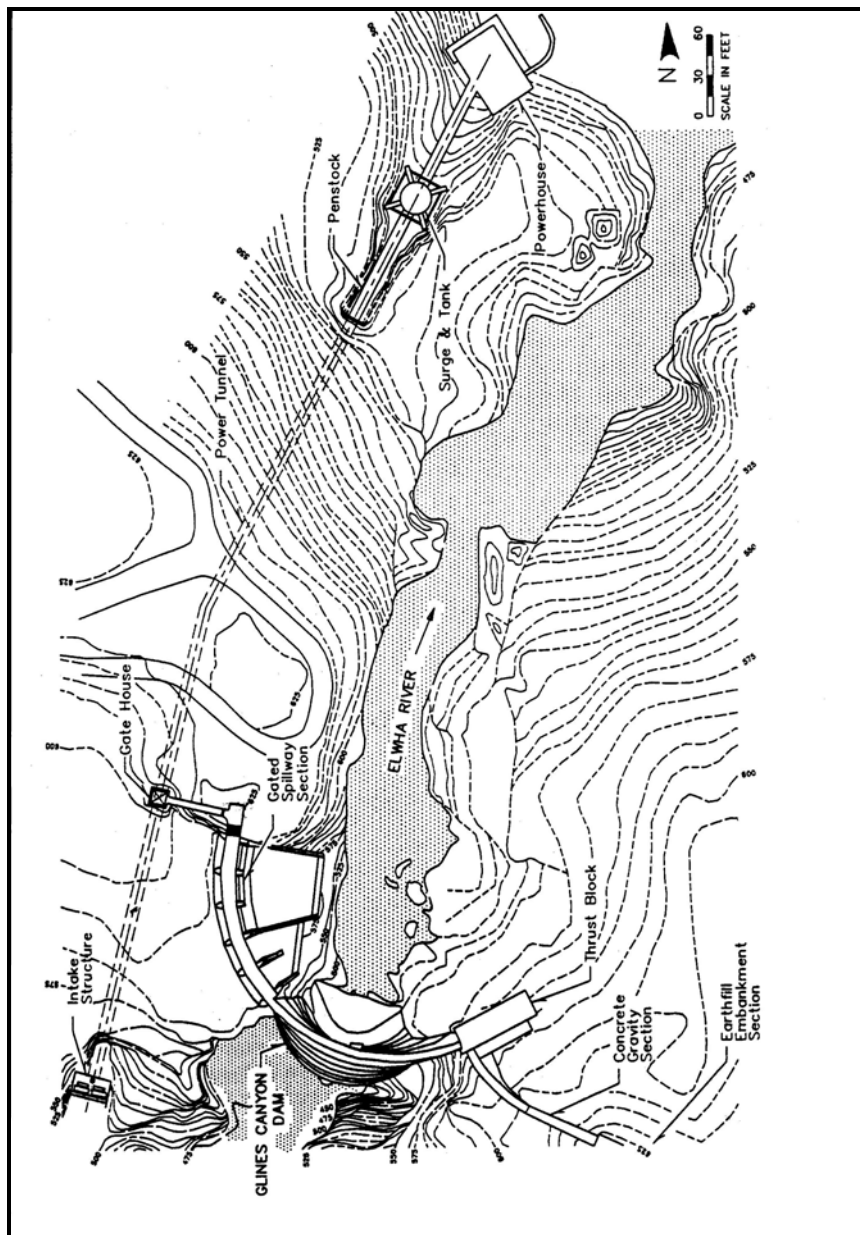


Figure 3. Site plan for Glines Canyon Dam and powerhouse (from FERC 1993).

The first stage in removal of the two dams is the draining of Lake Mills 80 feet using the existing power outlet. This will allow for some flood protection as a temporary diversion channel is constructed through the left abutment at Elwha Dam (ONP 1996). Once the diversion is completed, Lake Aldwell will be drained about half its depth and coffer dams constructed to isolate the area behind the concrete gravity section. This will allow for removal of the concrete gravity structure and the fill that was placed behind the dam when the foundation failed during filling of the reservoir in 1912 (Aldwell 1950). The historic river channel will be restored following removal of the dam and the fill material. The coffer dams will be removed in a controlled manner, the remaining reservoir drained, and the river channel reestablished.

Glines Canyon Dam will be removed concurrently with Elwha Dam. Once the temporary diversion channel is in operation at Elwha Dam, the upper 80 feet of the concrete gravity arch structure will be removed by cutting blocks out with a continuous diamond wire saw or with controlled blasting (ONP 1996). At this point, the reservoir will be drained over the remaining dam structure by cutting notches into the face of the dam and removing additional dam levels of concrete. The removal of both dams will take about 2.5 years, primarily because of limitations imposed by the sediment management plan (see below).

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## **Sediment Management**

Approximately 18 million yd<sup>3</sup> of material have accumulated within the two reservoirs since construction of the dams. This material is composed of 9.2 million yd<sup>3</sup> of highly erodable silt and clay, 6.2 million yd<sup>3</sup> of moderate to highly erodable sand, and 2.3 million yd<sup>3</sup> of more slow moving gravel and cobble (ONP 1996). Most of the coarse sediment is located in a delta at the heads of Lake Mills that reaches depths of up to 70 feet. The fine material is more evenly distributed over the bottoms of both reservoirs, in some places up to 10 feet deep.

The river will be allowed to move this material downstream, although much will remain within the former reservoir areas. Up to 60% of the fine material will erode downstream within a three to five year period during and following dam removal while only up to about 30% of the coarse material is estimated to leave the reservoir areas over a much longer time.

Release of the coarse sediment downstream will replace material eroded from below the dams over the past 90 years so is a beneficial aspect of the sediment management plan. In particular, the river has armored with large size cobble so the release of spawning sized gravel will help restore the lower river to allow fish restoration to occur.

The fine material can also be considered a resource, but release of 90 years worth of accumulation will greatly exceed safe limits for fish. Therefore, the dam removal contractor will be required to cease dam removal activities during the peak spring downstream migration period, the peak entry timing of chinook salmon, and the peak entry timing of coho, pink, and chum salmon. These closures total approximately 5.5 months each year although high stream flow events will also cause the contractor to cease work until flows recede. The closures are referred to as “fish windows” and are critical to the success of the fish restoration program (see below).

Release of large quantities of fine materials will also affect downstream municipal (City of Port Angeles) and industrial water users as well as two fish hatcheries. Water mitigation facilities are planned to protect these users during the dam removal period. The details of these efforts will be further analyzed in a supplemental environmental impact statement that will be released in 2004.

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## **Fish Restoration**

Remaining anadromous fish in the Elwha River are a combination of hatchery propagated and naturally spawning stocks (Wunderlich et al. 1994). The fish restoration program includes protection of the stocks during dam removal, hatchery propagation and outplanting following dam removal for a period of 10 years, and monitoring and harvest management to ensure adequate returns (ONP 1996).

The working assumptions of the fish restoration plan include the following (ONP 1996; Wunderlich 1994):

- The two hatcheries can serve as fish refuges during dam removal.
- The “fish windows” will permit escapement to hatcheries or other clean water areas as well as allowing capture within the river.
- Hatchery outplanting will speed re-colonization and allow selective re-introduction of stocks.
- Hatchery outplanting at very early life stages will improve long-term survival of stocks.
- Natural re-colonization is a “fail-safe” long-term restoration measure for all stocks.

Protection of the water supplies for the two fish hatcheries will essentially allow them to serve as refuge for fish during the high sediment release period. The fish windows were designed to allow adequate numbers of adult fish to return to the river rather than risk avoidance of the river mouth because suspended sediment levels could be too high. Once the fish return to the river, as many as possible will be captured and placed in the two fish hatcheries to protect them from the high suspended sediment concentrations expected to occur outside of the fish windows.

The fish will be spawned in the hatcheries and the resulting progeny released from those facilities during dam removal (within the appropriate fish window) to migrate downstream. Following dam removal, fish will still be captured, spawned in the hatcheries, and the progeny released within the river after transport upstream by helicopter, deep within Olympic National Park or by truck below the site of Glines Canyon Dam.

Scientific peer reviews of the proposed fish restoration plan (see ONP 1996) has resulted in refinements to the plan. Improvements include multiple outplanting strategies and improved monitoring to document the success or failure of the different strategies. Adaptive management will likely be required to successfully restore each of the fish stocks.

Public participation in the fish restoration program will be actively pursued. Opportunities to assist include the collection and transport of fish during the fish windows, help with fish transport and outplanting activities following dam removal, and stream surveys to document the success of the program.

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## Revegetation

Prior to reservoir filling, the hill slopes were clearcut and the valuable timber from the floodplain areas was harvested. The focus of the plan to revegetate these areas is to achieve old growth characteristics as quickly as possible, with the ultimate goal of managing the restored area within Olympic National Park as wilderness.

The revegetation plan includes many component actions beginning before dam removal, during draining of the reservoirs, and following complete removal of the dams (Table 1). Grow trials using fine sediments (primarily a mixture of silts and clays) obtained from the bottom of Lake Mills were conducted to determine the ability of these materials to support native vegetation. The grow trials and chemical analyses of the sediments indicated that these fines are nutrient poor and provide an unsuitable substrate for most plant species, although red alder readily, albeit with slow initial growth, takes hold in this material and, with its nitrogen fixing characteristics, would prepare the soil for later successional species.

The greatest depths of these fine sediments are along the reservoir bottoms. While up to approximately two thirds of this material will be eroded downstream, much will remain within the floodplain areas. Fine sediments along the currently inundated hill slopes are expected to erode down slope during the slow process of reservoir drawdown, but some active manipulation may be necessary to expose the original soil surface, or close to it. Native trees and other vegetation will be planted along these exposed slopes as the reservoirs are drained. The exposed floodplain areas will be allowed to revegetate naturally since this area will be relatively unstable for many years as the river adjusts to its historic gradient.

Seeds and cones from Douglas fir (*Pseudotsuga menzeisii* var. *menzeisii*) and grand fir (*Abies grandis*) have already been collected and are currently in storage. Seeds and cuttings from other native plants will also be collected to provide root stock for the planting program (ONP 1996).

One of the major components of the revegetation plan is the control of nonnative invasive species. Many nonnative plants are present within the watershed, including English holly (*Ilex aquifolium*), Scot's broom (*Cytisus scoparius*), common chickweed (*Cerastium fontanum*) and Canada thistle (*Cirsium arvense* var. *horridum*), among many others (ONP 1996).

Public volunteers were used during the cone collection activities and opportunities will be available to assist with the planting and nonnative invasive species management programs.

**Table 1. Summary of actions to reestablish native vegetation within the drained areas of Lake Mills and Lake Aldwell.**

Timing <sup>1</sup>	Revegetation Actions
Before	Conduct grow trials using reservoir bottom sediments.
Before	Collect seeds and cones within the watershed.
During & After	Relocate coarse woody debris for recolonization.
During & After	Employ biotechnical slope stabilization, as needed.
During	Seed and plant hill slopes as reservoirs drain.
After	Rely on natural recolonization of reservoir beds.
After	Control and remove nonnative invasive plants.
During & After	Monitor effectiveness.
After	Implement remedial measures, as needed

<sup>1</sup> Before, during, and after dam removal activities.

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## Conclusion

Removal of the Elwha and Glines Canyon dams is a project with many large construction related aspects. Public participation in these activities is necessarily limited. However, the revegetation and fish restoration programs offer many opportunities for public participation and involvement. In addition, they provide a wonderful opportunity to teach people about various aspects of ecosystem restoration which potentially far reaching benefits. The Elwha River Restoration Project does not yet have a volunteer outreach program or coordinator, but I hope that will be remedied before dam removal commences in 2007.

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## References

- Aldwell, T.T. 1950. *Conquering the Last Frontier*. American Book-Knickerbocker Press, Inc., New York, NY.
- FERC (Federal Energy Regulatory Commission). 1993. Draft Staff Report, Volume I, Glines Canyon (FERC No. 588) and Elwha (FERC No. 2683) Hydroelectric Projects, Washington. Federal Energy Regulatory Commission, Office of Hydropower Licensing, Washington, D.D.
- ONP (Olympic National Park). 1994. Draft Environmental Impact Statement, Elwha River Ecosystem Restoration. NPS D-253. Olympic National Park, Port Angeles, WA.
- ONP (Olympic National Park). 1995. Final Environmental Impact Statement, Elwha River Ecosystem Restoration. NPS D-253A. Olympic National Park, Port Angeles, WA.
- ONP (Olympic National Park). 1996. Draft Environmental Impact Statement, Elwha River Ecosystem Restoration Implementation. NPS D-271. Olympic National Park, Port Angeles, WA.
- Wunderlich, R.C., B.D. Winter, and J.H. Meyer. 1994. Restoration of the Elwha River ecosystem. *Fisheries* 19(8):11-19

## Responses of Streams to Riparian Restoration in the Spring Creek Watershed, Central Pennsylvania

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**ABSTRACT**—Sediment originating from intensively grazed pastures was linked to depressed reproduction of brown trout *Salmo trutta* in Spring Creek, a limestone stream in central Pennsylvania. The Spring Creek Chapter of Trout Unlimited with support of public agencies initiated a project in 1990 that was designed to restore degraded riparian areas and reduce sediment loading. Improvements included stabilizing eroding stream banks, installing rock-lined animal accesses and stream crossings, and constructing fences along the streams.

Spring Creek was divided into three major regions for this study: (1) the upper region was comprised of the Slab Cabin Run basin, the Cedar Run basin, and the upper Spring Creek basin; (2) the middle reach of Spring Creek, where reproduction of brown trout had been depressed; and, (3) the lower reach of Spring Creek. Restoration efforts were concentrated in two tributaries in the upper region. There were 2.55 miles of stream flowing through unfenced riparian pastures in the Slab Cabin Run basin, and 67% of this stream length was improved and well maintained through 2003. There were 1.55 miles of stream flowing through unfenced pastures in the Cedar Run basin, and 98% of this stream length was improved and well maintained through 2003. Upper Spring Creek, which had no unfenced riparian pastures, was used as a reference. Similar restoration efforts were applied to six properties on the middle reach of Spring Creek.

The primary objective of this study was to quantify the effects of stream bank fencing and stabilization in Slab Cabin Run and Cedar Run. We measured channel morphology, substrate composition, stream temperatures, discharge, water quality, macroinvertebrate, and fish communities prior to restoration in 1991-1992. Restoration activities were completed in 1992-1998, and post-restoration assessments were made in 2001-2003. A secondary objective was to quantify brown trout spawning activity in the middle reach of Spring Creek prior to and after riparian restoration activities.

Stream bank fencing resulted in re-vegetation of eroded banks with primarily grasses and a few shrubs. No trees were planted, and none invaded the buffer zone. Stream channel morphology did not change after restoration. Total suspended solids during base flow in Cedar Run declined by 36 to 45% and in Slab Cabin Run total suspended solids declined by 77 to 82% after restoration, though below-average discharge contributed somewhat to these reductions. During storm flow there were significant reductions in total suspended solids in one of two years in Cedar Run and in both years in Slab Cabin Run. There were no significant changes in concentrations of nitrogen or phosphorus after restoration. The amount of fine sediments in the substrate of Cedar Run declined after restoration, but similar changes were not evident in Slab Cabin Run. There was no indication that stream temperatures changed as a result of stream bank restoration. Composition of the macroinvertebrate communities did not change,

but there were significant increases in densities of macroinvertebrates after restoration. Composition of the fish communities and densities of wild brown trout in Cedar Run and Slab Cabin Run were similar before and after restoration.

We conducted redd surveys on 34 miles of Spring Creek in 1988 and 1989 and after restoration in 1997-2000 and 2002. Numbers of brown trout redds in the middle reach of Spring Creek increased by 460% after restoration. During this same period, numbers of brown trout redds in the upper reach of Spring Creek decreased by 35% and in the lower reach of Spring Creek increased by 33%. Density of age-1 and older brown trout increased by 125% in 2000 compared to 1988 in the middle reach. During these same years, density increased by 10% in the upper reach and by 58% in the lower reach.

We concluded that riparian restoration along the tributaries led to re-vegetation of eroded banks, reductions in total suspended solids, and increases in densities of macroinvertebrates. This reduced sediment loading apparently benefited an 8-mile reach of the main stem, where brown trout redds increased substantially.

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## Managing Brook Trout Populations in an Urbanizing Environment

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**ABSTRACT**—Urbanization effects, from an increasing human population, threaten all mid-Atlantic trout populations. Currently, Maryland is experiencing acute anthropogenic problems that are particularly severe in Maryland's Northern Piedmont ecoregion, an area of significant precolonial native *Salvelinus fontinalis* (brook trout) populations, but now containing only remnant and highly fragmented populations. These relic populations are highly vulnerable to urbanization stresses, and many may become extinct in the near future. Employing primarily Maryland Biological Stream Survey (MBSS) data, we determined urbanization effects on Maryland brook trout streams, focusing principally on the Northern Piedmont ecoregion. Combining GIS with the MBSS data set, landscape-based urban characteristics, including watershed impervious surface, road density, roads near streams, forest fragmentation, and others were examined to determine effects on stream community structure. We also investigated brook trout population fragmentation, exotic species effects, and stream connectivity. Impervious surface greater than 0.3% in a watershed effectively eliminated brook trout populations, with urbanization, road density, and roads near streams severely affecting stream community structure. Effective brook trout management plans need to be developed to specifically address urbanization effects in the Northern Piedmont ecoregion.

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### Introduction

When human population reaches a critical threshold within a watershed, the “urban syndrome” prevails (Paul and Meyer 2001), effecting complex alterations on biotic, chemical, and physical watershed characteristics and processes that result in generally degraded streams with subsequent biotic alterations (Wang et al. 1997, Roth et al. 1999, Wang and Kanehl 2001, Paul and Meyer 2001, Brabec et al. 2002, Gergel et al. 2002, Groffman et al. 2003, Center for Watershed Protection 2003). Urbanization effects are a major contributing factor affecting biotic assemblages worldwide (Forman and Alexander 1998, Forman et al. 2003, Paul and Meyer 2001). Paul and Meyer (2001) state that urbanization is second only to agriculture as a major causative agent to stream degradation in the United States (USEPA 2000). From destroying intermittent and perennial low order streams, increasing impervious surface area, changing hydrological regimes,

elevating nutrients and contaminants to altering biotic assemblages, urbanization is a major stressor that is difficult to mediate, and reverse, once it becomes watershed dominant.

Numerous studies have determined that land use change within a watershed affects stream fish populations (e. g. Fraker et al. 2002), but there are limited studies in the literature that examine fish assemblage and community responses to urbanization, and even fewer that address coldwater species (Kemp and Spotila 1997). For example, Paul and Meyer (2001) list only six studies that specifically deal with biological responses of fish to urbanization (primarily impervious surface). Most studies generally found significant changes in either fish diversity or fish indexes of biotic integrity (IBI) correlated to either increasing impervious surface or urban land use in the watershed (Klein 1979, Steedman 1988, Schueler and Galli 1992, Weaver and Garman 1994, Wang et al. 1997 and Yoder et al. 1999), with the overall conclusion that significant biotic changes occur at watershed impervious values of 10-12%.

In this paper, we address urbanization effects on brook trout populations in the Northern Piedmont ecoregion (EPA Level III) of Maryland—an area bounded by the Southeastern Plains ecoregion to the east, and the Blue Ridge ecoregion to the west. The Northern Piedmont ecoregion is subject to increasing urbanization stress due to population growth along the Baltimore - Washington corridor.

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## Methods

MBSS data (Roth et al., 1999) from 1995-1997 (first round) and 2000-2002 (partial second round) for trout populations in Maryland were used with ESRI software (ArcView 3.2 and ArcView Spatial Analyst Version 1.1) to examine trout population attributes and to calculate various landscape variables (first round MBSS data only) for streams in the Northern Piedmont ecoregion (Holt 2003). This ecoregion includes sections of the Susquehanna, Bush, Gunpowder, Patapsco, Patuxent, Potomac Washington Metro and Middle Potomac basins (Roth et al. 1999).

GIS layers included watershed delineations, elevation, land use/land cover (LULC), hydrographic data, and roads; Maryland State Plane coordinate system and NAD 1983 geographical datum were selected to format all GIS data. Shape files were obtained from the MBSS containing polygons representing the drainage area for each station in the 1995-1997 MBSS public dataset. LULC data was obtained from the National Land Cover Dataset derived from Landsat Thematic Mapper imagery. Landscape watershed characteristics generated included proportional land coverage (%) with urban, agriculture, forest, barren, and wetland (Holt 2003); other parameters included riparian urban, riparian agriculture, riparian forest, riparian barren, riparian wetland, agriculture on steep slopes, forest fragmentation on steep slopes, road density, roads near streams, municipal sewage loadings, and basin size (Holt 2003). Nested stations with overlapping watershed areas were removed from the data set, thus ensuring independent data and eliminating pseudoreplication.

Random (quantitative) and non-random (qualitative) MBSS locations were plotted on a Maryland stream reach map that was derived from the 1:100,000 scale National Hydrography Dataset. The stream reach length was recorded for every first to third order stream reach (above the fall line) where brook trout were collected by the MBSS. Stream reach lengths were also recorded for stream reaches where brook trout and other species of trout were collected and for

stream reaches where no brook trout were collected. Stream reach lengths, not sampled by the MBSS upstream of stream reaches where brook trout were collected, were recorded as stream reaches where brook trout were possibly or probably present. All MBSS sites for the Northern Piedmont ecoregion, with either greater than 65% agriculture or any wastewater treatment plant present, were removed from the data set prior to analyses of landscape-community relationships (effective number of MBSS sites remaining equaled 153). Statistical techniques for derived MBSS data sets included regression analyses and ANOVA, using Statistica, Stata, and SAS programs.

## Results

Within the six drainage basins occurring in the Northern Piedmont ecoregion, only the Susquehanna (20% of stream miles) and Gunpowder (22%) still support significant extant brook trout populations, with residual populations present in the Patapsco (3.4%) and Patuxent (0.6%) drainages (Table 1). Three drainages no longer contain brook trout.

**Table 1. Summary of stream length analyses for brook trout streams in the Northern Piedmont ecoregion of Maryland (1 = first order stream; 2 = second; 3 = third).**

Basin	Brook Trout (Exotics) (km)	Possible Brook Trout (km)	No Brook Trout (km)	Total Stream Length (km)	% Total Stream Length with Brook Trout
Susquehanna	1. 23	1. 45	1. 263	1. 332	1. 20.6
	2. 8.6	2. 5.7	2. 59	2. 73	2. 19.5
		3. 5.0	3. 29	3. 34	3. 14.6
					Overall % = 20.0
Bush			1. 100	1. 100	1. 0
			2. 22	2. 22	2. 0
			3. 30	3. 30	3. 0
					Overall % = 0
Gunpowder	1. 50	1. 38	1. 314	1. 402	1. 21.8
		2. 6.9	2. 25	2. 32	2. 21.7
					Overall % = 21.8
Patapsco	1. 11	1. 9.3	1. 501	1. 521	1. 3.9
	2. 3.3	2. 2.2	2. 153	2. 159	2. 3.5
			3. 83	3. 83	3. 0
					Overall % = 3.4
Patuxent <sup>1</sup>		1. 2.2	1. 293	1. 295	1. 0.75
			2. 59	2. 59	2. 0
			3. 48	3. 48	3. 0
					Overall % = 0.55
Potomac Washington Metro			1. 471	1. 471	1. 0
			2. 145	2. 145	2. 0
			3. 65	3. 65	3. 0
					Overall % = 0
Middle Potomac <sup>1</sup>			1. 1,036	1. 1,036	1. 0
			2. 224	2. 224	2. 0
			3. 153	3. 153	3. 0
					Overall % = 0

<sup>1</sup> Only one possible brook trout population (2.2 km) remains in the northern Patuxent basin—this needs to be confirmed through additional sampling.

<sup>2</sup> The Middle Potomac abuts onto the Blue Ridge ecoregion of Maryland where significant populations of brook trout are present—these populations may extend slightly into the Middle Potomac drainage.

Using basically the same assumptions for Maryland brook trout as listed in Roth et al. (p. 4-21, 1999) and an estimate of 0.35 brook trout/m, we calculated that the precolonial Northern Piedmont ecoregion held 1.6 million brook trout, but currently holds only 0.081 million fish, or 5.2% of the precolonial population estimate. However, this estimate may be skewed since it is an average based on selected MBSS brook trout sites assumed to be most analogous to historical conditions (Roth et al. 1999). Utilizing population data collected from western Maryland trout streams from 1988-1990, we estimated precolonial and current brook trout numbers (Morgan 1988, 1989, 1999). This analysis, using an exponential distribution function ( $N = 111$ ) for the number of trout/m and stream meters/basin, yielded a precolonial estimate of 1.3 million brook trout. Extant populations in the Northern Piedmont ecoregion now total 0.070 million brook trout (95% confidence interval = 42,400—98,200 trout)—both our precolonial and extant estimates are slightly lower, but in close agreement with Roth et al. (1999).

For brook trout streams in the Northern Piedmont ecoregion, stream fragment length did not vary significantly (ANOVA,  $p = 0.39$ ,  $F = 1.01$ ,  $df = 3, 149$ ) among the three basins (Savage River watershed in western Maryland employed as a control watershed), with mean fragment length ranging from 2.0—2.8 km (Table 2). However, each of the three Northern Piedmont basins contained a number of stream fragments at risk (based on isolation from other brook trout populations or the presence of competitive exotic trout species). In addition, there were a number of brook trout subpopulations, within each basin, that had become compressed (Table 2). Usually, compression of a brook trout subpopulation resulted from the presence of an exotic species in the lower section of a stream segment, isolation due to the presence of exotic species in nearby stream reaches, or the presence of physical barriers. Both brook trout in stream fragments at risk and compressed subpopulations are vulnerable to extinction in the near term.

We also examined a number of landscape parameters that could potentially affect brook trout populations in the Northern Piedmont ecoregion. A piecewise linear regression model, comparing brook trout density with impervious surface within the site watershed, explained 76% of the variance (Table 3). In the

**Table 2. Summary of stream fragment analyses for brook trout streams in three basins of the Northern Piedmont ecoregion of Maryland (Savage drainage used as comparison).**

Basin	Mean Fragment Length (km) and Number	Fragments at Risk	Number of Compressed Populations
Susquehanna <sup>1</sup>	2.8 / 30	10	10
Gunpowder	2.8 / 43	25	7
Patapsco	2.0 / 13	8	5
Savage	2.7 / 67	0	0

<sup>1</sup> One small population of brook trout (Winch Run) was sampled on 931116 (vmd). and is now extinct.

**Table 3. Summary of piecewise linear regression model (least squares), with estimated breakpoint (N = 103). BT = brook trout/m<sup>2</sup> and WIS = watershed impervious surface.**

Estimated $b_{01}$	WIS <sub>1</sub>	Estimated $b_{02}$	WIS <sub>2</sub>	Breakpoint
0.0808	-0.0189	0.532	-0.998	0.27
BT <sub>1</sub> = 0.0808—0.0189(WIS)		BT <sub>2</sub> = 0.532—0.998(WIS)		R = 0.87

Maryland State of the Streams Report, Roth et al. (1999) stated that the majority of Maryland brook trout populations were found in watersheds with less than 0.5% impervious surface, and that no brook trout were collected from those watersheds with greater than 2% impervious surface. Results from the current analyses agree very well with the previous conclusions in Roth et al. (1999), although our estimated statistical breakpoint was 0.27% watershed impervious surface, approximately one-half of the previous estimate of 0.5% (Table 3).

In this study using both 1995-1997 and 2000-2002 MBSS data, there were eight brook trout populations found at an impervious surface intensity greater than 0.5%, with three brook trout populations present in watersheds with over 2.0% impervious surface (highest = 3.2%). However, brook trout density in these eight populations averaged only 0.038/m<sup>2</sup> (SE = 0.013), or 24% of the mean density for all 103 brook trout only populations combined, indicating that brook trout populations may exist at higher impervious surface levels, although raising questions of long-term population survival at these very low densities.

In addition, we compared the density of the 103 brook trout only populations with an additional 33 brook trout populations that had exotic trout present, predominantly *Salmo trutta* (brown trout) and infrequently *Oncorhynchus mykiss* (rainbow trout). There was a significant difference ( $p = 0.0020$ ,  $t = 3.2$ ,  $df = 134$ ) between the two groups, with brook trout only populations equal to a density of 0.16/m<sup>2</sup> (SE = 0.019) and brook trout and exotic species present equal to 0.050/m<sup>2</sup> (SE = 0.011)—a reduction of ~70%. The mechanism for this density difference is not known, although it may be a combination of interspecific competition and landuse change (Fausch 1988).

Although watershed impervious surface appears to be a critical factor for brook trout sustainability in urbanizing regions, we found other landscape parameters associated with stream benthic community structure to be very important (Table 4). Using regression analyses, cutpoint estimates were made for four key benthic parameters using MBSS BIBI cutpoints (all highly significant regressions -  $p < 0.0000$  ranged from 0.18 to 0.38  $r^2$ ). While there were a number of significant correlations among all landscape variables, urban, urban riparian, road density and roads near streams were selected for further analyses.

**Table 4. Analyses of landscape and community biological parameters for the Northern Piedmont ecoregion, with estimates made using regression analyses. Urban = proportion of watershed with urban land cover; urban riparian = proportion of watershed with urban land cover adjacent to stream edge; road density = average number of km of roads per km<sup>2</sup> of watershed; and roads near streams = proportion of total stream length having roads within 30 m. MBSS cutpoint used was the upper breakpoint between a score of 1 and 3; BIBI is the Maryland benthic index of biotic integrity (non-coastal plain).**

Biological Metric/ (MBSS Cutpoint)	Landscape Parameter			
	Urban	Urban Riparian	Road Density	Roads near Streams
Total Taxa (15)	29%	15%	6.6	9%
EPT Taxa (4)	36%	22%	7.6	13%
Intolerant Species (2)	40%	24%	8.2	13%
BIBI (2.9)	10%	4%	3.8	5%

For the first three individual metrics, all were higher estimates than observed for the BIBI alone (Table 4). However, using a BIBI value of 2.9, where the cutpoint from poor to good equals 3.0, the four landscape parameters define maximum urbanization levels for brook trout sustainability within a watershed. To protect, or to perhaps restore, a brook trout stream, the watershed must have an urban land cover less than 10%, an urban riparian cover less than 4%, and a total stream length of roads within 30 m of less than 5%. In addition, the watershed road density must be below 3.8 km/km<sup>2</sup>. Sixteen (12%) of the MBSS brook trout sites had BIBI values less than 2.9; however, trout density averaged 0.025 trout/m<sup>2</sup> at these sites—a possible response to poor stream food quality.

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## Discussion

Three important processes fragmentation, compression, and extinction of brook trout populations are occurring as a result of increasing urbanization in the Northern Piedmont ecoregion of Maryland. Fragmentation and compression reduce effective brook trout population size, and accelerate extinction, or at the very least, an increased extinction probability (Gilpin and Soule 1986). In addition, structural changes in stream trophic levels due to urban effects may expedite these three processes. Urbanization also affects Maryland brook trout populations through the loss of both evolutionary equity and evolutionary services through population reduction and loss of unique genetic variability (Morgan and Danzmann 1998, Hall et al. 2002).

Urbanization is an acute problem in Maryland, especially with increasing development along the Baltimore - Washington corridor in the Northern Piedmont ecoregion. From 1970 to 2000, the human population in Maryland increased from 3.9 to 5.3 million, with a projected population increase from 5.3 million (2000) to 6.3 million in 2025, further saturating an expanding urban environment with an additional million people in approximately 25 years. In recent years, the landscape in mid-Atlantic ecoregions, especially the Southeastern Plains (Coastal Plain of Maryland) and Northern Piedmont have experienced significant changes, resulting in increased forest fragmentation and forest cover loss that affect stream processes (Griffith et al. 2003).

Effective management of native brook trout populations in the Northern Piedmont ecoregion is problematical due to increasing urbanization of the landscape. To facilitate brook trout management in urban environments, a few specific management recommendations may be made based on the results from the Northern Piedmont ecoregion of Maryland (Table 5). Although these apocalyptic recommendations are not to be all-inclusive management options, they serve as a starting point to protect brook trout populations in rapidly growing urban areas that have brook trout present.

**Table 5. Urban specific brook trout management recommendations for the Northern Piedmont ecoregion of Maryland.**

<b>Impervious surface</b>	Limit impervious surface within a coldwater watershed to less than 0.5%, and minimize road density.
<b>Roads</b>	Eliminate all parallel streamside roads within 200 meters of a stream, minimize stream crossings (perpendicular bridge crossings only and no culverts), and eliminate all road and urban storm water runoff.
<b>Exotics</b>	No stocking of any exotic trout species within a brook trout dominated watershed.
<b>Riparian Buffer</b>	Maintain, or restore, minimum streamside buffer of 200 meters (or greater)—no timber harvest in riparian buffer. Increase connectivity of urban riparian buffers, and reduce sediment input.
<b>Groundwater</b>	Limit, or eliminate, groundwater removal in urban watersheds with brook trout to maintain springs and seeps.

However, there remains one looming specter threatening brook trout populations throughout Maryland, and all brook trout in the southern Appalachians, even if major efforts were made to protect urban coldwater streams. Climate change may well lead to increased fragmentation of brook trout populations (Flebbe 1997, Meisner 1990), resulting in an increasing extinction probability. For Maryland, the climate warming model, developed by Meisner (1990), predicts that brook trout will be confined to only the western two counties, and all eastern Maryland brook trout will be extinct. If that prediction does occur over the next 100 years, it will represent a loss of genetically unique brook trout populations, and may result in alternative coldwater management techniques in eastern Maryland, using non-native coldwater and coolwater species.

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## Literature Cited

- Brabec, E, S Schulte, and PL Richards. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. *Journal of Planning Literature* 16: 499-514.
- Center for Watershed Protection. 2003. Impacts of impervious surfaces on aquatic systems. Research Monograph Number 1, Center for Watershed Protection, Ellicott City, MD.
- Fausch, KD. 1988. Tests of competition between native and introduced salmonids in streams: what have we learned? *Canadian Journal of Fisheries and Aquatic Sciences* 45:2238-2246.
- Flebbe, PA. 1997. Global climate change and fragmentation of native brook trout distribution in the southern Appalachian Mountains. Pp. 117-121, *In*: RE Gresswell,

- P Dwyer and RH Hamre (eds.), Proceedings of Wild Trout VI - Putting the Native Back in Wild Trout, Bozeman, MT.
- Forman, RTT and LE Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207-231.
- Forman, RTT, D Sperling, JA Bissonette, AP Clevenger, CD Cutshall, VH Dale, L Fahrig, R France, CR Goldman, K Heanue, JA Jones, FJ Swanson, T Turrentine, and TC Winter. 2003. Road Ecology: Science and Solutions, Island Press, Washington, DC.
- Fraker, ME, JW Snodgrass and F Morgan. 2002. Differences in the growth and maturation of blacknose dace across an urban-rural environment. Copeia 2002:1122-1127.
- Gergel, SE, MG Turner, JR Miller, JM Melack and EH Stanley. 2002. Landscape indicators of human impacts to riverine systems. Aquatic Sciences 64:118-128.
- Gilpin, ME and ME Soule. 1986. Minimum viable populations: Processes of species extinction. Pp. 19-34, *In*: ME Soule (ed.), Conservation Biology: The science of scarcity and diversity. Sinauer Associates, Inc., Sunderland, MA.
- Griffith, JA, SV Stehman and TR Loveland. 2003. Landscape trends in Mid-Atlantic and Southeastern United States ecoregions. Environmental Management 32:572-588.
- Groffman, PM, DJ Bain, LE Band, KT Belt, GS Brush, JM Grove, RV Pouyat, IC Yesilonis and WC Zipperer. 2003. Down by the riverside: urban riparian ecology. Frontiers in Ecology and the Environment 2003:315-321.
- Hall, M, RP Morgan II and RG Danzmann. 2002. Mitochondrial DNA analyses of mid-Atlantic USA populations of brook trout (*Salvelinus fontinalis*): the zone of contact for major historical lineages. Transactions of the American Fisheries Society 131:1140-1151.
- Holt, JD. 2003. Predicting stream biological integrity using landscape characteristics. MS Thesis, Frostburg State University, Frostburg, MD.
- Kemp, SJ and JR Spotila. 1997. Effects of urbanization on brown trout *Salmo trutta*, other fishes and macroinvertebrates in Valley Creek, Valley Forge, Pennsylvania. American Midland Naturalist 138:55-68.
- Klein, RD. 1979. Urbanization and stream quality impairment. Water Resources Bulletin 15:948-963.
- Meisner, JD. 1990. Effect of climate warming on the southern margins of the native range of brook trout, *Salvelinus fontinalis*. Canadian Journal of Fisheries and Aquatic Sciences 47:1065-1070.
- Morgan II, RP and R Danzmann. 2001. The evolutionary significance of Maryland brook trout populations. Pp. 225-232. *In*: GD Therres (ed.), Conservation of Biological Diversity: A key to the restoration of the Chesapeake Bay diversity and beyond. Maryland Department of Natural Resources, Annapolis, MD.
- Morgan II, RP 1988. Final report - 1988. Development of a coldwater data base for Allegany and Garrett counties - Phase II. To: Tidewater Administration, Maryland Department of Natural Resources, Annapolis, MD.
- Morgan II, RP 1989. Final report - 1989. Development of a coldwater data base for Allegany and Garrett counties - Phase II. To: Tidewater Administration, Maryland Department of Natural Resources, Annapolis, MD.
- Morgan II, RP 1990. Final report - 1990. Development of a coldwater data base for Allegany and Garrett counties - Phase II. To: Tidewater Administration, Maryland Department of Natural Resources, Annapolis, MD.
- Paul, MJ and JL Meyer. 2001. Streams in the urban landscape. Annual Review of Ecology and Systematics 32:333-365.
- Roth NE, MT Southerland, G Mercurio, JC Chaillou, PF Kazyak, SS Stranko, AP Prochaska, DG Heimbuch and JC Seibel. 1999. State of the Streams: 1995-1997 Maryland Biological Stream Survey results. Maryland Department of Natural Resources, Monitoring and Non-Tidal Assessment Division. Annapolis, MD.

- Schueler, TR and J Galli. 1992. Environmental impacts of stormwater ponds. P Kumble and T Schueler (editors). Watershed Restoration Source Book, Metropolitan Council of Government, Washington, DC.
- Steedman, RJ 1988. Modification and assessment of an index of biotic integrity to quantify stream quality in southern Ontario. *Canadian Journal of Fisheries and Aquatic Science* 45:492-501.
- United States Environmental Protection Agency (USEPA). 2000. The quality of our nation's waters. Report to Congress, USEPA, Washington, DC. EPA 841-S-00-001.
- Wang, L and P Kanehl. 2003. Influences of watershed urbanization and instream habitat on macroinvertebrates in cold water streams. *Journal of the American Water Resources Association* 39:1181-1196.
- Wang, L, J Lyons, P Kanehl, and R Gatti. 1997. Influences of watershed use on habitat quality and biotic integrity in Wisconsin streams. *Fisheries* 22:6-12.
- Wang, LZ, J Lyons and P Kanehl. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. *Environmental Management* 28:255-266.
- Weaver LA and GC Garman. 1994. Urbanization of a watershed and historical changes in a stream fish assemblage. *Transactions of the American Fisheries Society* 123:162-172.
- Yoder, CO, RJ Miltner and D White. 1999. Assessing the status of aquatic life designated uses in urban and suburban watersheds. Pp. 16-28, In: A Everson et al. (eds). *National Conference on Retrofit Opportunities for Water Resource Protection in Urban Environments*. USEPA, Office of Research and Development, Washington, DC. EPA/625/R-99/002.

## Lessons Learned from Trout Unlimited's Watershed Programs

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**ABSTRACT**— Since 1994 Trout Unlimited (TU) has launched more than a dozen large-scale watershed restoration projects through its Watershed Programs. Projects fall under several programs including the Home Rivers Initiative, which focuses on private lands, and Bring Back the Natives and Strategies for Native Trout, both public lands programs. All projects are collaborative multi-year efforts that combine scientific and economic research; community outreach; on-the-ground restoration; and the development of long-term conservation and management strategies and tools. TU has a strong record of accomplishment tackling a range of restoration challenges in diverse regions of the country and has some unique perspectives to share. Interviews with project managers reveal the importance of number of factors, including the pivotal role of partnerships, the pros and cons of the range of management arrangements, the challenges of working with landowners, the importance of outreach efforts, and frustrations related to funding, to name but a few. As a national-level nongovernmental institution convening locally based projects, TU fills a unique niche. They bring credibility to local conservation efforts, flexibility to act where others are not able, and often serve as a bridge among organizations and between landowners and government agencies.

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### Introduction

In 1994 Trout Unlimited (TU) began its experiment with large-scale watershed restoration projects when it launched the first Home Rivers Initiative on the Beaverkill-Willowemoc River system in New York. Since the early 1990s, many organizations have been testing the “new” approach to watershed restoration. Top-down government management and a narrow focus on the river corridor had previously characterized restoration and protection efforts. The new approach uses the entire watershed as the unit of analysis and management, relies on sound science to guide decisions, and most notably utilizes collaborative consensus-driven arrangements among multiple levels of agencies, the local community, and other partners to coordinate resources, information, and activities. Local organizations or government agencies commonly catalyze these initiatives (Born and Genskow, 2001). Some national level organizations have resisted becoming involved in collaborative watershed efforts for fear of being co-opted or not being in control while sitting across the table from traditional “enemies” (Huntington and Sommarstrom 2000). Therefore, TU is somewhat distinctive in its experience.

In the intervening years, the national office of TU has implemented more than a dozen watershed restoration projects across the country under the auspices of several programs that address an impressive array of restoration challenges (Figure 1, Table 1). The Home Rivers Initiative focuses primarily on private lands and is our flagship watershed restoration program. Bring Back the Natives (BBN) is a grant program established to fund restoration of native aquatic species and their habitats on public lands. Founded in 1991, it is a partnership between

TU and the National Fish and Wildlife Foundation, Bureau of Land Management, US Forest Service, Bureau of Reclamation, and U.S. Fish and Wildlife Service. In 2001 the BBN program was reoriented to focus on watershed-scale conservation efforts based on the results of an assessment conducted by TU (Harig and McGurrin). *Strategies for Native Trout (Strategies)*, a partnership program similar to BBN, was initiated in 2001 to address some of the most pressing information needs in large-scale restoration of inland native trout, and focuses on monitoring and evaluation of several native trout projects. In addition, TU has initiated a number of other large-scale restoration initiatives that follow the watershed programs model but focus on a broader region or multiple rivers.

All the programs adhere to the principles of the new watershed approach. In using this approach, TU selects watersheds where we can both make a significant difference in the condition of the particular river or fishery, and demonstrate innovative and transferable restoration strategies and techniques. This has led to some impressive successes on issues such as acid mine drainage, western water flows, and native species restoration efforts. In just a few short years, TU's Watershed Programs have grown to become one of the organization's largest and most visible programs.

After a decade of work in numerous locations around the country, it is fitting that TU assemble the lessons learned for both its own internal benefit, and so other organizations and agencies involved with watershed restoration may gain from our experiences. There have been a number of other efforts to collect case studies and evaluate collaborative approaches to watershed restoration (Born and Genskow 2001; Huntington and Sommarstrom 2000; USDA Forest Service 2003; Williams et al. 1997). TU's own findings corroborate many of the broader lessons learned in these other studies, but also offer unique insights.

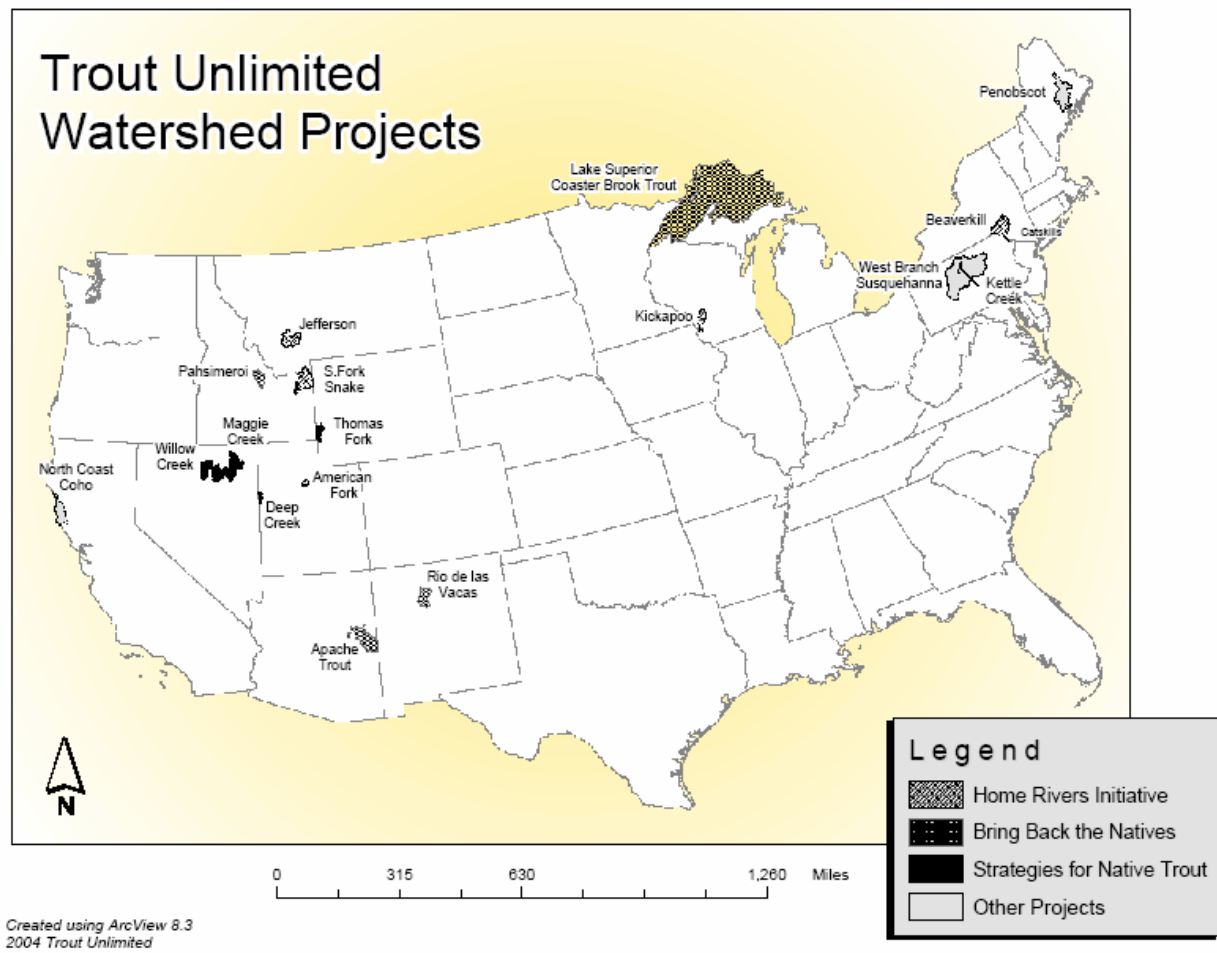


Figure 1. Locations of Trout Unlimited's Watershed Projects.

**Table 1. Summary of TU Watershed Projects**

<b>Project Site</b>	<b>Program</b>	<b>Year Initiated</b>	<b>Target Trout Species</b>	<b>Primary Conservation Focus</b>
Beaverkill River, NY	HRI	1994-2001	Brown, Rainbow	Assessment, Stormwater Flows
Kickapoo River, WI	HRI	1996-1999	Brook*, Brown	Channel Restoration, Land Use, Native Species Reintroduction
Kettle Creek, PA	HRI	1998	Brook*, Brown	Acid Mine Drainage Remediation, Channel Restoration
Jefferson River, MT	HRI	2001	Brown	Drought Planning, Irrigation Efficiency, Spawning Channel Improvement
S. Fork Snake River, ID	HRI	2001	Yellowstone Cutthroats*	Stream and Dam Flows, Tributary Reconnections, Hybridization
American Fork River, UT	HRI	2004	Bonneville Cutthroats*	Abandoned Hard Rock Mine Remediation
Pahsimeroi River, ID	BBN	2003	Bull*	Tributary Reconnection, Irrigation Efficiency
Lake Superior, MN/WI/MI	BBN	2003**	Coaster (migratory) Brook*	Harvest Regulations, Habitat Improvement, Remnant Stock Protection
Rio de las Vacas, NM	BBN	2003	Rio Grande Cutthroat*	Exotic Management, Road Retirement
Black, White, and Little Colorado Rivers, AZ	BBN	2003	Apache*	Exotic Management, Riparian Habitat Improvement
Thomas Fork, ID/WY	Strategies	2001	Fluvial Bonneville Cutthroats*	Barrier Removal, Habitat Restoration, Monitoring
Maggie Creek, NV	Strategies	2001	Lahontan*	Barrier Removal, Monitoring
Willow Creek, NV	Strategies	2004	Lahontan*	Grazing Management, Habitat Restoration, Monitoring
Deep Creek, UT/NV	Strategies	2001-2003	Bonneville Cutthroat*	Exotic Management, Native Species Reintroduction, Monitoring
North Coast, CA	Other	1998	Coho Salmon*	Sediment Reduction, Stream Restoration
Catskills Initiatives, NY	Other	2001	Brown, Rainbow	River Flows, Stream Restoration
Penobscot River, ME	Other	2003	Atlantic Salmon*	Dam Removal
W. Branch Susquehanna River, PA	Other	2004	Brook*	Acid Mine Drainage Remediation

\*Native species

\*\*TU has been working in Lake Superior on Coaster issues since 1992. We received BBN funding in 2003.

## Methods

Semi-structured phone interviews were conducted with all of TU's current and most past watershed program staff. Fifteen interviews were conducted during July 2004. Each person was asked a standard set of questions on a range of topics including; project scope and scale, role of science and assessments, management and coordination, partner relationships, landowner relations, public outreach, funding, and project selection and design criteria. Results from the interviews were synthesized with complementary information from TU reports and relevant watershed management literature.

## Results and Discussion

In 1998, this author co-wrote a paper synthesizing lessons learned based on her experience managing the Kickapoo project, TU's second Home Rivers Initiative project (Hewitt and Born 1998). In recent years, there have been a number of broader analyses and collections of case studies aimed at synthesizing and characterizing the common experiences from collaborative watershed restoration projects (Born and Genskow 2001; CSPWS 1998; Huntington and Sommarstrom 2000; USDA Forest Service 2003; Williams et al. 1997). There were many similarities in the findings among these studies, which have been further corroborated by the recent interviews with TU's Watershed Programs staff.

There were several major areas of agreement between TU's experience catalyzing watershed projects, and other watershed initiatives that have been similarly evaluated. High quality assessments and strong scientific underpinnings for restoration techniques are invaluable in guiding and executing conservation plans. They help ensure that scarce resources are used most effectively (Hewitt and Born 1998).

Given a site with good conservation potential, all TU's project managers agreed without exception, that good partnerships and effective coordination are the most important aspect for successful watershed restoration projects. This is echoed strongly in a number of the other studies (Born and Sonzogni 1995; Born and Genskow 2001; Hewitt and Born 1998; Sommarstrom 2000; USDA Forest Service 2003). The role of the project manager is central to cultivating partners, coordinating activities, leading outreach efforts, and resolving inevitable conflicts. Successful coordinators have excellent people skills, an ability to understand the relevant technical issues, good organizational skills, and are able to maintain both a sense of the "big picture" and all of the moving parts (Sommarstrom 2000).

Finally, stable and adequate funding is necessary to maintain the viability of watershed restoration efforts. It is reasonably easy to find funding for the on-the-ground restoration work for good projects. However, securing sufficient resources to support the work that is necessary to plan and implement good projects - such as staff and organizational support, engineering and scoping plans, or research and monitoring - is often much more challenging (Huntington and Sommarstrom 2000).

As a national level nongovernmental organization convening locally based watershed projects, TU holds a unique position. TU has the existing network to garner resources that might not be available to local organizations, and the benefit of experience coordinating numerous other watershed projects. TU's stature as a national organization can also increase the level of awareness and

credibility among the local community relative to ongoing conservation and restoration activities (Genskow 1999). However, TU does not initiate these projects with the intention of remaining in the watershed indefinitely. A central element of TU's watershed model is to help develop the management tools and organizations to carry on the work into the future, without the ongoing presence of TU. TU aims to remain in a watershed for three to five years, but will occasionally stay longer if funding and work permit. This presents the additional challenge of developing and executing a sensitive exit strategy from projects. We are unable to adequately evaluate this particular aspect, as TU is still active in most of its project sites.

What is abundantly clear both from TU's and others work is that even though science plays an extremely important role, working successfully with partners, landowners, and the local community is critical to the success of these efforts. In addition to these major themes, the interviews with TU's watershed project managers yielded a rich level of detail worth sharing with a broader audience.

### **Role of Science and Assessments**

As evident in Table 1, TU's watershed work spans a wide array of restoration issues. TU projects have served as laboratories for innovative science and restoration work, such as using aerial remote sensing to detect acid mine drainage, using temporary ditch liners to improve irrigation efficiency, and monitoring native species restoration projects. It is obviously important to have the scientific assessments and analysis to determine what the underlying stressors are to a system, and how to address them. Where assessments have not been done, their absence has been felt and TU frequently moves to fill the void. The assessments and reports serve others purposes as well. They are useful when approaching partners, landowners, and potential funders to help develop buy-in and secure resources and commitment. In cases where TU initiated assessments, those reports established TU as a local expert, generally increasing our credibility.

### **Partners**

TU recognizes the tremendous importance of developing and maintaining good partner relationships and, in particular, the vital role of natural resource agencies (Born and Genskow 2001). However, this was a lesson hard learned through our first Home Rivers project on the Beaverkill. In that case, TU failed to consult sufficiently the natural resource agencies or other potential partners before project initiation, and announced the project through an aggressive media campaign that proclaimed the impending demise of the river and the failure of agency managers to act on its behalf. TU repeatedly overstated its own role and underplayed that of other organizations. Unsurprisingly, TU alienated some very important partners which significantly impeded progress for many years (Conyningham and McGurrin 1997). TU quickly learned to mend its ways and currently we enjoy excellent relationships on most projects. Partners are often grateful for the roles that TU plays in these efforts including seeking out additional funds, public outreach, acting as a bridge among various groups and interests, and serving as a catalyst in recognizing problems and implementing solutions.

Productive partnerships share common characteristics as do unproductive ones (Table 2). In the best circumstances, good partnerships also have the ability to broaden the scope of a project. Unproductive partnerships can slow progress or

even defuse projects. In the worst cases, a single defiant person in the right position can doom an entire project. TU persisted in the Beaverkill and eventually developed some excellent working relationships with partners, but in other cases we simply pulled out of potential projects when the intransigence of prospective partners grew to be overwhelming. We have experience on a few projects where changes in key staff positions have helped previously stalled projects move forward. Other evaluations have found that successful watershed projects tend to occur where there is already high local civic capacity, where individuals and organizations have constructive networks and communication (USDA Forest Service 2003). For instance, both the Kickapoo and Jefferson River projects benefit greatly from a positive history of cooperation among agencies or the existence of a functional watershed council.

**Table 2. Characteristics of Productive and Unproductive Watershed Project Partnerships**

Productive Partnerships	Unproductive Partnerships
Common values and vision of problems and solutions	Territoriality of management turf or scientific data
Mutual benefits shared in outcomes	Personality clashes
Positive interpersonal relationships	Enforced cooperation through regulatory action
Investments of time, expertise, and resources	Lack of champions of sufficient status within an organization to commit resources
Proactive attitudes	Interested solely in partner funding, not in working collaboratively
Effectiveness within own organizations	
Willingness to share credit	

### Management and Coordination

Coordination is the key element to making integrated watershed conservation projects operational and successful. Facilitating the exchange of information and resources and addressing the inescapable conflicts provide the fuel for moving a project forward. It should never be treated as an afterthought (Born and Sonzogni 1995; Sommarstrom 2000). In this light, the role of a coordinator is clearly essential. The downside is that effective coordination can be extremely time consuming. The challenge for TU is to not become overburdened by process, but to provide sufficient opportunities and structure for interaction and communication to maintain the relationships, trust, and momentum.

TU's watershed model allows for flexibility in management and coordination arrangements. Project management arrangements range from the formal, to ad hoc. The more formal arrangements have an established body, such as a watershed council or an advisory committee that meets on a regular basis. Regular interaction and communication among the partners helps build strong relationships and increases visibility, credibility, and trust. Less formal arrangements have a regular partner group that may meet annually or semiannually. Ad hoc arrangements have various combinations of partners that meet as needed on a project-by-project basis. Ad hoc and less formal arrangements work well when there are a small number of partners and relatively discrete work objectives.

### Landowners

In watersheds dominated by private lands, working cooperatively with landowners is another critical factor to project success. TU projects, like other

watershed initiatives, have experienced a number of instances where lower priority conservation sites are restored because project initiators were unable to get landowner cooperation on more strategic sites (Sommarstrom 2000). Working in a watershed large enough to provide numerous private landowner opportunities is helpful to avoid being held “captive” by uncooperative parties in particular site or subwatershed.

In one sense, landowners are just another partner group, but they bring unique concerns to the table. In many rural areas local landowners are suspicious of both outsiders and government agencies. Hiring a project manager with local ties can ease relations with the local community. In our experience, some landowners prefer working with TU rather than government agencies, thus we serve as an important liaison. Knowledge or awareness of the successes and failures of past projects can have a huge influence on how well disposed landowners are to cooperating. Landowners (and partners and funders) like to be involved with successful projects.

A number of our project managers experience certain regulatory issues that affect landowners. In projects where the goal is to restore populations of an endangered species, landowners may be reluctant to cooperate for fear of limitations associated with the Endangered Species Act. Across the West, water rights are paramount. In addition, in the case of attempting to clean up abandoned hard rock mining waste, the ability to become exempt from federal liability under CERCLA for abandoned mine clean up is of overriding concern to landowners.

Finally, on working landscapes, asking for landowner cooperation could mean asking them to take a risk with their livelihoods. Project managers have learned to take enough time to build a trusting relationship with these landowners, keep them well informed, and always follow through on commitments. Especially when dealing with financial or legal access issues it is also a good idea to get things in writing. Providing creative incentives that could also help them improve their own operations, such as irrigation improvements, has proven to be a compelling enticement to cooperate.

### **Outreach**

Outreach is the vehicle for keeping partners, landowners, and the local community informed about project activities. The standard tools that describe the project and its outputs, such as brochures, newsletters, reports, press releases, web sites, presentations, and interpretive signs are all used to varying degrees by the individual projects. Many project managers interviewed for this study rightly emphasized the worth of “face time” in local community establishments and kitchens to help build relationships and awareness. All the managers recognized its importance, but most expressed a desire or need to do more. As one manager aptly noted, “You need to get information out to the local community regularly, or they assume you are up to no good.” Ideally, education and engagement can help overcome disinterest and even distrust of restoration activities, although some project managers have been surprised by the limited role that education and awareness alone can play in changing attitudes and behaviors (Wood et al. 1997).

### **Funding**

Funding, a critical element to project viability, is not unlike landowner or partner cooperation. Proven success often leads to additional funding flowing more easily to project. However, many project managers identified locating sufficient matching grant funds as a significant issue for their projects. Most of

the projects have grants from federal sources, which require equal or greater levels of nonfederal match. This can be difficult to find, particularly in the West where there is an abundance of federal money, but nonfederal match is extremely scarce. In some cases, we have had to leave money on the table for lack of matching funds. In other cases, we have identified lack of government funding as a major impediment to project progress. In the case of abandoned mine remediation in the West, there are virtually no federal government programs to help fund clean ups on private lands, and it is even limited for clean ups on public lands.

### **Project Selection and Initiation**

Since the first project on the Beaverkill, TU's approach to selecting and initiating projects has evolved. The primary criteria that we use are conservation benefit, the presence of willing and capable partners, and the availability of adequate funding. When we have allowed outside political pressures to occasionally nudge us into a project, we have struggled because of the lack of at least one key element. Once projects have been selected, we approach the community and partners more conscientiously, collecting existing information, consulting them about our plans, being careful to share credit and not assign blame. TU learned early that entering an area with a "white knight" attitude towards saving the river and fishery wins few allies. Some project managers expressed a desire to have more project funding lined up at the outset of the project to avoid so much front end time being devoted to fundraising.

### **Project Scope and Scale**

Most project managers found the size and scope of their projects manageable, though acknowledged the heavy time demands required to travel through a large area or coordinate among many partners. Home Rivers sites range from ~200 to 800 square miles. Several managers pointed out that TU does not take a truly comprehensive approach to watershed restoration. TU's strategic focus is on restoring processes that will improve water quality, healthy channel-forming processes, and robust fisheries. TU is less concerned with terrestrial species, except where they influence the river. While this strategic scope allows TU and its partners to focus more effectively on key issues, the fact remains that the projects generally address some comprehensive issues. On the other end of the spectrum, as TU develops experience on certain key issues they are recognizing the need to move up to the next geographic scale in order to effectively address impacts.

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## **Conclusion**

Watershed restoration is central to TU's mission, so it is not surprising that we fill this distinctive niche among national conservation organizations. This paper has detailed an impressive range of lessons learned from the array of TU's watershed projects. Many of these are common to the experiences of most other watershed restoration initiatives, other are unique to TU. This kind of reflection on our experiences provides excellent grounding and intelligence about the range of issues one might face as TU and other groups embark on new watershed adventures. However, we must resist the effort to generalize these into a rigid formula for implementing future watershed restoration projects. As our experience illustrates tactics that may work beautifully in one setting may not transfer successfully to another location. The true strength of TU's Watershed

Programs model is its commitment to broad principles, but great flexibility in implementation.

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## References

- Born, S.M. and K.D. Genskow. 2001. *Toward Understanding New Watershed Initiatives: A Report from the Madison Watershed Workshop, July 20-21, 2000*. University of Wisconsin– Madison.
- Born, S.M. and W. Sonzogni. 1995. *Integrated Environmental Management: Strengthening the Conceptualization*. *Environmental Management*, Vol. 19, No. 2, pp. 167-181.
- Citizen Science Partnership for Watershed Sustainability. 1998. *Citizens, Science, Watershed Partnerships, and Sustainability: The Case in Minnesota*. The Surdna Foundation, Minnesota Department of Natural Resources, and the Science Museum of Minnesota.
- Conyngham, J. and J.M. McGurrin. 1997. *Restoration of Trout Waters in the East: Beaverkill-Willowemoc Watershed of New York*. In J.E. Williams, C.A. Wood, and M.P. Dombeck, editors. *Watershed restoration: principles and practices*. American Fisheries Society, Bethesda, MD.
- Genskow, K.D. 1999. *An Assessment of the Kickapoo Valley Watershed Conservation Project's Collaborative Management Approach*. Prepared for Trout Unlimited, Madison, WI.
- Harig, A.L. and J.M. McGurrin. 2001. *Bring Back the Natives: An Assessment of Program History and Restoration Activities 1992-2001*. Submitted to BBN Program Partners: National Fish and Wildlife Foundation, U.S. Bureau of Land Management, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Forest Service. Trout Unlimited, Arlington, VA.
- Hewitt, L.E. and S.M. Born. 1998. *The Role of Nonprofit Organizations in Coordinating integrated Watershed Conservation Efforts: Trout Unlimited in Wisconsin's Kickapoo Valley*. *Proceedings from Watershed Management: Moving from Theory to Implementation*. May 3-6, 1998 Denver, CO. Water Environment Federation, Alexandria, VA.
- Huntington, C.W., and S. Sommarstrom. 2000. *An Evaluation of Selected Watershed Councils in the Pacific Northwest and Northern California*. Parts I, II, III. Prepared for Trout Unlimited and Pacific Rivers Council, Eugene, OR.  
<http://www.pacrivers.org/publications/index.cfm?topicID=105>
- Sommarstrom, S. 2000. *Evaluating the Effectiveness of Watershed Councils in Four Western States*. *Proceedings of the Eighth Watershed Management Council Conference*, November 27-30, 2000.
- USDA Forest Service. 2003. *Community-Based Watershed Restoration Partnerships: Accomplishments for FY 2000-2002*. USDA Forest Service, FS-770, Washington, D.C.
- Williams, J.E., C.A. Wood, and M.P. Dombeck, editors. 1997. *Watershed restoration: principles and practices*. American Fisheries Society, Bethesda, MD.

## A Watershed Scale Approach for Conserving Fluvial Bonneville Cutthroat Trout in the Bear River, ID-WY

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**ABSTRACT**—Bonneville cutthroat trout (BCT) occupy <5% of their historic range and are largely relegated to isolated headwater tributaries. Bear River BCT, however, are unique in that they continue to persist in the mainstem river system in which they evolved, despite habitat degradation and introductions of non-native competitors. These fish exhibit a fluvial life history strategy, traveling large distances to satisfy specific habitat requirements during different life stages—a trait that renders them especially sensitive to habitat fragmentation and presents unique conservation challenges. In 2002 Trout Unlimited partnered with federal and state agencies and local landowners to combine research, public outreach, and on-the-ground habitat restoration to implement a watershed scale BCT conservation program in the upper Bear River drainage. In 2003 we used two way fish traps and electrofishing to document BCT migrations between tributary spawning habitats and mainstem overwintering habitats. We found that (i) large numbers of juvenile BCT migrated out of spawning tributaries during spring, (ii) few adults moved downstream during the summer, and (iii) BCT captured moving downstream did not represent a cross-section of resident populations upstream. We used this information to gain local support for rebuilding existing irrigation barriers to accommodate fish movements during peak migration periods.

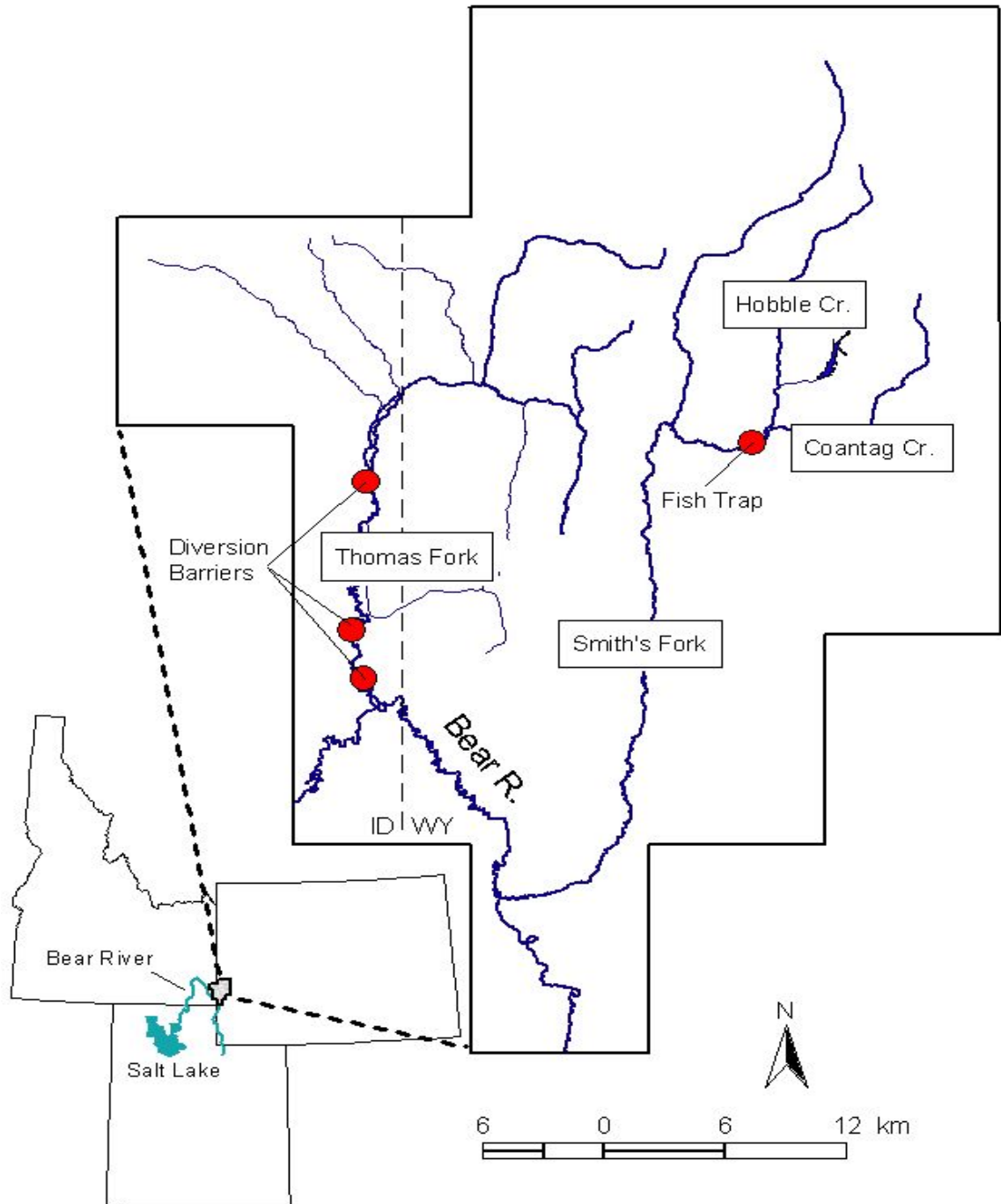
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### Introduction

Bonneville cutthroat trout (BCT) currently occupy <5% of their historic range and the subspecies is designated as ‘Sensitive’ by the USDA Forest Service and the state of Wyoming, and ‘a Species of Concern’ by the states of Utah and Idaho. The Thomas Fork, the neighboring Smith’s Fork, and sections of the Bear River between these two tributaries support one of the most genetically pure populations of BCT throughout its native range and comprise what is likely the last connected large river habitat available to the subspecies (**Figure 1**). Independent research projects were initiated in 1998 and 1999 by the University of Wyoming and Utah State University, respectively, with the goal of gaining a better understanding of the life history characteristics, habitat requirements, and movement patterns of BCT within the Thomas Fork and Bear River. These studies showed that BCT in this system exhibited a fluvial life history strategy, using habitats in lower elevation, mainstem rivers for growth and maintenance and migrating large distances (up to 90 km) to headwater habitats to spawn. This research also indicated that three full-spanning diversion structures on the Thomas Fork block access to upstream spawning habitats and entrain downstream migrants in irrigation canals (Colyer 2002, Schrank 2002).

These studies and others like them suggest that past efforts to protect native cutthroat trout subspecies through isolation (Stuber et al. 1988, Moyle and Sato 1991, Young 1995) may have come at the expense of localized life history adaptations and genetic diversity. In addition to habitat and space limitations that might render isolated tributary populations especially vulnerable to extinction

(Dunning et al. 1992, Hilderbrand and Kershner 2000, Harig and Fausch 2002, Novinger and Rahel 2003), these ‘conservation by isolation’ techniques also select against migratory life histories and can lead to genetic and behavioral changes within the isolated population (Northcote et al. 1970, Northcote 1992, Young 1996). As a result, reestablishing watershed connectivity is now the preferred conservation tool in many systems.



**Figure 1. Upper Bear River watershed project area showing Thomas Fork diversion barriers and Hobble Creek fish trapping site.**

The Thomas Fork—Smith's Fork—Bear River network constitutes what is likely the last mainstem river habitat available to fluvial BCT and provides a unique opportunity for this type of large-scale watershed reconnection project. In 2002 Trout Unlimited partnered with the US Forest Service, the US Fish and Wildlife Service, Idaho Department of Fish and Game, Faucet Irrigation Co., and several private landowners in the Thomas Fork Valley in southeastern Idaho to begin retrofitting the three full-spanning irrigation diversion structures in the Thomas Fork with fish screens and fish bypass channels. Fluvial BCT in this system face a two-fold challenge during their migrations between mainstem and spawning habitats. During dry years adults in the mainstems of the Thomas Fork and Bear River are prevented from accessing spawning habitats in the upper Thomas Fork and its tributaries by full spanning irrigation diversions along the lower Thomas Fork (Colyer 2002). During wet years irrigation activities begin late enough to allow upstream migration of fish past irrigation diversions, but nearly 50% of those fish subsequently die in unscreened irrigation ditches during their post-spawn return to mainstem habitats (Schrank 2002, Thomas Fork landowners, pers. comm.). Current research suggests that adult BCT moving downstream in the Smith's Fork suffer a similar fate in irrigation canals (J. Roberts, University of Wyoming, pers. comm.). To date, research has focused on adult BCT in the system, and we now have a better understanding of adult fluvial BCT movement patterns and life history requirements. However, we still know very little about the effective size of this population component or about juvenile migration patterns and distributions throughout the system. To that end, Trout Unlimited initiated research in 2003 in the Smith's Fork of the Bear River to gain a better understanding of (i) fluvial BCT population numbers, and (ii) juvenile distributions and outmigration timing in the Bear River and its tributaries. We will use this information to evaluate population recovery in the Thomas Fork following our restoration activities.

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## Methods

In addition to acting as project lead on habitat restoration and barrier removal efforts in the Thomas Fork, Trout Unlimited is also conducting all follow-up monitoring and evaluation activities associated with the fish passage project. As part of a BACI (before-after-control-impact) study design, we began in June 2003 to monitor downstream BCT movements in Hobble Creek in western Wyoming, a tributary that is known to provide spawning habitat for fluvial migrants from the lower Smith's Fork and the Bear River. We used picket weirs and two way trap boxes to capture fish greater than 100 mm moving upstream and downstream in Hobble Creek. We also conducted three pass depletion electrofishing surveys in 100 m reaches throughout the upper drainage.

### Trapping

We monitored upstream and downstream movements in Hobble Creek from June 30, 2003 through September 22, 2003 using a picket weir with upstream and downstream trap boxes. The weir was located approximately 400 m downstream from the confluence of Hobble and Coantag Creeks (4690144 N 517065 E, UTM NAD27, zone 12). All BCT were weighed and measured and those >130 mm total length were anesthetized with clove oil (30 mg/L; Prince and Powell 2000) and implanted with Passive Integrated Transponder (P.I.T.) tags (Biomark, Inc., Boise, ID). We implanted all BCT >200 mm with Visible

Implant (V.I.) tags (Northwest Marine Technology, Shaw Island, WA) in addition to the P.I.T. tags. All captured brown trout (BNT) were measured, and BCT and BNT captured prior to August 1 were given adipose clips. On August 1 we began to clip the right maxillary of all captured BCT in order to differentiate between fish that we had clipped and the adipose clipped fish that were released into the Smith's Fork in July by WYG&F. We counted and recorded the direction of movement for all other fish species that we captured. Following handling, all fish were released either upstream or downstream of the trap depending on their direction of travel.

### Population Surveys

We conducted electrofishing surveys upstream from the weir location site in both Hobble and Coantag Creeks. We established 100 m survey sites at 1 km intervals moving upstream from the trap, and used block nets with a standard three-pass depletion methodology. We conducted a third pass only if the second pass yielded >20% of the total number of trout captured in the first two passes. We calculated maximum likelihood abundance estimates for BCT captured during surveys using the Zippin estimator within the program CAPTURE (White et al. 1982). All BCT were weighed and measured and tagged according to the same size criteria used for weir captures. All BNT were measured and numbers of mountain whitefish (MWF) and sculpins (S) were recorded.

### Angling

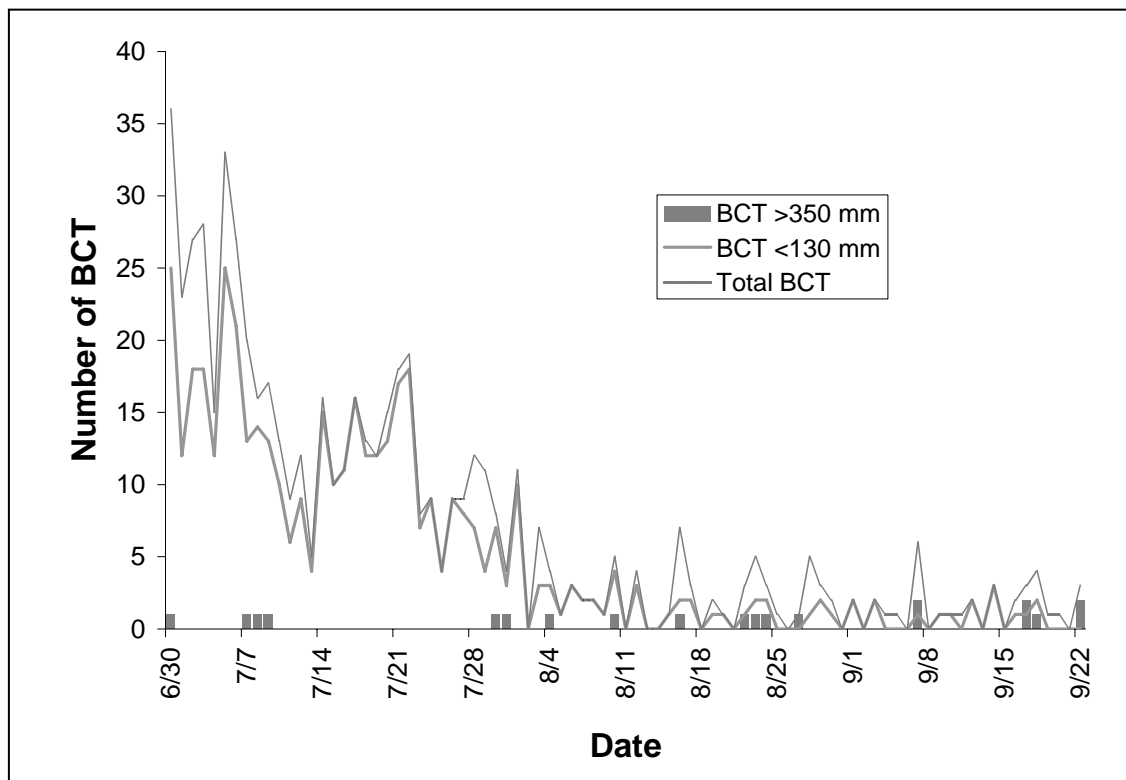
We periodically angled for BCT and tagged captured fish with P.I.T. and V.I. tags to document trends in fluvial BCT densities in habitats upstream of our traps and to see whether these fish later moved through our traps. All angled fish were captured with artificial flies tied on single barbless hooks and kept in in-stream live wells for no longer than 15 minutes before processing. All angled BCT were anesthetized, weighed, measured, and tagged according to the protocol previously outlined. All angled BNT were measured and recorded.

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## Results

### Trapping

Between June 30 and September 22 we captured a total of 623 BCT, 133 BNT, 166 sculpins (S), 231 mountain whitefish (MWF), and 3 suckers (not identified to species). Ninety-six percent of captured BCT were moving downstream (595 of 623). Mean total length for captured BCT was 130 mm and ranged from 89 to 480 mm. Length frequency comparisons between BCT captured in weir traps and those captured during electrofishing surveys in Hobble and Coantag Creeks indicated that BCT moving through the weir were not representative of the size classes present in upstream populations. BCT between 90 and 120 mm TL accounted for roughly 67% of all of the BCT captured in our traps, while that size class made up only 18% and 35% of BCT surveyed in Hobble and Coantag Creeks, respectively. BCT capture rates were high at the outset of trapping and declined throughout July and August, suggesting that we installed our weir at or just after the peak of outmigration (Figure 2).



**Figure 2. Chart of outmigration numbers and timing for two size classes of BCT. Numbers of juvenile BCT moving downstream through the weir traps were greatest during July and decreased throughout the summer. In contrast, the few large adult BCT that were captured in our traps moved throughout the study period in no obvious pattern.**

### Population Surveys

We surveyed 13 sites in Hobble Creek between July 23 - 27 and captured a total of 96 BCT, 38 BNT, and 681 S. We tagged 47 BCT with P.I.T. tags and 25 with V.I. tags. We had 6 mortalities, all of which appeared to be due to electrofishing injuries. Abundance estimates ranged from 4 to 19 BCT per 100 m reach and mean total length ranged from 105 to 308 mm across sample sites, indicating a non-uniform distribution of size classes among sites. We surveyed 8 sites in Coantag Creek between August 18 - 21 and captured 97 BCT, 5 BNT, 1 MWF, and 613 S. We tagged 33 BCT with P.I.T. tags and 16 with V.I. tags. We had 5 mortalities that were probably due to injuries incurred during electrofishing. Abundance estimates in Coantag Creek ranged from 5 to 26 BCT per 100 m reach. Mean total length ranged from 91 to 204 mm, again indicating a non-uniform distribution of age classes among our sample sites (Table 1).

### Angling

We captured 15 BCT by angling on four different occasions. All angled fish were tagged with P.I.T tags and 11 of the 15 received V.I. tags. Total lengths ranged from 168 to 470 mm. Two of these fish were subsequently recaptured by angling several weeks after they were tagged at or near their initial locations. However, none of the BCT tagged during angling had moved downstream through our weir by the time it was removed at the end of September.

**Table 1: Bonneville cutthroat trout (BCT) abundance and size data from three-pass depletion electrofishing on 100 m reaches in Hobble and Coantag Creeks in July and August 2003.  $N$  = population estimate,  $p$  = capture probability, SE = standard error, and CI = confidence interval.**

Reach	No. of BCT			BCT Abundance				Total Length (mm)		Weight (g)	
	1	2	3	$p$	$N$	SE	95% CI	Mean	SE	Mean	SE
Hobble Creek--July 23-27, 2003											
1 <sup>1</sup>	5							307.6	54.0		
2 <sup>1</sup>	4							215.0	53.8	170.7	88.6
3 <sup>1</sup>	6							286.2	42.7	439.1 <sup>3</sup>	159.5
4	16	3		0.86	19	0.8	19-19	125.6	13.6	38.3 <sup>4</sup>	14.5
5	6	1		0.87	7	0.4	7-7	145.7	17.9	42.5	13.1
6	3	0			3 <sup>2</sup>			104.7	12.8	11.9	4.4
7	2	2	1	0.56	5	1.2	5-5	124.2	22.9	33.6	19.4
8	7	1		0.89	8	0.4	8-8	126.6	27.5	47.5	34.4
9	3	1	0	0.80	4	0.2	4-4	106.5	17.7	16.8	9.0
10	8	4	2	0.61	14	1.5	14-24	116.9	15.7	35.0 <sup>5</sup>	13.2
11	4	2	2	0.52	9	1.9	9-20	166.3	27.2	75.1	29.1
12	3	1	0	0.80	4	0.2	4-4	152.8	15.5	45.0	12.6
13	6	2	1	0.70	9	0.7	9-9	193.8	24.8	105.4	31.8
Coantag Creek—August 18-21, 2003											
14	6	5	2	0.50	14	2.8	14-29	146.5	16.0	52.0	17.7
15	6	1		0.87	7	0.4	7-7	133.7	27.8	52.4	31.9
16	14	9	2	0.60	26	2	26-36	108.2	7.7	21.6	10.1
17	4	1		0.83	5	0.5	5-5	90.6	6.2	7.6	2.0
18	8	1		0.90	9	0.4	9-9	203.2	24.9	131.6	38.3
19 <sup>6</sup>	8	4	3	0.51	17	2.8	16-31	146.5	28.5	122.2	73.7
20	8	4	1	0.68	13	0.9	13-13	204.4	31.7	215.2	101.8
21	7	2	1	0.71	10	0.6	10-10	138.5	15.6	40.8	13.0

<sup>1</sup> Stream flow prevented the use of block nets so we did not attempt depletion sampling but instead made only one pass.

<sup>2</sup> Capture probability and a reliable population estimate could not be calculated when BCT were not captured on the second pass so the number of captures was reported without confidence intervals for this reach.

<sup>3</sup> Mean weight was calculated from only 5 BCT because one BCT was not weighed accurately (TL = 126).

<sup>4</sup> Mean weight was calculated from only 18 BCT because one BCT was not weighed accurately (TL = 76).

<sup>5</sup> Mean weight was calculated from only 13 BCT because one BCT was not weighed accurately (TL = 67)

<sup>6</sup> ONE BCT ESCAPEE (TL ~ 110) WAS INCLUDED IN PASS TOTALS BUT NOT MEASURED OR WEIGHED.

## Discussion

Our trapping and electrofishing results indicate that: (i) large numbers of juvenile BCT between 90-120 mm TL migrated out of Hobble Creek during spring run-off, (ii) few large adults moved downstream during the summer, and (iii) BCT that moved downstream through our weir did not represent a cross-section of resident populations upstream.

Hobble Creek is thought to provide spawning habitat for fluvial Bear River BCT (Colyer 2002) and we suspect that these outmigrants are fluvial offspring. Juveniles were captured in surprisingly high numbers (i.e. 25-30 individuals per day) at the outset of trapping, but those numbers declined throughout July and August, suggesting that we installed our weir sometime at or just after the peak of juvenile outmigration. If we assume that outmigration numbers follow a somewhat normal distribution, then we can conclude that many of these fish were probably outmigrating during June, as well. Our trap boxes were able to reliably retain only BCT that were greater than 100 mm in length, so we cannot say whether YOY were outmigrating during this time. At the outset of this study we expected that fluvial BCT offspring probably remained in tributaries for 2-3 years until they attained greater sizes, at which point they would start to gradually move downstream. In fact, sixty-seven percent of BCT that we captured were probably age 2 fish (90-120 mm TL; otolith analysis pending), suggesting that many juvenile BCT appear to remain in spawning tributaries for only one full year after they emerge before moving downstream.

Recent studies have significantly improved our understanding of the life history requirements, seasonal distributions, habitat preferences, and migration patterns of fluvial BCT in the Bear River (Schrack 2002, Schrank et al. 2002, Colyer 2002, Burnett 2003), but we still know very little about the effective size of this population component. Initially we had hoped to use weirs to estimate the numbers of fluvial adults that were spawning in Hobble Creek without disturbing spawning fish by electrofishing or snorkeling. Based on studies conducted in the neighboring Thomas Fork drainage, we assumed that BCT would be actively spawning between May 15 and June 15 (Colyer 2002, Schrank 2002). However, high streamflows prevented us from installing our weirs prior to June 30, and we caught surprisingly few adult outmigrants after that date.

One possible explanation is that fluvial adults remained in Hobble Creek after they spawned and did not make it downstream to our weir by the time it was removed at the end of September. We captured several large (>400 mm) fish upstream from our weir in Hobble creek during angling and electrofishing surveys in July and August, but none of these tagged fish moved downstream through the weir. We did capture a few untagged adults moving downstream during the last few days of trapping in late September, which suggests the possibility that adults were just beginning to move when we removed our weirs. However, a more likely explanation is that many of the fluvial spawners had already left Hobble Creek by the time we installed our weir. Schrank (2002) found that only 20% of tagged post-spawn adult BCT in the Thomas Fork remained in the tributaries in which they had spawned. Similarly, anecdotal evidence suggests that large numbers of adult spawners use a fairly discrete section of Hobble Creek for spawning, but then begin to move downstream soon afterwards (H. Berge, USDA Forest Service volunteer, pers. comm.). Researchers in the lower Thomas Fork and the Bear River found that radio tagged BCT that overwintered in these mainstem reaches disappeared in the

spring and then reappeared at the beginning of the fall. A few of these fish were successfully tracked to upstream locations in Hobble Creek during May and June prior to transmitter failure (Colyer et al. in prep).

Juvenile BCT ranging in size from 90 to 120 mm accounted for 67% of all weir captures, but that size class made up only 35% and 18% of our survey populations in Coantag and Hobble Creeks, respectively. Electrofishing surveys further indicated that juvenile fish were not evenly distributed throughout the two streams but were concentrated at specific sites. In Coantag and Hobble Creeks we found that juveniles dominated our samples at only one site in each stream. Survey reach 16 in Coantag Creek had a population estimate of 26 fish, with all but one of them ranging in size between 77 and 132 mm TL. Similarly, reach 4 in Hobble Creek had a population estimate of 19, with 14 of those ranging in size between 72 and 131 mm TL. This concentration of age 1 BCT these sites may suggest that fluvial spawning activity occurs nearby. This hypothesis is corroborated by anecdotal evidence that spawning BCT return each year to spawn in the same sections of Coantag and Hobble Creeks (H. Berge, USDA Forest Service volunteer, pers. comm.), so we intend to test this hypothesis in the future.

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### Conservation Implications

Telemetry studies in 1998-1999 showed that adult fluvial Bear River Bonneville cutthroat trout used spawning habitats in both the Thomas Fork and the Smith's Fork. Our current study suggests that many of the offspring of these fluvial fish ultimately migrate out of spawning tributaries, thus contributing a major source of individuals to the mainstem Bear River BCT population. Currently, however, drought conditions combined with diversion barriers are preventing BCT from accessing Thomas Fork tributaries, and some of the only spawning habitat now available to BCT is found in the Smith's Fork drainage. Fish have been documented moving out of the Thomas Fork and upstream into the Smith's Fork when the Thomas Fork is not passable (Colyer 2002). Trout Unlimited and the project partners have used this information to gain the support of local landowners and water users for rebuilding the Thomas Fork irrigation diversions to accommodate fish movements. We believe that maintaining open migration corridors between the Bear River and the upper Thomas and Smith's Forks is critical to ensure the long-term persistence of BCT populations in the Bear River system.

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## References

- Burnett, P.B. 2003. Factors affecting spawning and survival of Bear Lake Bonneville cutthroat trout in St. Charles Creek, Idaho. Master's thesis. Utah State University, Logan, UT. 87p.
- Colyer, W.T. 2002. Seasonal movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho—Wyoming. Master's thesis. Utah State University, Logan, UT. 53p.
- Colyer, W.T., J.L. Kershner, and R.H. Hilderbrand. (*in prep*). Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, ID—WY.
- Dunning, J. B., B. J. Danielson, and H. R. Pulliam. 1992. Ecological processes that affect populations in complex landscapes. *Oikos* 65:169-175.
- Hartig, A.L., and K.D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. *Ecological Applications* 12: 535-551.
- 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.
- Moyle, P.B., and G. M. Sato. 1991. On the design of preserves to protect native fishes. Pages 155-170 in W.L. Minckley and J. E. Deacon, editors. *Battle against extinction: native fish management in the American West*. University of Arizona Press, Tucson, Arizona.
- Northcote, T. G. 1992. Migration and residency in stream salmonids: some ecological considerations and evolutionary consequences. *Nordic Journal of Freshwater Research* 67:5-17.
- Northcote, T. G., S. N. Williscroft, and H. Tsuyuki. 1970. Meristic and lactate dehydrogenase genotype differences in stream populations of rainbow trout below and above a waterfall. *Journal of the Fisheries Research Board of Canada* 27:1987-1995.
- Novinger, D.C., and F.J. Rahel. 2003. Isolation management with artificial barriers as a conservation strategy for cutthroat trout in headwater streams. *Conservation Biology* 17:772-781.
- Prince, A. and C. Powell. 2000. Clove oil as an anesthetic for invasive field procedures on adult rainbow trout. *North American Journal of Fisheries Management* 20:1029-1032.
- Schrank, A.J. 2002. Ecological significance of movement patterns of Bonneville cutthroat trout in a western Wyoming watershed. Ph.D. dissertation. University of Wyoming, Laramie, WY. 196p.
- Schrank, A.J., F.J. Rahel, and H.C. Johnstone. 2002. Evaluating laboratory-derived thermal criteria in the field: an example involving Bonneville cutthroat trout. *Transactions of the American Fisheries Society* 132:100-109.
- Stuber, R. J., B. D. Rosenlund, and J. R. Bennett. 1988. Greenback cutthroat trout recovery program: management overview. *American Fisheries Society Symposium* 4:71-74.
- White, G.C., D.R. Anderson, K.P. Burnham, and D.L. Otis. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos National Laboratory LA-8787-NERP, Los Alamos, New Mexico.
- Young, M. K. 1995. Conservation assessment for inland cutthroat trout. U.S. Forest Service General Technical Report RM-GTR-256, Fort Collins, Colorado.
- Young, M. K. 1996. Summer movements and habitat use by Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in small, montane streams. *Canadian Journal of Fisheries and Aquatic Sciences* 53:1403-1408.

## A Large-scale Risk Assessment of the Biotic Integrity of Native Brook Trout Watersheds

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**ABSTRACT**—Many physical, chemical and biological watershed level changes over the last hundred years have threatened the long-term integrity of native brook trout (*Salvelinus fontinalis*) in the eastern United States. Evaluations of the integrity of native brook trout watersheds over their native range are useful to guide decision makers, managers and publics in setting priorities for watershed level restoration, inventory and monitoring programs. Our objective was to 1) develop meaningful physical, chemical and biological metrics that could be used in watershed level risk, and prioritization assessments and 2) determine the current range of conditions for each watershed level metric to establish a benchmark to assist managers in evaluating the relative conditions of their watersheds at various scales of interest. We screened over 100 metrics and developed a multi-metric risk model (Watershed Integrity Rating—WIR) using metrics that related to watershed and water corridor; land use, sedimentation, fragmentation, air quality and human population. We tested the Watershed Integrity Rating on all 5<sup>th</sup> level watersheds in the eastern United States that contained National Forest (NFS) lands and native brook trout (current and historic). Watersheds in the Western Great Lakes region had the highest Watershed Integrity ratings while New England and the Southern Appalachians had the lowest ratings. Many individual watersheds throughout the native range appear to be at risk for brook trout survival with a high percentage of these found in the Southern Appalachians and New England.

### Introduction

Many physical, chemical, and biological watershed level changes over the last hundred years (Marschall and Crowder 1996; Galbreath et al. 2001) have threatened the long-term integrity of native brook trout (*Salvelinus fontinalis*) in their historic range in the eastern United States. Evaluations of the integrity of native brook trout watersheds over their native range are useful to guide decision makers, managers, and publics in setting priorities for watershed level restoration, inventory and monitoring programs. Large-scale assessments for many aquatic species have been useful in identifying and quantifying: problems, information gaps, restoration priorities and funding needs (Williams et al. 1993; Davis and Simon 1995; Frissell and Bayles 1996; Warren et al. 1997; Master et al. 1998; McDougal et al. 2001). We developed a multi-metric Watershed Integrity Rating (WIR) that uses whole watershed (Moyle and Randle 1998) and water corridor variables for metrics instead of site-specific variables. Multi-metric indices can assist managers in their evaluations of watershed health by giving an indicator of overall health when many anthropogenic factors may be

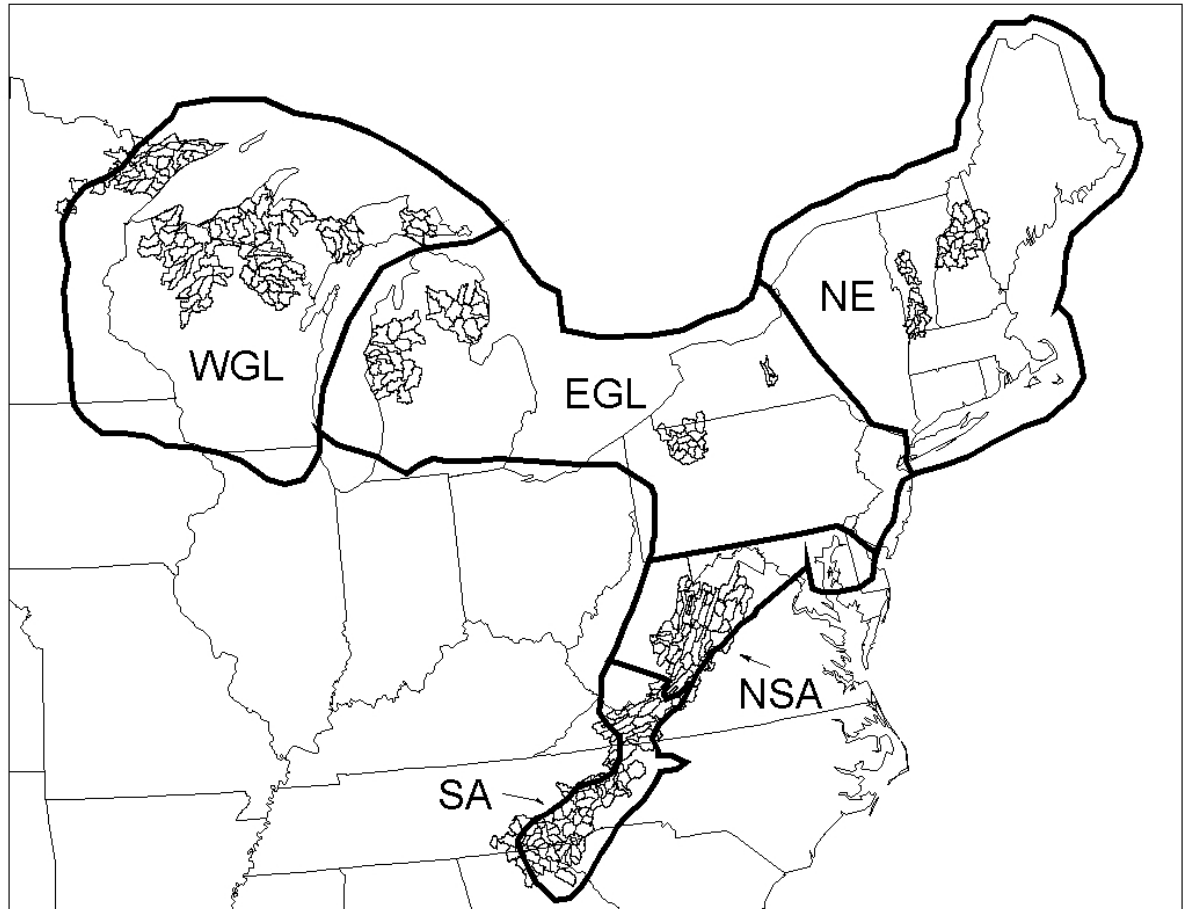
contributing to a problem and by assisting in identifying key limiting factors (Barbour et al. 1999; McCormick et al. 2001). Our objective was to: 1) develop meaningful physical, chemical and biological metrics that could be used in watershed level and prioritization assessments; 2) determine the current range of conditions for each metric to establish a benchmark to assist managers in evaluating the relative conditions of their watersheds at various scales of interest; and 3) test the utility of the WIR for setting restoration priorities on National Forest lands that contain native brook trout (current and historic).

## Methods

We used 5<sup>th</sup> level Hydrologic Unit (HU) watersheds (mean size 452 km<sup>2</sup> ±SD 248) for this assessment (Seaber et al. 1987; EPA 2002; USGS 2002b). The 5<sup>th</sup> level HU was chosen because: 1) it was the smallest size where data was currently available, 2) it is a level of great interest for land management, and 3) it is a size where plans can be developed for conservation management at a reasonable scale (Moyle and Yoshiyama 1994; Master et al. 1998). The watersheds (n = 344) in our study represent all watersheds that contained National Forest lands within the native distribution of brook trout (McCrimmon and Campell 1969; Behnke 2002). We artificially grouped the watersheds for statistical analysis into: Western Great Lakes (WGL), Eastern Great Lakes (EGL), New England (NE), Northern Southern Appalachians (NSA) and Southern Appalachians (SA) (Figure 1). If an ANOVA on the watershed groups was significant, a Tukey HSD multiple comparisons test was conducted (Sokal and Rohlf 2003). The range of the southern Appalachian strain of brook trout delineated the SA region.

The water corridor was 100 m on both sides of all streams and lakes within the watershed. The National Hydrography Dataset (NHD) (1:100,000) layers were used for streams and lakes (USGS 1994). Data on roads was developed using improved Topological Integrated Geographic Encoding and Referencing system (TIGER) data (Navtech 2001). These databases were analyzed using GIS programs that divided the National Hydrography Dataset (NHD) stream layer into gradient segments (Kendal Cikanek, Superior National Forest, personal communication). The spatial data from the 30m National Elevation Dataset (NED)(USGS 2004), 5<sup>th</sup> level HU coverage, the gradient divided NHD, human census data and the roads data were analyzed to compute metrics related to watersheds, streams, gradient, and roads. Output data included area in the watershed (total, land, and lake), stream/road crossings (total, per stream, by gradient), and road density (total, by distance from stream, by gradient).

We screened over 100 candidate metrics (Whalen 2004) for 1) completeness, 2) redundancy, 3) range, 4) variability, and 5) responsiveness (Hughes et al. 1998; McCormick et al. 2001). All candidate metrics were required to have the same data resolution and definitions for all watersheds and were obtained and/or developed as a Geographic Information System (GIS) to allow for data analysis in a spatial context (Lo and Yueng 2002). Many potential databases (metrics) were eliminated from consideration because they were not available for all watersheds at the same or a suitable resolution. No direct biological metrics met the criteria. The final multi-metric index Watershed Integrity Rating (WIR) consists of five-impact categories sedimentation, fragmentation, land use, human population and air quality each with an associated indicator or surrogate for the watershed and the water corridor within that watershed (Table 1).



**Figure 1.** Historic range of brook trout in the eastern United States divided into five watershed groups; Western Great Lakes (WGL), Eastern Great Lakes (EGL), New England (NE), Northern Southern Appalachians (NSA) and Southern Appalachians (SA). The small polygons are 5<sup>th</sup> level hydrologic unit watersheds with National Forest lands within the native brook trout range.

**Table 1.** Final watershed and water corridor metrics used in the Watershed Integrity Rating and the mean and range of values. Water corridor is 100m either side of all streams and lakes. Each of the 10 indicators is worth 0-10 points. \*\*Air quality score for the watershed indicator is scored 0-5 points for NO<sub>3</sub> deposition and 0-5 points SO<sub>4</sub> deposition. \*\*Human score for watershed is scored 0-5 points for human population density in 2000 and 0-5 points for growth rate.

Impact	Watershed indicators (10 points each)*	Median (range)	Water corridor indicators (10 points each)	Median (range)
Sedimentation (20 points)	Road density (km/km <sup>2</sup> )	1.23 (0.01 —4.89)	Road density (km/km <sup>2</sup> )	1.53 (0.00-10.00)
Fragmentation (20 points)	# Dams/km <sup>2</sup>	0.01 (0.00—0.11)	# Road crossings/stream km	0.42 (0.00-2.08)
Land use (20 points)	% Land with human uses	8.53 (0.31 —79.81)	% Land with human uses	3.66 (0.24-30.51)
Human (20 points)	Population/km <sup>2</sup> Growth rate (1790-2000)	10 (0-281) 12 (1-25)	% Land with residential use	0.25 (0.00-14.30)
Air quality (20 points)	NO <sub>3</sub> deposition SO <sub>4</sub> deposition (kg/ha)	11 (9-18) 14 (7-21)	% Soils in water corridor with buffering capacity pH < 5.0	3.87 (0.00-100.00)

The range of conditions for each indicator metric was determined for all watersheds or water corridors then a percentile score was assigned for each indicator (Davis and Simon 1995; Barbour et al. 1999; Klemm et al. 2002). A scoring system is needed for standardization in the final risk assessment. The WIR scored all ten metrics on the same scoring range (0-10) based on the range of values for that indicator on all watersheds. Metrics were given a score based on the percentile in which they were found, for example if a watershed was in the 83 percentile for a particular metric it would get a score of 8.3. The final score was a summation of the ten metrics for a total range of scores from 0-100.

### Final Metrics (Indicators)

Sedimentation was indicated by the surrogate road density (km of road per km<sup>2</sup> of watershed) at the watershed level and by road density within the water corridor (Whalen 2004). Fragmentation at the watershed level was indicated by the number of dams per km<sup>2</sup> of watershed and was calculated from the National Inventory of Dams (NID) (United States Army Corps of Engineers 1998). Fragmentation at the water corridor level was indicated by the number of road crossings per kilometer of stream (Whalen 2004). Land use at the watershed level was indicated by the percentage of the watershed classified as human use in the National Land Cover Data (NLCD)(USGS 2002a). The NLCD was produced using satellite imagery data acquired in 30 m grid coverage. Human use includes low and high intensity residential, transitional, orchards/vines, pasture/hay, row crops, small grain crops, urban recreation, quarries/mines/gravel and commercial/industrial/transportation classifications. Land use at the water corridor level was indicated by the percentage of human land uses within the water corridor. Human population at the watershed level was indicated by a combination of the population density in 2000 and the population growth rate of that watershed since 1790 (Geolytics 2001; U.S. Census Bureau 2002; Price 2003; Whalen 2004). The water corridor level metric for human population was the percentage of the corridor that was designated as high or low residential use in the NLCD. Air quality at the watershed level was indicated by the average 1999 nitrate and sulfate deposition (kg/ha) within the watershed (National Atmospheric Deposition Program 2003). Average deposition was based on isopleths that were developed from set sampling points. We used the average nitrate and average sulfate deposition value for each watershed as air quality watershed metric (Whalen 2004). Air quality at the stream corridor level was indicated by the buffering capacity of soils within the corridor (NRCS 2004; PSU 2004) The indicator represents the percentage of soils (upper 10 cm) in the water corridor with a buffering capacity of < 5.0 pH.

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## Results and Discussion

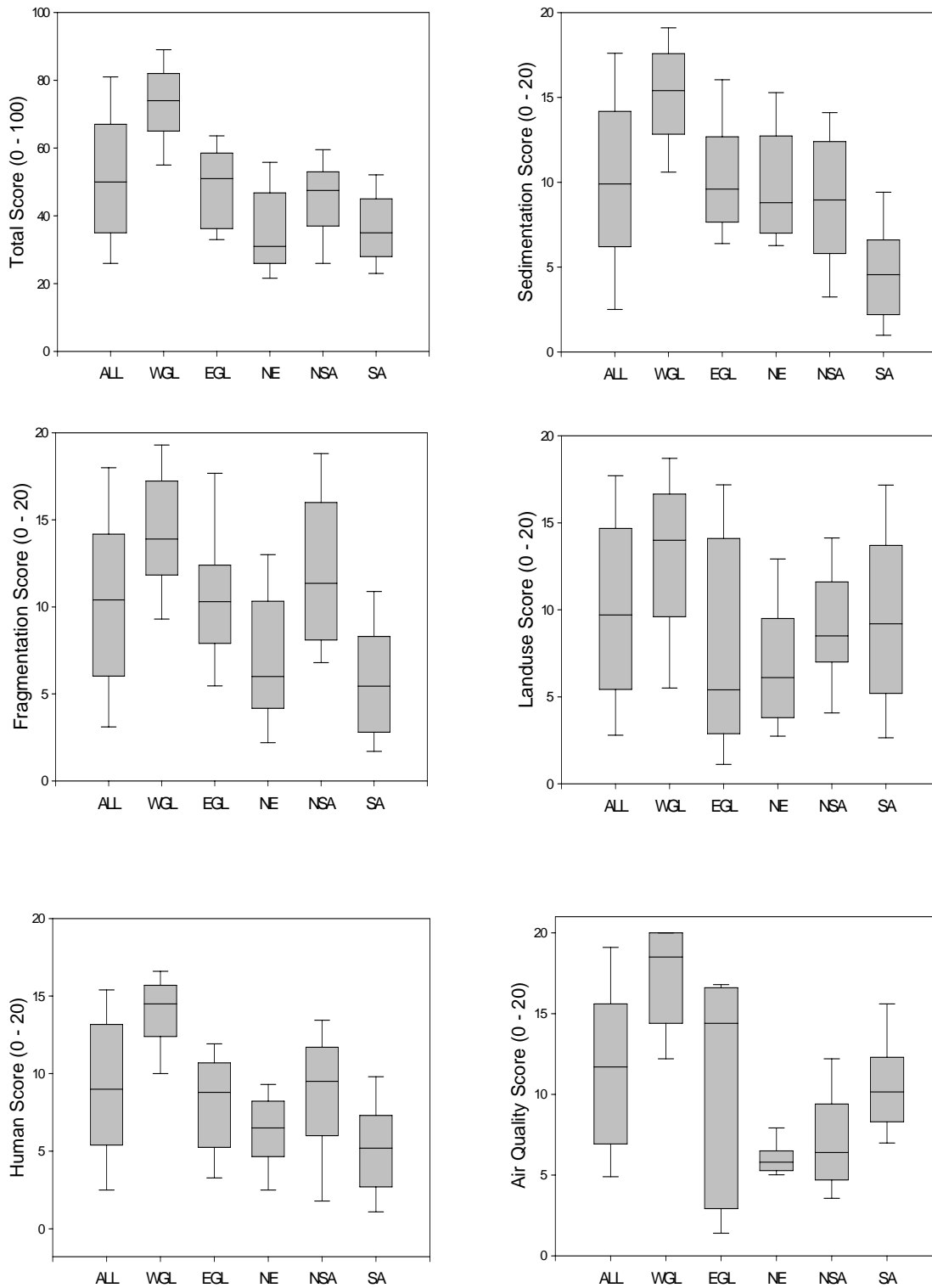
The mean WIR score was 51 with a range from 14 to 96 (Table 2, Figure 2). The mean scores among the watershed groups were significantly different (ANOVA,  $df = 344$ ,  $F = 130$ ,  $p < 0.0001$ ). The mean scores in all impact indicator categories were also significantly different (ANOVA,  $df = 344$ ,  $p < 0.0001$ ) among the watershed groups. The indicator values (actual not scored) are summarized (mean and range) in table 1.

**Table 2. Mean ( $\pm$  SE) Watershed Integrity Ranking (WIR), and impact scores for the Western Great Lakes (WGL), Eastern Great Lakes (EGL), New England (NE), Northern Southern Appalachians (NSA), Southern Appalachians (SA) and all watersheds (ALL) groups. Means followed by a common letter in a column are not statistically significantly different (ANOVA,  $p < 0.001$ ; Tukey HSD multiple comparison test)**

	WIR	Sedimentation	Fragmentation	Land use	Human	Air quality
<b>WGL</b>	72.5 (1.26) a	14.9 (0.31) a	14.2 (0.35) a	12.8(0.48) a	13.7(0.26) a	16.9 (0.29) a
<b>EGL</b>	48.4 (1.66) b	10.4 (0.52) b	10.9 (0.59) b	7.9 (0.85) b	8.0 (0.48) b	11.2 (0.87) b
<b>NE</b>	36.1 (2.02) c	9.8 (0.55) b	6.9 (0.64) c	7.1 (0.64) b	6.2 (0.41) c	6.1 (0.20) c
<b>NSA</b>	45.8 (1.65) b	9.0 (0.56) b	12.0 (0.61) b	9.1 (0.52) b	8.7 (0.54) b	7.0 (0.44) c
<b>SA</b>	36.4 (1.27) c	4.87 (0.37) c	6.0 (0.39) c	9.5 (0.53) b	5.4 (0.34) c	10.7 (0.33) b
<b>All Watersheds</b>	51.2 (1.06)	10.1 (0.28)	10.4 (0.28)	10.0 (0.29)	9.1 (0.25)	11.7 (0.28)

The WGL watershed group consistently had the highest mean WIR and impact indicator scores (Table 2, Figure 2). The NE and SA watershed groups had the lowest mean WIR scores and the lowest mean indicator scores for sedimentation, fragmentation and human population. Many individual watersheds have been impacted from multi anthropogenic impacts, with a high percentage of these in the NE and SA watershed groups. These watersheds are also some of the most impacted from exotic fish introductions. We were not able to obtain data at the appropriate resolution to incorporate the impacts from exotics on native brook trout. The effects of stocked brook trout and stocked and naturalized rainbow trout and brown trout have greatly affected native brook trout populations in these regions (Larson and Moore 1985; Galbreath et al. 2001). The introductions of exotic cool and warm water species such as smallmouth bass and walleye have also affected native brook trout waters. A metric that can separate out populations of brook trout not impacted by exotics would be useful in future analysis.

This study was designed to identify the integrity of entire 5<sup>th</sup> level watersheds across the native range of brook trout in the eastern United States. The WIR is a useful starting point for answering questions appropriate to the scale of analysis. An analysis of indicators from impact categories is a second step that can help identify potential limiting factors. While the WIR and impact scores can help decision makers decide which watersheds to focus in and identify potential limiting factors, project specific restoration and conservation projects will need finer scale data and local knowledge to make wise decisions as brook trout streams in need of restoration and protection can be found in any watershed regardless of WIR score. Improvements in the data that allow for an analysis at a scale such as 6<sup>th</sup> level HU or individual stream reach are necessary to identify these important within watershed restoration or conservation projects. We used best available surrogates for many impacts because direct measurement data was not available across the range of this study. If available, direct measurement data should be used for restoration decisions.



**Figure 2. Range of conditions for the Watershed Integrity Rating (WIR) (total score) and individual impact indicators (sedimentation, fragmentation, land use, human population, air quality) for all watersheds (ALL), Western Great Lakes (WGL), Eastern Great Lakes (EGL), New England (NE), Northern Southern Appalachians (NSA) and Southern Appalachians (SA) watershed groups.**

We did not run the analysis with 1:24,000 NHD stream and lake data, because it was not available for every watershed, however we conducted many watershed analyses where we had both 1:100,000 and 1:24,000 NHD data. In most cases, the metric indicator values were different but highly correlated ( $r > 0.90$ ) and the relative rankings of the watersheds were not statistically different using a Spearman Rank Correlation test. There were also only small shifts in a watershed's percentile scores for each indicator. We believe our watershed and watershed group findings will be similar when the analysis can be run with a complete 1:24,000 NHD data set. We also did not conduct the analysis on all the 5<sup>th</sup> level HU within the brook trout historic range because of data gaps (primarily missing official 5<sup>th</sup> level watershed boundaries). Our experiences with working with all the National Forest watersheds ( $n = 991$ ) in the eastern United States instead of a subset of brook trout only watersheds ( $n = 344$ ) showed the range of conditions for most of the indicator metrics to be similar (Whalen 2004). We believe that watersheds with National Forest lands (average ownership 56%) may have better WIR scores on average than the complete set of brook trout watersheds but the impact indicator scores will show similar trends among the watershed groups. The exception may be the NE scores where watersheds with National Forest lands are few and do not include most of the state of Maine where human population and land use indicators may score higher. An analysis for all watersheds is recommended as soon as the final 5<sup>th</sup> and 6<sup>th</sup> level HU become available.

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## References

- Barbour, M. T., J. Gerritsen, B. D. Snyder, and J. B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.
- Behnke, R.J. 2002. Trout and Salmon of North America. Free Press, Simon and Shuster, Inc. New York, New York. 359 p.
- Davis, W. S. and T. P. Simon. 1995. Biological Assessment and Criteria: Tools for watershed resource planning and decision making. Lewis Publishers, Washington, D.C.
- Doppelt, B., M. Scurlock, C. A. Frissell, and J. Karr. 1993. Entering the watershed. Island Press, Covello, California.
- Environmental Protection Agency (EPA). 2002. <http://www.epa.gov/region02/gis/atlas/hucs.htm>. 6 January 2003.
- Frissell, C. A., and D. Bayles. 1996. Ecosystem management and the conservation of aquatic biodiversity and ecological integrity. *Water Resources Bulletin* 32:229-240.
- Galbreath, P. F., N. D. Adams, S. Z. Guffey, C. J. Moore, and J. L. West. 2001. Persistence of Native Southern Appalachian Brook Trout Populations in the Pigeon River System, North Carolina. *North American Journal of Fisheries Management* 21: 927-934.
- Geolytics. 2001. Census CD<sup>+</sup> Maps 1990. CD-Rom, <http://www.censused.com>.

- Hughes, R. M., P. R. Kaufmann, A. T. Herlihy, T. M. Kincaid, L. Reynolds, and D. P. Larsen. 1998. A process for developing and evaluating indices of fish assemblage integrity. *Canadian Journal of Fisheries and Aquatic Sciences* 55: 1618-1631.
- Klemm, D. J., K. A. Blocksom, W. T. Thoeny, F. A. Fulk, A. T. Herlihy, P. R. Kaufmann, and S. M. Cormier. 2002. Methods Development and Use of Macroinvertebrates as Indicators of Ecological Conditions for Streams in the Mid-Atlantic Highlands Region. *Environmental Monitoring and Assessment* 78: 169-212.
- Larson, G.L. and S.E. Moore. 1985. Encroachment of exotic rainbow trout into stream populations of native brook trout in the southern Appalachian mountains. *Transactions of the American Fisheries Society* 114: 195-203.
- Lo, C. P., and A. K. W. Yeung. 2002. *Concepts and Techniques of Geographic Information Systems*. Prentice Hall, Inc., Upper Saddle River, New Jersey.
- Marschall, E. A. and L.B. Crowder. 1996. Assessing Population Responses to Multiple Anthropogenic Effects: A Case Study with Brook Trout. *Ecological Applications* 6(1): 152-167.
- Master, L. L., S. R. Flack, and B. A. Stein, editors. 1998. *Rivers of Life: Critical watersheds for protecting freshwater biodiversity*. The Nature Conservancy, Arlington, VA.
- McCormick, F. H., R. M. Hughes, P. R. Kaufmann, D. V. Peck, J. L. Stoddard, and A. T. Herlihy. 2001. Development of an Index of Biotic Integrity for the Mid-Atlantic Highlands Region. *Transactions of the American Fisheries Society* 130(5): 857-877.
- McCrimmon, H.R. and J.S. Campell. 1969. World distribution of brook trout, *Salvelinus fontinalis*. *Journal of the Fisheries Research Board of Canada*. 26:1699-1725.
- McDougal, L. A., K. M. Russell, and K. N. Leftwich, editors. 2001. "A Conservation Assessment of Freshwater Fauna and Habitat in the Southern National Forests." USDA Forest Service, Southern Region, Atlanta Georgia. R8-TP 35 August 2001.
- Moyle P. B., and P. J. Randall. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. *Conservation Biology* 12(6): 1318-1326.
- Moyle P. B. and R. M. Yoshiyama. 1994. Protection of aquatic biodiversity in California: a five-tiered approach. *Fisheries* 19: 6-18.
- National Atmospheric Deposition Program. 2003. NO<sub>3</sub> and SO<sub>4</sub> Isopleths. <http://nadp.sws.uiuc.edu/isopleths/annualmaps.asp>.
- Natural Resources Conservation Service (NRCS). 2004. State soil geographic database (STATSGO). <http://www.ncgc.nrcs.usda.gov/branch/ssb/products/statsgo/index.html>
- Navtech. 2001. Navstreets: streets data. CD-Rom, Version 2.5. <http://www.navtech.com/data/data.html>
- Pennsylvania State University (PSU). 2004. Earth System Science Center, Pennsylvania State University. Soil information for environmental modeling and ecosystem management. [http://www.essc.psu.edu/soil\\_info](http://www.essc.psu.edu/soil_info)
- Price, C. 2003. 1990 population density by block group for the conterminous United States. USGS. <http://water.usgs.gov/lookup/getspatial?uspopd90x10s>.
- Seaber, P.R., Kapinos, F.P., and Knapp, G.L. 1987. Hydrologic Unit Maps: U.S. Geological Survey Water-Supply Paper 2294.
- Sokal, R.R. and F.J. Rohlf. 2003. *Biometry: The principles and practice of statistics in biological research*. W.H. Freeman and Company, New York, New York. 888p.
- U.S. Army Corps of Engineers. 1998. National Inventory of Dams data. <http://corpsgeo1.usace.army.mil/CECG/hq.html>. 13 December 2002.
- U.S. Census Bureau. 2002. Census 2000: Summary Files. <http://www.census.gov>. 2 November 2002.
- U.S. Geological Survey (USGS). 1994. National Hydrography Dataset. <http://nhd.usgs.gov> July 7, 2004.
- U.S. Geological Survey (USGS). 2002a. National Land Cover Dataset (NLCD). <http://landcover.usgs.gov>. 13 December 2002.
- U.S. Geological Survey (USGS). 2002b. Water Resources: Hydrologic Unit Maps. <http://water.usgs.gov/GIS/huc.html>. 13 December 2002.

- U.S. Geological Survey (USGS). 2004. National elevation data set.  
<http://edcnts12.cr.usgs.gov/ned/>
- Warren, M. L., Jr., P. L. Angermeier, B. M. Burr, and W. R. Haag. 1997. Decline of a diverse fish fauna: patterns of imperilment and protection in the southeastern United States. Pages 105-164 in Benz, G. W. and D. E. Collins (editors). *Aquatic Fauna in Peril: The Southeastern Perspective*. Special Publication 1, Southeast Aquatic Research Institute, Lenz Design and Communications, Decatur, GA.
- Whalen, J.K. 2004. A risk assessment for crayfish conservation on national forest lands in the eastern U.S. Masters Thesis, James Madison University, Harrisonburg, VA.
- Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. *Fisheries* 18(9): 6-22.

