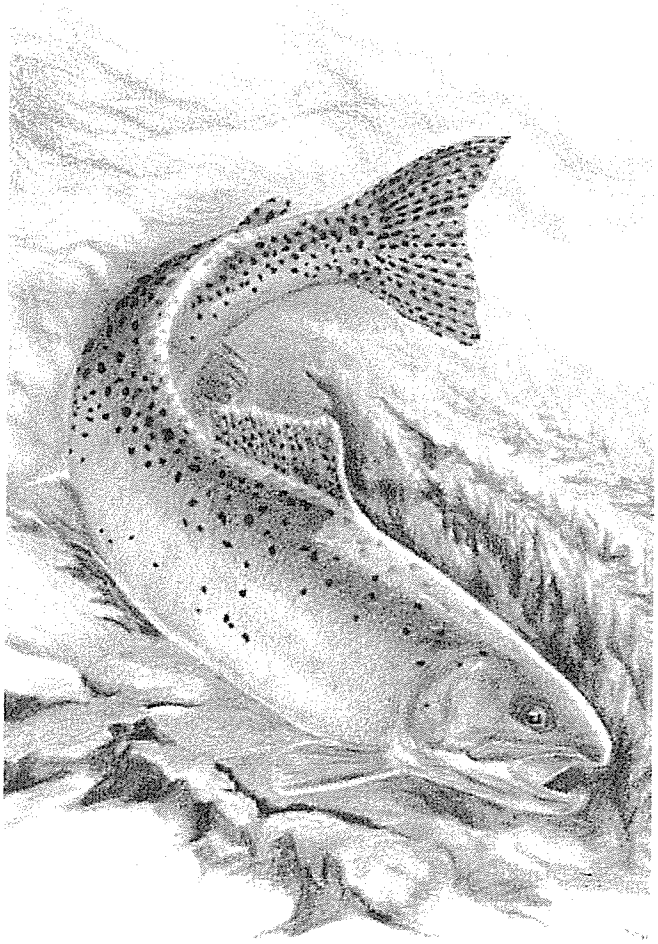
Wild Trout VII

Management in the New Millennium:

Are We Ready?



Old Faithful Inn
Yellowstone National Park
October 1-4, 2000

Wild Trout VII

Symposium Chair and Local Arrangements
Pat Byorth

Program Committee
Dan Schill, Co-chair
Steve Moore, Co-chair
Bob Gresswell
Dave Lentz
Sandy Nobel
Marty Seldon
Bob Wiley
Bob Hooten
Pat Byorth

Fund Raising
Don Duff, Chair

Treasurer
Joe Urbani

Photography
Spencer Turner

A. Starker Leopold Award Committee
Marty Seldon, Chair
Roger Barnhart
Robert Behnke
Gardner Grant
Ron Jones
Frank Richardson
Ernie Schwiebert

Technical and Administrative Support
Liz Mamer

Editorial Committee
Bob Hamre, Co-chair
Carol LoSapio, Co-chair

Web Page Editor
Wayne Black

Conference Arrangements
Montana State University Conference Services

Note

As part of the planning for this symposium, we asked each author to assume full responsibility for submitting reviewed manuscripts in photoready format within tight deadlines. Thus the manuscripts did not receive conventional editorial processing, and consequently you may find some typographical errors and slight differences in format. We feel quick publication of the proceedings is an essential part of the symposium concept, and far outweighs these relatively minor distractions. The views expressed in each paper are those of the authors, and not necessarily those of the sponsoring organizations.

Cover art by Mimi Matsuda

Desktop Publishing/Layout Design by Carol LoSapio, Beyond Words.

Wild Trout VII

Management in the New Millennium: Are We Ready?

Old Faithful Inn

Yellowstone National Park

October 1-4, 2000

Technical Editors

Dan Schill
Idaho Fish and Game

Steve Moore
USDI National Park Service

Pat Byorth
Montana State University

Bob Hamre
USDA Forest Service (Retired)

Sponsors:

National Park Service

Trout and Salmon Foundation

USDA Forest Service

US Fish and Wildlife Service

Montana Fish, Wildlife, and Parks

Yellowstone National Park

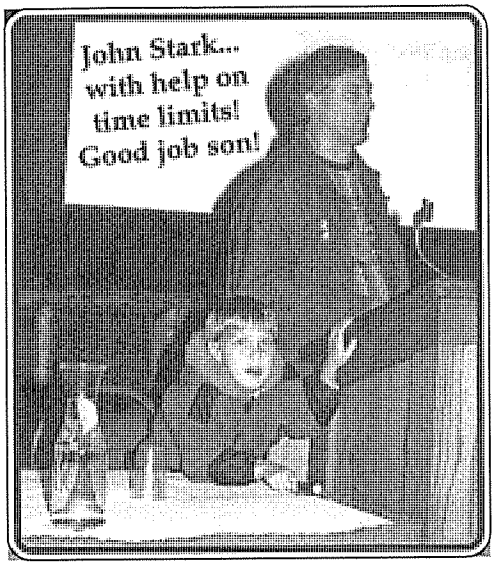
Montana Chapter American Fisheries Society

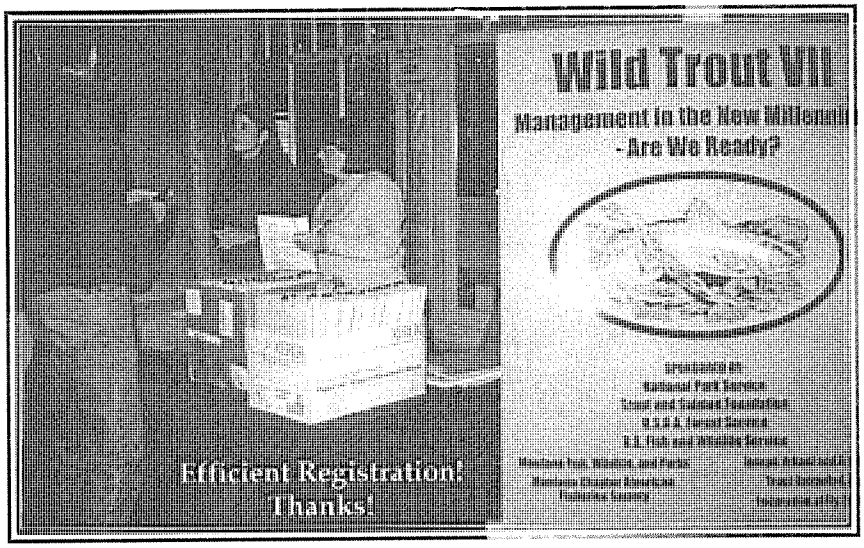
Joseph Urbani and Associates

Trout Unlimited, Inc.

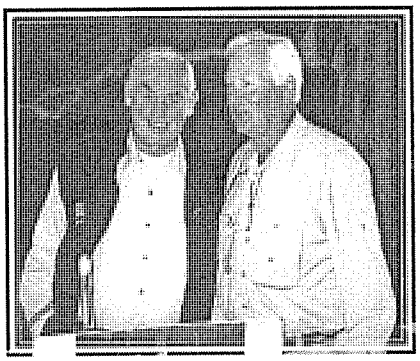
Federation of Fly Fishers

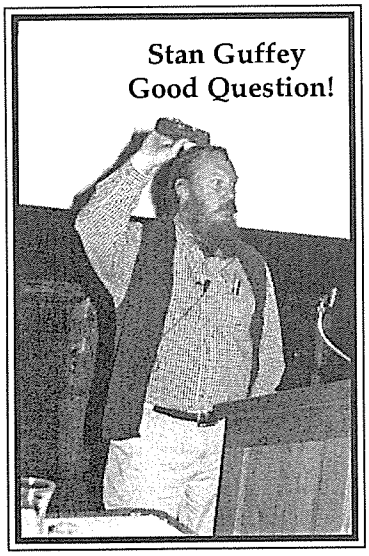
Native Utah Cutthrout Association

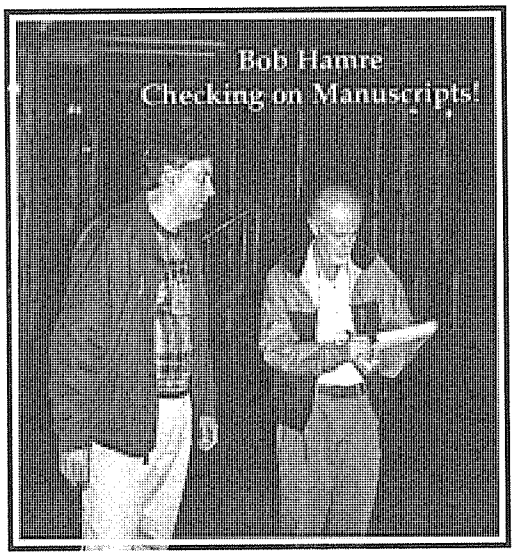


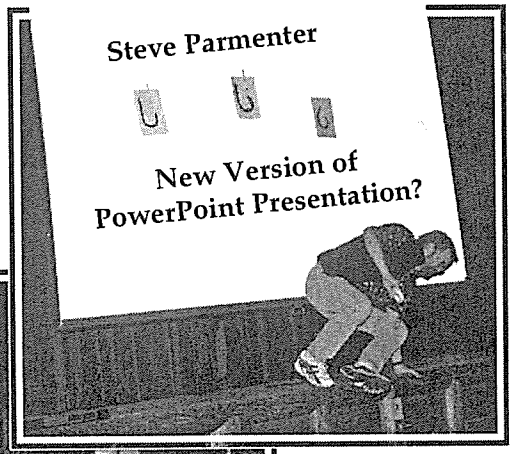


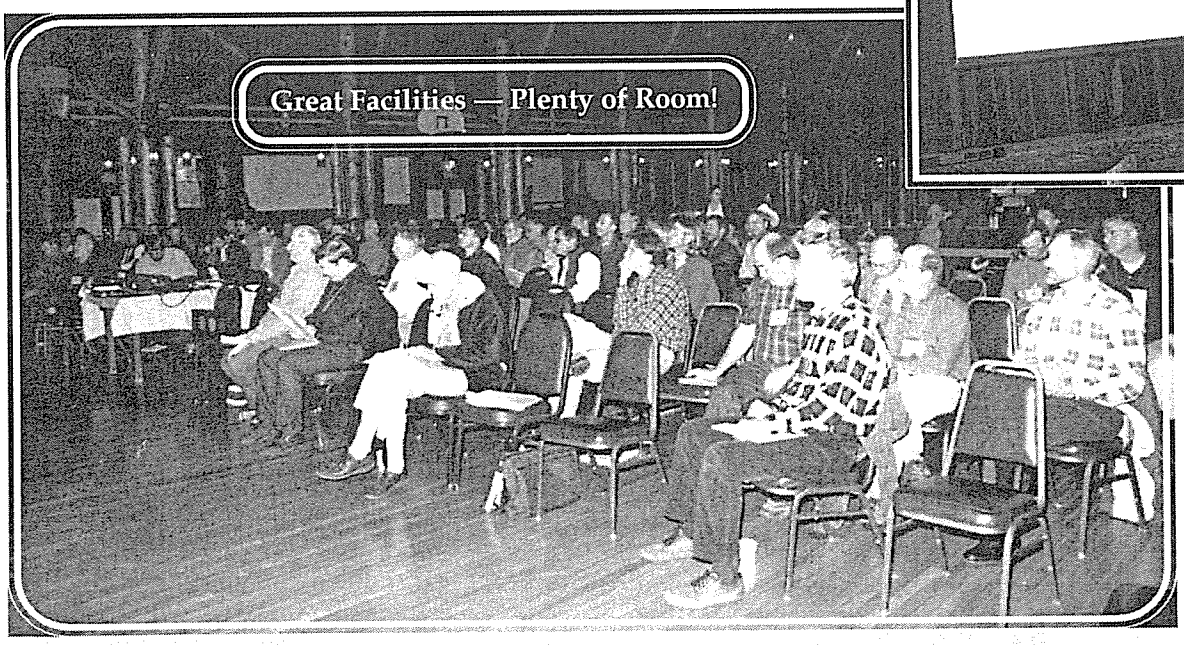
A. Starker Leopold Awards
Bud Lilly & Frank Richardson











Contents

Setting the Stage

Wild Trout VII – Exceptional Subject, Exceptional Symposium
Patrick A Byroth 1

Wild Trout VII: A Summary
Robert W. Wiley 2

Keynote Address: New Directions in the National Park Service
Karen P. Wade 5

Luncheon Address: Do Fish Feel Pain?
James D. Rose 9

Banquet Address: The Many Sides of the Wild Trout Issue
Thomas McGuane 14

Manage First For Wild Trout
Robert L. Hunt 16

2000 A. Starker Leopold Wild Trout Awards
Marty Seldon 18

History of the Wild Trout Symposiums
Marty Seldon 21

Wild Trout Regulations - Mark Gamblin, moderator

Resumption of a Limited Harvest Fishery for Bull Trout in Lake Pend Oreille, Idaho: Could We, Should We, Would We?
Charles E. Corsi and Christopher C. Downs 25

Wild Trout Regulations and Natural Bait in North Carolina
James C. Borawa and Micky M. Clemmons 35

Management History and Angler Behavior in a Northeast Oregon Trout Fishery With Implications for Setting Wild Trout Regulations
William J. Knox 42

The Effects of Hook Size on Hooking Mortality of Juvenile Summer Steelhead, *Oncorhynchus mykiss*, Captured on Adult Summer Steelhead Gear
Greg A. Taylor, Mary A. Buckman, and David V. Buchanan 51

Biological and SocioEconomic Aspects of Natural State Catch and Release Regulations
John Stark, Stan Todd, Larry Rider 55

Circle Hooks: Remedy for Bait Angling Mortality?
Steve Parmenter 61

The Endangered Species Act and Management of Native Salmonids - Steve Moore, moderator

An Overview of Endangered Species Act Processes
Michael M. Long 67

A Case History of the Jarbidge River Bull Trout Listing
Selena J. Werdon 74

Listing and Recovery Planning for Bull Trout
Samuel Lohr, Timothy Cummings, Wade Fredenberg, Stephen Duke 80

Improving on the Endangered Species Act – Oregon's Approach to Restoring Salmon and Watershed Health
Jay W. Nicholas 88

Gila Trout Recovery in SouthwesternNew Mexico: Overcoming Obstacles Through Synergism
J. E. Brooks, John Kramer, J. A. Monzingo, D. L. Propst, and Russell Ward 95

Threats and Opportunities - Dave Lentz, moderator

The Role of Large Rivers in the Evolution and Conservation of Redband Trout
Kenneth P. Currens, Carl B. Schreck, and Hiram W. Li 99
Triploid Hatchery Trout Programs in Idaho – Meeting Public Demand for Consumptive Angling while Protecting Genetic Integrity of Native Trout
Jeff Dillon, Dan Schill, David Teuscher, and Douglas Megargle 105
Persistence of Native Brook Trout in Great Smoky Mountains National Park after 35 Years of Stocking with Northern Derived Hatchery Strains
Stan Guffey 109
Recovery and Conservation of the Henrys Lake Yellowstone Cutthroat Trout Population
Mark Gamblin, Jeff Dillon, and Matt Powell 119
Whirling Disease: Putting the Pieces Together
David Nickum and Jerri Bartholomew 125

Restoration Projects - Bob Wiley, moderator

Response of a Resident Bull Trout Population to Nine Years of Brook Trout Removal, Crater Lake National Park, Oregon
M.W.Buktenica, B.D. Mahoney, S.F. Girdner, and G.L. Larson 127
Restoration of Two Adirondack Brook Trout Populations Lost to Acidification
William H. Gordon 133
Application of a Model to Predict Success of Cutthroat Trout Translocations in Central and Southern Rocky Mountain Streams
Amy L. Harig, Kurt D. Fausch, and Paula M. Guenther-Gloss 141
The Grand Portage Project, A Successful Model for the Reintroduction of Lake Superior Coaster Brook Trout Populations
Lee E. Newman 149
Recovery Status of Apache Trout *(Oncorhynchus apache)*
Leslie D. Ruiz and James R. Novy 155
Blackfoot River Restoration: A Private Land Fisheries Initiative
Ron Pierce 161
A Plan to Gain Public Support for Native Trout Restoration by Improving Sport Fishing
Dale K. Hepworth, Charles B. Chamberlain, and Michael J. Ottenbacher 169
Mitigating Stream Acidification in a Wilderness Watershed Using Limestone Sand
Larry O. Mohn, Paul E. Bugas, Jr., Dawn M. Kirk, and Daniel M. Downey 176
Multiple Electrofishing Removals for Eliminating Rainbow Trout in a Small Southern Appalachian Stream
Matt A. Kulp, Stephen E. Moore, and John M. Hammonds 185

Ecosystem Management - Bob Hooten, moderator

Developing a Sampling Frame for Watersheds at a Large Regional Scale
Douglas S. Bateman, Robert E. Gresswell, George Lienkaemper, and Troy Guy 193
Patterns of Fish Distribution at the Watershed Scale
Robert E. Gresswell, Douglas S. Bateman, and Mark A. Ricca 195
The Influence of Non-Fish Bearing Streams on the Structure of Fish Bearing Streams in the Coast Range Mountains of Oregon
Christine L. May and Robert E. Gresswell 198
Ecosystem Planning Approach for Reintroducing Bonneville Cutthroat Trout in Nevada
Neal W. Darby and Tod B. Williams 201
Multi-partnership Success for Bonneville Cutthroat Trout Conservation in Nevada
Neal W. Darby, Chris A. Crookshanks, James Whelan, and Jennifer Coons 203

Limited Entry-Trout Fisheries – tool of the future or a bad idea? - *Dan Schill, moderator*

British Columbia's Dean River—Limited Entry: A Management Tool for Maintaining a Quality Angling Experience
Jack Leggett 205
Limited Access Fisheries – Management Options for the Future
Mac Minard 208
Limited Entry—No Demand Way!
David K. Berry 211
Limited Entry to Public Trout Water: The Pros and Cons
Gilbert Bergen 213

Electrofishing Injury - Jim Reynolds, moderator

Effects of Electrofishing on Survival and Growth of Wild Brown Trout (*Salmo trutta*) from Central Pennsylvania Strems
Robert Jay Weber and Robert Carline 215
Healing of Electroshock-Induced Hemorrhages in Hatchery Rainbow Trout
Daniel J. Schill and F. Steven Elle 224
Effects of Annual Electrofishing with High-Frequency DC on Wild Brown Trout
Robert F. Carline 227
Impacts of Electrofishing Injury on Idaho Stream Salmonids at the Population Scale
F. Steven Elle and Daniel J. Schill 229
Guidelines for Assessment and Reduction of Electrofishing-Induced Injuries in Trout and Salmon
J.B. Reynolds and F.M. Holliman 235

Native Fish - Bob Gresswell, moderator

Native and Non-Native: What's the Difference?
Stan Guffey 241
Using Partnerships for Attaining Long Term Sustainability of Bull Trout *Salvelinus confluentus* Populations in the Upper Willamette Basin, Oregon
Jeffrey S. Ziller and Greg A. Taylor 247
Conservation Agreements: Balancing the Interest of Anglers and ESA in Utah
Yvette Converse, Bryce Nielson, Chad Crosby, Dale Hepworth, and Charlie Thompson 256
Protection of Native Cutthroat Trout Using a Removal Program for a Non-Native Predator: Lake Trout Reduction in Yellowstone Lake
Daniel Mahony and James R. Ruzycki 256

Posters

Whirling Disease, Water Flows and Spawning Habitat Destruction on the Madison River
Randy J. Cain 257
Trout Stream Mitigation for Highway Construction Impacts
Mickey Clemmons 258
The Status of Native Cutthroat Trout Subspecies Under the Endangered Species Act
Jessica Gourley, Yvette Converse, and Janet Mizzi 259
Spatial and Temporal Variation in Habitat Use of Coastal Cutthroat Trout Above Barriers to Anadromy
Steven R. Hendricks and Robert E. Gresswell 259
Rapid Temperature Flux Can Permanently Mark Fish Otoliths in Tailwaters
Mark A. King, Scott M. Smith, and Colin W. Krause 260

Distribution of *Myxobolus Cerebralis* in Yellowstone Cutthroat Trout from the Yellowstone Lake Basin
Daniel Mahony and Crystal Hudson 260
Barging Hatchery Steelhead Smolts Down Columbia River Does Not Interfere with Performance in Sea Water
Juhani Pirhonen and Carl B. Schreck 261
Effects of a Catastrophic Flood and Debris Flow on Density and Growth of Brook Trout (*Salvelinus Fontinalis*) in the Staunton River, Shenandoah National Park, Virginia
Craig Roghair and C. Andrew Dolloff 262
Fintrol Concentrate
Nick and Mary Romeo 263
Effects of Episodic Stream Acidification on Wild Brook Trout Distribution in Stone Run, Pennsylvania, USA
W. E. Sharpe, S. J. Dolte, and B. R. Swistock 264
The Use of Major Histocompatibility Complex Genes of Rainbow Trout and Brown Trout in Population Analysis
Benny P. Shum, Laura L. Flodin, Mark A. Adkison, Ronald P. Hedrick, R. Barry Nehring, and Peter R. Parham 264
Acidic Deposition and the Status of Virginia's Wild Trout Resource: Revisited
J.R. Webb, F.A. Deviney, Jr., B.J. Cosby, A.J. Bulger, and J.N. Galloway 265
Profitable Stream Positions Differ for Brook Trout and Cutthroat Trout
Peggy Wilzbach and Kenneth W. Cummins 265
Threats and Opportunities for Native Trout Populations and Their Management—Get Those Roads Out of the River's Flood Plain!
Ray Zubik and Pamela K. McClelland 266
"TU's Trout in a Frige"
Don Duff 267

Wild Trout VII: Attendees and How to Contact Them *269*

Wild Trout VII – Exceptional Subject, Exceptional Symposium

Patrick A. Byorth[1]

Wild trout are exceptional. Not that any other species or strain of fish is of less interest or value, but wild trout have something special. Salmonids are attractive critters – and sporting quarry - but the wild ones are, well...wild, which makes all the difference. Wild trout, native and naturalized, are crafted by mother nature over decades, or millennia. They are built in wild places, by forces unmastered by humans. Wild trout are sculpted by predators, otters and ospreys; by prey, stoneflies and sculpins; and by habitats, gravels and glides. When anglers cast into the wild world of wild trout, we are hardwired to our same wild roots, the same forces that sculpted us, and the same forces that are still largely at work in our brooks, rivers, and lakes.

Could there be a more appropriate place to celebrate wild trout than America's crown jewel of wildness, Yellowstone National Park? Wild Trout VII convened downwind of Old Faithful, in her mist to question our readiness as anglers, conservationists and biologists to eke out a place for wild trout in the new millennium. We gathered from far corners of North America to hear Karen Wade, Director of the Intermountain Region of the National Park Service, voice a call to collectively guard wildness in our Parks as a place for wild, native trout. We learned of the utility and effectiveness of our tools at conserving wild trout, from regulations to endangered species policy. We engaged in lively debates on the merits of the Endangered Species Act and limited entry fisheries. We heard hopeful tales of native species restoration and challenges to their survival. We celebrated the careers of Bud Lilly and Bob Hunt, respective legends of fishing and fisheries science, in memory of A. Starker Leopold. Most importantly, perhaps, we gathered to share perspectives and camaraderie between anglers, biologists, conservationists, and managers surrounding our common interests and concerns for wild trout. The strength of these common interests will ensure the persistence of wild trout and their wild places.

Our common interests in and enjoyment of wild trout have brought us together at Wild Trout symposia since 1974. We look forward to continuing the tradition in 2004, the 30th anniversary of the symposia, in Yellowstone National Park, at Wild Trout VIII. Hope to see you there!

Until then, keep up the good work of protecting wild trout and their wild places. Remember to take the time to cast a line, hook up, and reconnect to the real world. Thankfully, we still have wild trout ...lest we forget!

Old Faithful Lodge—Yellowstone National Park

[1]-*Symposium Chairman*

Wild Trout VII: A Summary

Robert W. Wiley[1]

Wild Trout VII was successful with a varied program, well-prepared presentations, entertaining and informative luncheon and dinner speakers, plus added attractions of poster displays describing several aspects of fisheries resource management. A challenge for organizers of Wild Trout VIII is to determine how to attract resource users and their representatives, plus others who appreciate fish and fisheries. Without them, those responsible for management for fishes will continue preaching to and educating themselves.

Following 2.5 days of talking about fish, fisheries managers would do well to consider two axioms applicable to modern fisheries management.

- All fish are equal partners in the aquatic world. Our job is all fish, not just sport fish.
- Conservation agencies and people who work for them cannot escape responsibility for public perception of the quality of the fishing experience because their actions largely created it (Clawson 1963).

The first statement caused much discussion at a 1994 fisheries meeting in Albuquerque, New Mexico. There, a fisheries manager responded that all fish are equal partners, but sport fish are more equal than all the rest. Sport fish are sometimes viewed as more important because people must purchase a license to use the resource, and license fees generate money for fisheries work. If we fisheries professionals are really stewards of the fisheries resource, attention must be given all fish in the waters we manage.

My summary of the conference consists of thoughts and observations about fisheries management based on experiencing Wild Trout I through VII plus experiencing more than three decades in fisheries management. A good way to highlight is to summarize the nuggets of wisdom offered by invited speakers and from each of the eight sessions.

Thomas McGuane (Wild Trout VII) and **Bill Luch** (Wild Trout I) had very similar messages about resource management. Bill Luch, a longshoreman and passionate steelhead angler was very concerned about a several-year-decline in his favorite fisheries, laying responsibility at the feet of professional fisheries managers. He implored us, in longshoreman's language, to put things right. Because of his passion and blustering, his audience paid his important message scant attention.

Thomas McGuane also encouraged us to share our knowledge, translating science into terms that resource aficionados, politicians, and public decision makers can understand. He did so in less colorful but similarly emotional style. We seemed to listen. At least I heard no murmurs of criticism. Will we, can we translate our science to something the public understands as easily as we do?

At the **Awards Luncheon**, Bob Hunt advised to manage first for wild trout and encouraged us to ask ourselves; if not wild trout, why not? We must also keep an eye on aquatic habitat because good fish populations cannot be managed separately from the habitat that sustains them.

Dr. Jim Rose (luncheon speaker, 2 October 2000) educated and entertained us about whether trout can feel pain. He admonished the audience to guard against translating human perceptions of pain to other animals, especially those with smaller, less complex, and less developed brains. He said that a salmon being eaten alive by a grizzly bear doesn't know that he is in trouble. The salmon (trout or other fish) feel no pain because the cerebellum, where sensation of pain is processed, is not developed in fishes. We understand Jim's research and his conclusions. Our challenge is to convey similar understanding to those less informed of neuro-science. How can we teach The Little Old Lady From Pasadena to understand that when a salmon is eaten alive by a bear, carried off by a bird of prey, or hooked by an angler, it feels no pain?

The experience of inviting Jim Rose to Wild Trout VII is worth thinking about. Approval for the program required knowing "which side" he represented. That is, would he be angler-friendly or would he more likely charge anglers (or fisheries biologists) with cruelty to fish. That Dr. Rose spoke as he did was comfortable for conference participants. However, as fisheries professionals and anglers we cannot afford to reject, out of hand, alternate points of view.

[1]*Section Manager, Fisheries Management, Wyoming Game & Fish Department, Cheyenne, Wyoming*

Keynoter, **Karen Wade,** advised that collaboration among fisheries workers is vitally important. State, federal, tribal, public, and private interests must work together for the future of the resource.

Wild Trout Regulations. Three axioms pertain to this session.

- There are no good techno-fixes. Nature should guide our prescriptions for the resource.
- A system cannot be made to produce fish beyond its ability to sustain them. (Planting hatchery-reared catchable size trout can create the illusion of increased production.)
- *Fishing isn't as good as it used to be, and it never was* (Mullan 1956). (Most pleasant memories of fishing yesterdays are of days when many fish were landed; we soon forget the fishless times.)

ESA and Management of Native Species. This session spotlighted differences in opinion among people administering the Endangered Species Act and those charged with managing the fisheries resource, a dichotomy of state and federal opinion. Two important concepts epitomize the session.

- In considering the status of any species, we must first consider the coherence of an ecosystem, as it exists now, tributaries as well as mainstem impoundments, tailwaters and upstream systems, salmonids as well as other fish, native and introduced species, and wild as well as hatchery fish. *The past is irretrievable.*
- We (fisheries biologists) should not ask how much recovery is enough. Nobody is better qualified to describe how much recovery is practical and possible and provide rationale and support for the recommendations. (Steve Yundt, Idaho Fish & Game described an insightful recovery – extinction continuum that can aid fisheries managers in visualizing what level of recovery is desirable and practical.)

This session brought to mind Northern California's Mattole River, a favorite stream of college years,

The Mattole of 1962-1963 was a moderate-sized stream known mostly to locals from quaintly named villages like Honeydew and Petrolia. For a couple of college students, steelhead fishing was good enough to etch indelible memories. We knew that the upriver watershed was logged and that the lowlands were farmed and power-grazed. Steelhead were abundant and the fishing superb, dulling concern for watershed management. Epochal storms of 1964 triggered massive landslides and floods throughout the watershed, threatening runs of anadromous fish. Concerned citizens, fishermen, loggers, landowners, resource management agencies and others formed a coalition to work towards restoration of watershed and fishery. Of significance is that the coalition, formed after storm-caused watershed damage would have been unnecessary given a little forethought and care in land management practices. The message of the Mattole is worth remembering if we learn its lesson.

Threats and Opportunities. We heard about redband trout, uses for hatchery-reared triploid trout in management for wild trout, and more about results of genetic analyses. There are four topics for fisheries managers, scientists, and researchers to consider.

- Recall that conservation agencies cannot escape their responsibility for public perception of the quality of the fishing experience because their (our) actions largely created it.
- Have we (fisheries professionals) chiefly focused on the *hook and bullet* stakeholders, the license buyers?
- W. E. Ricker's classic 1972 paper, *Hereditary and Environmental Factors Affecting Certain Salmonid Populations* (H. R. MacMillan Lectures in Fisheries) should be required reading for every fisheries biologists. Therein is presented common-sense fisheries information about salmon and trout stocks well before detailed and complex genetic analyses were popular.
- Fisheries biologists should also read *Trout Fisheries in New Zealand* (Hobbs 1948) for an early understanding of how fisheries management practices can create public expectations and trends among anglers.

Restoration Projects. Restoration of Montana's Blackfoot River watershed was memorable among presentations in this session. Memorable, because cooperation among private landowners has been crucial to progress made thus far. Fisheries biologists often believe themselves too busy with on-the-water work to invest time in talking with farmers and ranchers along streams. The lesson of the Blackfoot River experience is that investing time in visiting with streamside landowners frequently pays big dividends for watershed and fisheries resources. Will many of us heed the lesson?

Ecosystem Management. This session illustrated the influence of watershed structure and function on the distribution of fishes. Maybe most intriguing was information about the importance of wood and the cycle of replenishing it in streams. Wood (down trees, limbs, branches, and so on) forms shelter for fish, helps store gravel, and assists in maintaining the friendly dynamics of stream systems.

These talks brought to mind Zane Grey's description of Deer Creek, Washington and steelhead fishing (Grey 1918). In 1918, Deer Creek, except at it's junction with the Stillaguamish River, was all but inaccessible. Grey's description of dense forests and heavily wooded stream banks, abundant (and large) steelhead contrasts sharply with what I saw in 1992. The effects of extensive logging and channel straightening were obvious and had contributed to the decline of anadromous fish stocks in Deer Creek. Again, the tireless pursuit of manifest destiny was evident as was after-the-fact realization that fish were nearly gone and that watershed reclamation was necessary. As the 21st Century dawns, perhaps the public as well as fisheries managers will realize that good resource stewardship can conserve fish on balance with sensible development.

Limited Entry Fisheries. Limited entry is most often thought of as a tool for managing commercial fishing. Applied to recreational angling it is another subject about which there are two strong points of view; anglers and fisheries biologists are either strongly opposed to or strongly advocate limited entry fishing.

A favorite Yogi Berra quote seems applicable. *It isn't the things you don't know that can hurt you, it is the things you know for sure that just aint so.*

The limited entry fisheries issue boils down to resource allocation. The basic tenet of fishing as a public resource open and available to all, free of royalty or rent and without undue restriction (Loftus, Holder, and Regier 1980) is already gone. We decry limited entry fisheries as exclusionary, yet when we set slot limits, implement tackle restrictions, or offer catch and release fishing (as here in Yellowstone), anglers wishing to fish otherwise must change their method or face exclusion!

Diamond Lake, highly productive and on Wyoming's high plains, was once private water under the care of a sportsman's club. A $5.00 fee was charged for a limited number of fishing permits. Large fish (5 pounds or more) were frequently landed. Public access to the lake was secured and general, statewide angling regulations applied. With increased fishing, average sized fish (12-14 inches) became most common. A region-wide survey showed anglers agreeable to special regulations, tackle limitations, and keeping fewer fish. By tackle and harvest restriction, Wyoming fisheries managers allocated the fishery among anglers willing to fish according to regulation. People not willing to fish according to the new rules had to fish elsewhere; their entry to the Diamond Lake fishery limited by fishing regulations.

Other forms of limited entry are on the way; will fisheries managers be ready?

Electrofishing Injury. The results of studies completed and the concern for the fisheries resource shown by fisheries professionals is impressive. We really do care about the fish we work with. This concern for fish and Jim Reynolds *Guidelines for Electrofishing* have buried and written the epitaph for the old rule of thumb that if fish can be collected using 100 volts, 600 volts would work even better. I'm convinced that fisheries biologists know how to electrofish sensibly and with minimal risk to fish.

Native Fish. Native fish are important; the Endangered Species Act underscores the importance. Did we concentrate on Stan Guffey's message? He said that the predominant concept in biological conservation at the dawn of the 21st Century is biological diversity, and the compelling goal of conservation is the preservation of native biodiversity. He stressed maintenance of the *authenticity* of a region's biota. When the biota (including fishes, of course) of a region is chiefly composed of native species, it is authentic and distinguished from the "homogenous menagerie" that typifies much of the North American landscape. Retrieving much of the native species diversity of the past will surely challenge fisheries scientists as effort to suppress lake trout in Yellowstone Lake illustrates.

Overall, presenters at this conference should have successfully tweaked our thoughts towards new and insightful resource management goals. Conference organizers can be satisfied that a good program resulted from their work. I am confident that fisheries professionals, with the support of resource aficionados, can meet all the challenges.

REFERENCES

Clawson, M. 1963. Land and water for recreation. Rand McNally & Co., Chicago.

Grey, Zane. 1928. Deer Creek Washington – 1918. Pages 35-55 in Tales of Freshwater Fishing. Grosset & Dunlap, New York.

Hobbs, D. F. 1948. Trout Fisheries in New Zealand, their development and mana gement. New Zealand Marine Department, Fisheries Bulletin 9.

Loftus, K. H., A. S. Holder, and H. A. Regier. 1980. A necessary new strategy for allocating Ontario's fishery resources. Pages 255-264 IN J. H. Grover ed. Allocation of Fishery Resources, Proceedings of the Technical Consultation on Allocation of Fishery Resources, Vichy, France. UNFAO, New York.

Mullan, J. W. 1956. Trout Stream Management in Massachusetts. Massachusetts Division of Fisheries and Game.

Ricker, W. E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pages 27-160 IN P. A. Larkin and R. D. Simon, Eds. Proceedings of a Stock Identification Workshop, University of British Columbia, Vancouver.

Keynote Address: New Directions in the National Park Service

Karen P. Wade[1]

Good morning. I am especially pleased to be here to greet you in this, the very first (and Superintendent Mike Finley would say " THE best") of the 379 units that exist in the National Park System today. I am proud to address this distinguished group of men and women who are intensely interested in the scientific and sporting aspects of Wild Trout. As one who has often thrilled to the tug of a trout on my line, I understand the deep emotions this topic evokes. I have felt the adrenaline that flows when sampling the cold waters of a favorite fishing spot. The sheer pleasure of the contest between fisherman and fish. But there are other strong emotions too: the anger when you find that your favorite stretch of river has been contaminated by industrial or agricultural effluent. The frustration when your favorite stream is closed because of human health advisories, or when whirling disease appears suddenly in your favorite lake. The sense of invasion when you learn that a species of trout is listed as threatened or endangered because of competition with non-natives or because spawning habitat was lost to give way to construction of a dam. And so the story goes ... ...

I am with you today to talk a bit about new directions in the National Park Service which are positive indicators that things are changing. And I wouldn't be here at all if I didn't believe that, working together, we can individually and collectively make a difference.

Specifically, I'm pleased at this late date in my career to be able to say at last that my beloved National Park Service is evolving into an agency with a sharpened focus on its responsibilities for knowledge of our natural systems. In addition, we are seeing a very healthy expansion of curriculum based education programs linked specifically to the science being done in parks. The word is clearly out . . . . We must educate our young people and involve them directly in our conservation programs or we will not raise future generations who care two hoots about fish or fishing.

Our singular goal-our collective goal must always be to treasure these resources as a legacy. They must pass to future generations of Americans as unimpaired as we can possibly keep them. To do any thing less is a derelection of duty and a true national disgrace!

You may not be aware of the evolution of natural resource management in the National Park Service so I'd like to give you a brief history lesson. The agency was established in 1916; but a number of individual parks were created before that, for example, Yellowstone established in 1872. Beginning as far back as Yellowstone, we can say that resource management and protection, especially fishery management, has always played second fiddle to competing visitor recreational demands in the parks.

Over all this time, superintendents were primarily recognized and rewarded for park development projects to accommodate more and more visitors. Today, parks nationwide receive nearly 300 million visitors each year and a large share of them come to enjoy the pristine and primeval beauty, the clean waters, the unobstructed mountains and canyons, and a quality outdoors experience. What most of those 300 million visitors don't appreciate is that the ecosystem health in most of the parks they adore has been seriously compromised by well-meaning managers who have responded over time to the most vocal voices they hear. . . the voices of those demanding more services.

Today, more and more managers find themselves the target of litigation for decisions that don't give resource protection its rightful priority. The dilemma how to satisfy a growing public clamor for access to the spectacular resources in the parks, while at the same time find scarce funding for expensive programs that help conserve these resources "unim-

[1]*Director, Intermountain Region, National Park Service.*

paired for the enjoyment of future generations", as required by our 1916 organic legislation.

Our history of resource protection and visitor enjoyment has been well documented in a book written by Park Service Historian Richard Sellars, titled "Preserving Nature in the National Parks: A History", published in 1997. If you are at all interested in reading about the evolution of Park Service policy and philosophy in terms of resource protection or lack thereof, you may want to pick up a copy-it sets the stage for a new, era for this agency in resource conservation and restoration. Sellar's book all too clearly describes how, during the 125 years since the first park wars established, ecosystem protection and maintenance of native wildlife (including FISHERIES) in an unimpaired condition almost always has taken a back seat to visitor use and its associated infrastructure.

In 1998 Congress enacted the "National Parks Omnibus Management Act" which contained a very powerful and forward-looking mandate: Title II, National Park System Resource Inventory and Management. The Park Service is now required by law to undertake resource inventory and monitoring to establish baseline information and to provide data on long-term trends in the condition of park resources. We MUST do this with other Federal and State agencies, academia and other partners in the larger context of the ecosystems and watersheds within which national parks are found. The Act requires us to use scientific information in making decisions in parks that could affect resources-sounds like a "no brainer" doesn't it? It also requires us to consider trends in the condition of resources of the park in annual performance reviews of park superintendents. (Mike Finley will be called upon to account for how he uses sound science in his decisions in Yellowstone that could affect natural resources.) Finally, a really clear message from Congress that we MUST carry out a comprehensive program of scientific research. Park resources can no longer take a back seat in decisionmaking.

In order to help us carry out our culture shift toward a resource conservation ethic, NPS Director Bob Stanton announced last year a new initiative-the **Natural Resource Challenge.** The Challenge is an action plan and funding strategy to direct major new efforts and funding toward natural resource inventory and monitoring, restoration of natural systems, control of exotic species, recovery of threatened, endangered and other native species, environmental planning and compliance and partnerships with researchers and learning institutions.

While phase I of the funding strategy calls for doubling the agency's natural resource funding by 2004, it contemplates a long-term shift in direction for the agency in understanding, monitoring and protecting park resourcesand fisheries are a part of the effort!

Congress eagerly supported most of the budget increases requested the first year of the Challenge, appropriating over $14 million. In FY 2001 it looks like Congress will again support a very good portion of the $18 million request for the Challenge put forward in the President's budget. The first year funding has been targeted toward getting the inventory program up and running, exotic plant control, onthe-ground habitat restoration projects and establishment of a new national Biological Resource Management Division. Next year, monitoring of "ecological indicators", or vital signs, will get a substantial boost as will T&E recovery, exotic species control and water protection. New concepts of partnerships will be funded with the establishment of five "learning centers" to attract and support researchers at parks. A new partnership concept--Cooperative Ecosystem Studies Units or CESU's-has also been created. Each one consists of a formal network of Federal agencies, a host university and other partner colleges, universities and other academic institutions established to facilitate research on Federal lands.

We are excited about the new emphasis on resource management and protection created by this Challenge. I look forward to working with you and the agencies and organizations you represent in the coming years to make sure that the Challenge will be successful. Together we can make sure that the challenge will become institutionalized and forever change the nature of our business.

Now, on to some specific examples and issues related to trout fisheries and their management in national parks. The history of national parks is replete with efforts to provide recreational fishing to the public-sometimes this was done by restoring, enhancing or promoting the use of native stocks, but often it was the introduction of nonnative wild or hatchery reared stocks. Paul Schullery, in his book "Searching for Yellowstone", writes that "early surveyors were quick to notice that 40% of the park's area was devoid of fish." In response, park administrators worked quickly to increase the recreational fishing opportunities in the park, primarily through stocking. In 1881 the park superintendent (bless his heart!) even suggested stocking CARP into park waters, but fortunately was unable to pull this off.

The goal was to have the best possible sport fishing in all waters that could be stocked, thus a great deal of hasty stocking occurred, including some notable blunders like Atlantic salmon, black bass, yellow perch, and oh that wonderful but exotic rainbow trout, was stocked over native cutthroats! The race was on and by the mid-1900's the program had grown to include FIVE hatcheries, extensive put-and-take stocking programs, and a cutthroat trout hatchery that exported up to 40 million fish annually! Maximum sustained yield was the battle cry of the day for the park. Notably, though, even in the earliest part of the century some of Yellowstone's administrators attempted a level of discreteness about stocking and were opposed to bringing in new species of fish or even mixing species, in their fishery program. The story goes that in 1907 a U.S. Bureau of Fisheries employee was given a written reprimand by his superior for stocking rainbow trout over native cutthroats in Yellowstone Lake! In the 1920's the American Association for the Advancement of Science and the Ecological Society of America resolved to oppose any more introduction of "new" plants or animals to National Parks. Finally, in 1936 formal Park Service policy was established that prohibited stocking of nonnative fish where natives existed. It also discouraged propagation of native fish for stocking purposes, prohibited introduction of nonnative fish food organisms, and recognized that certain "fishless" waters were best left "fishless" in order to conserve the ecological system that had evolved absent fish. And in 1938 Yellowstone was the first park to begin active repair of damage that had been created through stocking by poisoning yellow perch in one small lake. By the 1960's Yellowstone and many other parks had backed away from the "maximum sustained yield" concept in fisheries management.

It may appear that I'm picking on Yellowstone, but this is NOT just about Yellowstone. Yellowstone is a convenient icon for how fisheries and fisheries management evolved in our parks and on our public lands in our zeal to meet the public demand for sport fishing.

As a result, habitats that support native fish have been dramatically altered, damaged and fouled throughout much of this nation. In 1987 a publication of the American Fisheries Society reported that of 743 full species of native freshwater fishes on this continent, over half were already receiving some degree of endangered species protection. Of these, 235 species were fully protected by one or more governmental agencies under endangered species legislation in all or part of their range. Since that time a substantial number of additional species have been listed under the Endangered Species Act or petitioned for listing. Throughout the west nearly all native trout populations are either listed or petitioned for listing.

The only way we can reverse this trend is through working together, agency with agency, organization with agency, and all of us with landowners, to understand the factors that are causing the severe decline of native fish. We must then stand together, sometimes in the face of great opposition from constituents and politicians, to take the actions needed to prevent further declines and restore viable and sustain native trout populations-YOURS AND MINE.

I am saddened to say that the Park Service has not been completely successful in following our own policies. We are STILL stocking non-natives in some areas, and have not restored natives yet in areas where we could. These are generally situations where our state partners are not yet in a position to back away from nonnative fisheries. But we are making serious progress. We are engaged in restoration of many native trout species and populations throughout the nation, and we are doing it in partnership with many of your agencies and organizations. Beginning right here, we are pursuing reduction of lake trout populations in Yellowstone Lake where this introduced species is not only impacting the native Yellowstone cutthroat (a petitioned species), but also another listed species the grizzly bear.

Grizzlies depend heavily on the cutthroat for food as the trout ascend small tributaries to spawn. This park is also restoring the westslope cutthroat and fluvial grayling populations. At Crater Lake National Park, listed bull trout populations are being restored through stream restoration and removal of nonnative species, primarily brook trout. The Bonneville cutthroat is being restored at Great Basin National Park including removal of nonnative trout--an effort that may preclude the need to list this population. A side benefit of the Great Basin program has been the discovery and protection of several populations of other imperiled aquatic species, which has for the moment precluded the need to list these as well. At Great Smoky Mountains National Park where I served as superintendent before coming to Denver, we were very actively engaged in restoring the native Appalachian brook trout where they had lost nearly 80 percent of their natural range due to encroachment of nonnative trout and stream acidification. At the Great Sand Dunes National Monument in Colorado, the Rio Grande cutthroat had been

nearly wiped out by the time it had been petitioned for listing under ESA. Sand Dunes staff and the state have partnered up since the 1980's to remove the nonnative German browns and brook trout and restore pure strain stocks to the major drainage of this park. A last example, the coaster brook trout subspecies that historically inhabited the Great Lakes and a popular game fish was almost fished to extinction and displaced by nonnatives in their spawning streams. The Park Service at Isle Royale and Pictured Rocks is an active partner in the restoration of this population in and around the parks of Lake Superior.

These are but a few of the active native trout restoration programs underway in the Park Service, and there are many more. But this isn't JUST about the Park Service-- the point is that we are all in this together with a common cause to restore populations and habitat of wild trout Native Trout in as many locations. as possible before the opportunities are gone forever.

Especially in recent times, Federal conservation agencies and states have often been at odds over the native vs. introduced trout issues. Many popular fisheries have been created through stocking of nonnatives-Flathead and Yellowstone Lake lake trout come to mind. But there has been a substantial cost that resulted from these introductions in loss or reduction in native species and legal classification of remaining native fish. As difficult and politically charged as some of these issues are, it is crucial that the Federal, State and Tribal fish and wildlife management agencies come to the table to forge cooperative programs to maintain healthy, viable ecosystems and the biological diversity inherent in healthy systems.

And this brings me to my final but all too important point-collectively, we who care about and have responsibility for the management and conservation of fish and wildlife and their habitats must engage the public in a serious dialogue and with serious education and outreach programs. We must involve them in our work and make them a part of our plans and actions to preserve and restore these important resources. To some, a trout is a trout is a trout and it doesn't matter if it's a native of the area or introduced from some other place. Perhaps to the casual observer, a beautiful reservoir built for flood control and recreation is okay if it provides a sport fishery comprised of introduced and hybrid fish. Perhaps to the casual observer, a stream is still beautiful even when its laced with heavy metals and other contaminants that create unhealthy conditions for people as well as aquatic species. Perhaps to the casual observer, there will always be a technological solution to the ecological problems of the planet.

But to you and me who know better. . .who know the dangers of contamination and insidious loss of habitat quantity as well as quality; who know the potential dangers of exotic species to native fish and wildlife; who know the dangers of a complacent public . . . WE must teach and reach out to bring the public into the equation. Yes, we need to continue to seek the answers to the scientific questions about ecosystems and species and genetics and human behavior, and good science must be used in decisionmaking. But in our world of politics and bureaucracies, decisionmaking is omen directly influenced by not only the scientific information available, but also the beliefs and perceptions of the public at large. Ladies and gentlemen, lets stand side-by-side, together, and ensure that the public constituencies know about and support the needs for scientific resource management and are willing to stand up and be counted when it comes time to express their views to the politicians and decisionmakers at all levels. We need to think about the future, and the youth who will be the voters and decisionmakers 10, 20 and 30 years from now and implement strategies to reach out to these young people, engage them in educational programs, employment, and recreational activities that will expose them to these wonderful resources and to accurate knowledge about their natural world. The academic world-at all levels-can help us in this endeavor through cirriculum development programs, research, classroom and outdoor classroom instruction, business management, and data management systems. There is a vast untapped pool of people interested in volunteering to help us just because of their love of nature and an opportunity to work with fish and wildlife-lets give them that opportunity today! If we are to succeed in our goal of preserving and restoring trout populations for use by the recreating public or for their ecological place in our waters, we must find ways to communicate with each other and with the public in meaningful and effective ways.

Thank you so much for inviting me to share some of my thoughts about a topic that is near and dear to my heart and soul, and to that of my agency. I wish you well in your sessions over the next several days, and as you return home. Have a wonderful week in YOUR National Park!

Luncheon Address: Do Fish Feel Pain?[1]

James D. Rose[2]

Abstract—Extensive research shows that pain is a psychological experience separate from behavioral reactions to injurious stimuli. Although reactions to noxious stimuli are universal in animal life, including protozoa, these reactions don't always mean that pain is experienced because it isn't necessary for a noxious stimulus to be consciously perceived for a behavioral reaction to occur. In all vertebrates, behavioral responses to noxious stimuli are controlled by lower levels of the nervous system: the brainstem and spinal cord. However, neural activity in these levels is not consciously perceived. The capacity to consciously perceive and suffer from noxious stimuli, as humans do, requires a complex brain, especially enlarged cerebral hemispheres composed of neocortex. Fish have small cerebral hemispheres lacking the type of cerebral cortex (or any alternative system) necessary for the psychological experience of pain. Therefore, it is highly unlikely that a fish's reactions to noxious stimuli are associated with feelings of pain or distress. Although noxious stimuli may cause physiological stress in fish, this stress response is controlled by unconscious, subcortical brain processes. Consequently, considerations of fish well being should recognize the impact of stress-causing conditions even though it is improbable that fish can experience emotional distress.

Do fish, like humans, experience pain and suffering? People hold very differing beliefs about this question. Some would believe that if fish react to stimuli that would cause a person to feel pain that the fish must also be feeling pain. Others assume that fish are too different from humans for the matter to be of concern. Many people don't know quite what to think about the issue. Neuroscience research has clarified the neurological and psychological processes that cause the experience of pain, so we can address this question from a large base of factual information.

PAIN IS A PSYCHOLOGICAL EXPERIENCE THAT IS SEPARATE FROM BEHAVIORAL REACTIONS TO INJURIOUS STIMULI

It has become very clear that pain is a psychological experience with both a perceptual aspect and an emotional aspect. The perceptual aspect tells us that we have been injured, like the first sensation when you hit your thumb with a hammer. The emotional aspect is separate as in the suffering that follows after we are first aware of hitting our thumb. But, injurious stimuli do not always lead to the experience of pain. Think of a trip to the dentist. When a dentist injects a local anesthetic into your jaw to block nerve conduction, some of your teeth and a part of your mouth feel numb. When a tooth is then drilled, the sensory nerve cells in the tooth that would normally trigger pain are still excited, but the nerve block prevents activity in these receptors from being sent to the brain, so pain is not felt. In addition, a person's behavioral reaction to pain is separate from pain experience. We see this separation when a person endures pain without showing any discomfort. On the other hand, people sometimes react behaviorally to injury without any feeling any experience of pain or suffering. This kind of separation between behavioral and psychological responses to injury results from certain forms of damage of the brain or spinal cord. Because the experience of pain is separate from the behavioral response to injury, the term nociception is used to refer to detection of injury by the nervous

[1] *A version of this paper was published in the January 2000 edition of In-Fisherman.*

[2] *Professor, Department of Psychology and Department of Zoology and Physiology, University of Wyoming, Laramie, WY.*

system (which may or may not lead to pain). Injurious stimuli that usually lead to pain experience are called nociceptive stimuli. The term pain should be used only to refer to the unpleasant psychological experience that can result from a nociceptive stimulus.

REACTIONS TO INJURY ARE PRESENT IN ALL FORMS OF ANIMAL LIFE BUT THESE REACTIONS DO NOT MEAN THAT PAIN IS EXPERIENCED

In humans, reactions to nociceptive stimuli are usually associated with feelings of pain. Consequently, humans often assume that reactions by animals to nociceptive stimuli mean that these animals experience similar pain. In reality, reactions to nociceptive stimuli are protective responses that can occur in forms of life that are incapable of perceiving pain. The ability to detect and react to nociceptive stimuli is a widespread characteristic of animal life. Single-celled creatures such as an ameba will move away from irritating chemical or mechanical stimuli. These reactions are automatic and because the ameba doesn't have a nervous system, it has no ability to actually sense the stimulus that causes its reaction or to feel pain. There are many other invertebrate organisms (animals without backbones) that also react to nociceptive stimuli, but with somewhat more complex patterns of escape than an ameba. For example, starfish have a primitive nervous system that interconnects sensory receptors detecting injurious stimuli with muscle cells that cause movements, enabling the starfish to slowly move away from a nociceptive stimulus. The starfish's nervous system has only a small number of nerve cells. It has no brain, so like the ameba, its reactions are not very precise or complex and it can't experience, in the way of humans, the stimuli that trigger its reactions. Thus, protective reactions don't require very complex nervous systems and can occur in animals incapable of perceiving, that is being aware of, the stimuli that cause such reactions.

IN VERTEBRATES, REACTIONS TO INJURIOUS STIMULI ARE CONTROLLED BY THE SPINAL CORD AND BRAINSTEM

Vertebrates generally have more complex nervous systems than invertebrates and vertebrates have a clearly developed brain. This brain receives information from the spinal cord about nociceptive stimuli that contact the body surface. Working together with the spinal cord, the brain generates rapid, coordinated responses that cause the organism to escape these stimuli. These automatically generated responses include withdrawal of the stimulated body part, struggling, locomotion and in some animals, vocalizations. All of these responses are generated by the lower levels of the nervous system, including the brainstem and spinal cord.

HUMAN EXISTENCE IS CEREBRALLY-DOMINATED- A FISH'S EXISTENCE IS BRAINSTEM DOMINATED

Human existence is dominated by functions of the massively developed cerebral hemispheres. Fishes have only primitive cerebral hemispheres and their existence is dominated by brainstem functions. The brains of vertebrate animals differ greatly in structural and functional complexity. Cold-blooded animals, such as fish, frogs, salamanders, lizards and snakes, have simpler brains than warm-blooded vertebrates, the birds and mammals. Fish have the simplest types of brains, of any vertebrates, while humans, have the most complex brains of any species (Fig. 1). All mammals have enlarged cerebral hemispheres that are mainly an outer layer of neocortex. Conscious awareness of sensations, emotions and pain in humans depend on our massively-developed neocortex and other specialized brain regions in the cerebral hemispheres. If the cerebral hemispheres of a human are destroyed, a comatose, vegetative state results. Fish, in contrast, have very small cerebral hemispheres that lack neocortex. If the cerebral hemispheres of a fish are destroyed, the fish's behavior is quite normal, because the simple behaviors of which a fish is capable (including all of its reactions to nociceptive stimuli) depend mainly on the brainstem and spinal cord. Thus, a human's existence is dominated by the cerebral hemispheres, but a fish is a brainstem-dominated organism.

The capacity to perceive and be aware of sensory stimuli, rather than just react to such stimuli requires a complex brain. In humans, the cerebral hemispheres, especially the neocortex, is the functional system that allows us to be aware of sensory stimuli. If the cortex of the human brain is damaged or made dysfunctional, we lose our awareness of sensations. For example, damage of the visual part of the cortex causes blindness, even though vision-related sensory activity is still occurring in subcortical parts of the brain. If the neocortex is widely damaged we lose

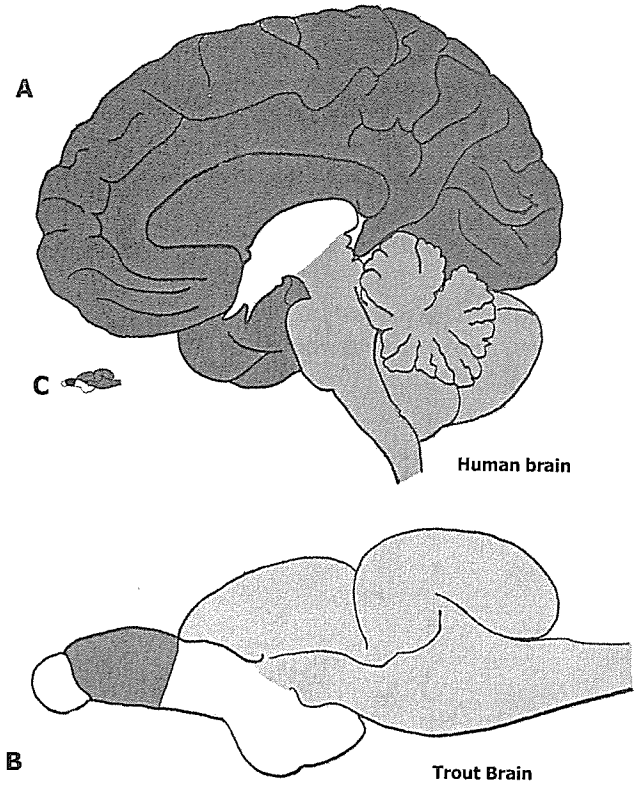


Figure 1.—Comparison of human brain with a trout brain. A. Diagram of a midline view of the human brain. The cerebral hemisphere is shaded in darker gray and the brainstem is in lighter gray. B. Diagram of a midline view of a rainbow trout brain. The cerebral hemisphere (darker gray) is very small relative to the size of the brainstem (lighter gray). The white region at the left of the cerebral hemisphere is the olfactory bulb, which processes odor information. The olfactory bulb of a trout and many other fishes is large compared to the size of the brain as a whole, but the olfactory bulb in humans is relatively small. C. Diagram of the brain of a 12 inch rainbow trout shown at the same scale as the human brain diagram.

our capacity to be aware of our existence in general. This loss of awareness occurs in spite of the fact that the levels of our nervous system below the cerebral hemispheres, the brainstem and spinal cord, can still be functioning and processing signals from sensory stimuli, including injurious stimuli. In a fish, "seeing" is performed by the brainstem and occurs automatically without awareness. Consequently, a fish's visual behavior is quite normal if the small cerebral hemispheres are removed, but a human is blind if the visual cortex region of the cerebral hemispheres is destroyed. This is because our visual behavior depends greatly on conscious awareness of visual sensations.

In spite of our unawareness of brainstem functions, the brainstem and spinal cord contain programs that control our more automatic behavioral functions. Smiling and laughter, vocalizations, keeping our balance, breathing, swallowing and sleeping are all processes that are generated by these lower, brainstem and spinal cord programs.

FISH DO NOT HAVE THE BRAIN DEVELOPMENT NECESSARY FOR THE PSYCHOLOGICAL EXPERIENCE OF PAIN OR ANY OTHER TYPE OF AWARENESS

The experience of pain depends on functions of our complex, enlarged cerebral hemispheres. The unpleasant emotional aspect of pain is generated by specific regions of the frontal lobes of the human cerebral hemispheres. The functional activity of these frontal lobe regions is closely tied to the emotional aspect of pain in humans and damage of these brain regions eliminates the unpleasantness of pain. These regions do not exist in a fish brain. Therefore, a fish doesn't appear to have the neurological capacity to experience the unpleasant psychological aspect of pain. The rapid, well-coordinated escape responses of a fish to nociceptive stimuli are generated automatically at brainstem and spinal cord levels but, if a fish's brainstem and spinal cord work like a humans (and it is very likely that they do) there is no awareness of neural activity occurring at these levels.

It might be argued that fish have the capacity to generate the psychological experience of pain by a different process than that occurring in the frontal lobes of the human brain, but such an argument is insupportable. The capacity to experience pain, as we know it, has required the massive expansion of our cerebral hemispheres, thus allocating large numbers of brain cells to the task of conscious experience, including the emotional reaction of pain. The small, relatively simple fish brain is fully devoted to regulating just the functions of which a fish is capable. A fish brain is simple and efficient, and capable of only a limited number of operations, much like a 1949 Volkswagen automobile. By comparison, the human brain is built on the same basic plan as that of a fish, but with massive expansions and additional capacities. The human brain is more like a modern luxury car with all-wheel drive, climate control, emission controls, electronic fuel injection, anti-theft devices and computerized systems monitoring. These refinements and additional functions couldn't exist with-

out massive additional hardware (Fig. 2). The massive additional neurological hardware of the human cerebral hemispheres makes possible the psychological dimension of our existence, including pain experience.

There are also huge differences between mammals in the degree of complexity of cerebral hemisphere development, especially within the frontal lobes. The brains of predatory mammals are typically larger and more complex than brains of their prey. For example, the brains of sheep and deer have a tiny fraction of the frontal lobe mass that is present in humans, making it probable that the kinds of psychological experience of these animals, including pain, is quite different from human experience.

THE REACTIONS OF FISH TO NOCICEPTIVE STIMULI ARE SIMILAR TO THEIR REACTIONS TO PREDATORS AND OTHER NON-NOCICEPTIVE STIMULI

When a fish is hooked by an angler, it typically responds with rapid swimming behavior that appears to be a flight response. Human observers sometimes interpret this flight response to be a reaction to pain, as if the fish was capable of the same kind of pain experience as a human. From the previous explanation, it should be clear that fish behavior is a result of brainstem and spinal patterns of activity that are automatically elicited by the stimulation of being hooked, but that fish don't have the brain

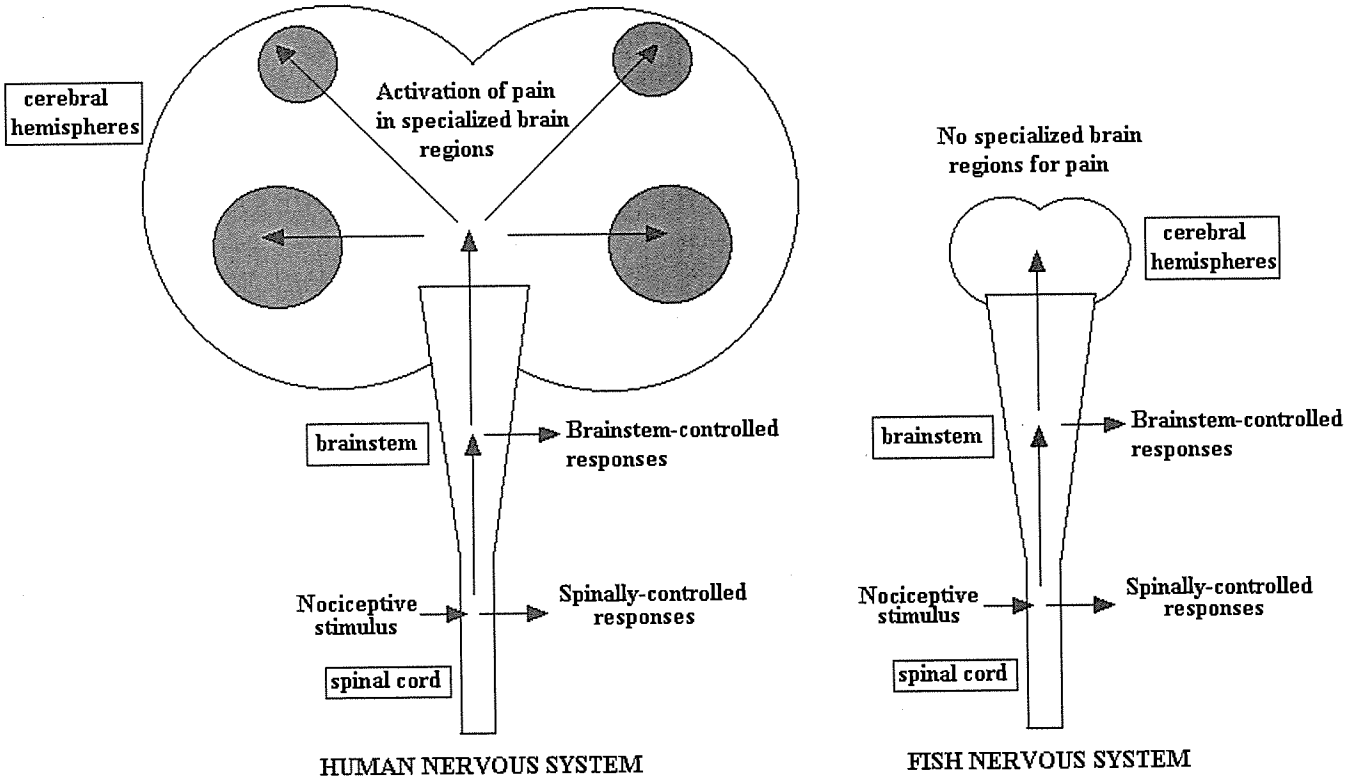


Figure 2.—The diagram on the left shows the basic regions of the human central nervous system, the large cerebral hemispheres, the brainstem and the spinal cord. Injurious sensory stimuli (nociceptive stimuli) on the body surface activate receptor neurons, which conduct that neural activity to the spinal cord. At the spinal cord level, some protective reactions are generated, including withdrawal of the stimulated body part and some aspects of locomotion. The nociceptive activity is transmitted to the brainstem where additional protective reactions are generated, including turning toward the stimulus, fully-developed locomotor and avoidance responses and vocalizations. The nociceptive activity is transmitted from the brainstem to certain parts of hemispheres cerebral where it activates conscious awareness of the nociceptive stimulus and generates the emotional unpleasantness of pain. Until the neural activity reaches the cerebral hemispheres, the reactions to the nociceptive stimulus are not consciously experienced, that is they are not associated with a feeling of pain. The fish central nervous system, shown on the right, consists of a simpler version of spinal cord and brainstem, with only very small and primitive cerebral hemispheres. The neural functions that generate behavioral responses to a nociceptive stimulus are much the same at the spinal cord and brainstem levels as in a human. But, because the fish cerebral hemispheres lack the regions necessary for conscious awareness and for generation of pain experience, there is no pain associated with the brainstem and spinally-generated behavioral reactions.

systems necessary to experience pain. It is very important to note that the flight responses of a hooked fish are essentially no different from responses of a fish being pursued by a visible predator or a fish that has been startled by a vibration in the water. These visual and vibratory stimuli do not activate nociceptive types of sensory neurons so the flight responses can't be due to activation of pain-triggering neural systems. Instead, these flight responses of fish are a general reaction to many types of potentially threatening stimuli and can't be taken to represent a response to pain. Also, these flight responses are unlikely to reflect fear because the brain regions known to be responsible for the experience of fear, which include some of the same regions necessary for the emotional aspect of pain, are not present in a fish brain. Instead, these responses are simply protective reactions to a wide range of stimuli associated with predators or other threats, to which a fish automatically and rapidly responds.

The facts about the neurological processes that generate pain make it highly unlikely that fish experience the emotional distress and suffering of pain. Thus, the struggles of a fish don't signify suffering when the fish is seized in the talons of an osprey, when it is devoured while still alive by a Kodiak bear, or when it is caught by an angler.

FURTHER READING

Much of the evidence supporting the conclusions of this paper is found only in specialized neuroscience literature. The references designated by * are more appropriate for the interests of non-specialist readers wishing to know more about species differences in brain function or the bases of conscious awareness of experiences, including pain.

*Allman, J. 1998. Evolving brains. Scientific American Library: New York

Butler, A. B. and Hodos, W. 1996. Comparativevertebrate neuroanatomy: Evolution and adaptation. Wiley-Liss: New York.

Craig, K.D. 1994. Emotional aspects of pain. In P.D. Wall & R. Melzack (Eds.), Textbook of Pain, 3rd Ed (pp. 261-274). Churchill Livingston: Edinburgh.

Davis, R. E. and Kassel, J. 1983. Behavioral functions of the teleostean telencephalon. In R. Davis and G. Northcutt (Eds.) Fish neurobiology. Vol. 2. Higher brain functions. (pp. 237-264). University of Michigan Press: Ann Arbor.

*Donald, M. 1991. Origins of the modern mind. Harvard University Press: Cambridge.

Jouvet, M. 1969. Coma and other disorders of consciousness. In P.J. Vinken & G.W. Bruyn (Eds.) Handbook of Clinical Neurology, Vol. (3) (pp. 62-79). New York: Elsevier Science Publishers.

Kandel, E. R., Schwartz, J. H. and Jessel, T. M. 2000. Principles of neural science. McGraw-Hill: New York.

*Kennedy, J. S. 1992. The new anthropomorphism. Cambridge University Press: Cambridge.

*Kolb, B. and Whishaw, I. Q. 1995. Fundamentals of human neuropsychology. W. H. Freeman: New York.

Libet, B. 1997. Consciousness: neural basis of conscious experience. G. Adelman and B. H. Smith (Eds.), The encyclopedia of neuroscience. Elsevier: Amsterdam. CD ROM

*Macphail,-Euan-M. 1998. The evolution of consciousness. Oxford University Press: New York.

Melzack, R., and Fuchs, P.N. 1997. Pain, general. In G. Adelman & B. Smith (Eds.) Encyclopedia of Neuroscience. Elsevier: Amsterdam. CD ROM.

Nieuwenhuys, R., ten Donkelaar, H. J. and Nicholson, C. 1998 The central nervous system of vertebrates. Springer: Berlin

Overmier, J.B. and Hollis, K. 1983. The teleostean telencephalon and learning. In R. Davis and G. Northcutt (Eds.) Fish neurobiology. Vol. 2. Higher brain functions. (pp. 265-284). University of Michigan Press: Ann Arbor.

Preuss, T. M. 2000. What's human about the human brain? In M. S. Gazzaniga (Ed.), The new cognitive neurosciences. (pp. 1219-1234). MIT Press: Cambridge.

Treede, R.-D., Kenshalo, D. R., Gracely, R. H. and Jones, A. K. P. 1999. The cortical representation of pain. Pain. 79/ 105-111.

Wall, P.D. 1987. Pain: Neurophysiological mechanisms. In G. Adelman & B. Smith (Eds.) Encyclopedia of Neuroscience. Elsevier: Amsterdam. CD ROM.

Wulliman, M. F. The central nervous system. 1998. In D. H. Evans (Ed.) The Physiology of Fishes. (pp. 245-282). CRC Press: Boca Raton

Young, G. B., Ropper, A. H. and Bolton, C. F. 1998. Coma and impaired consciousness. McGraw-Hill: New York.

Xu, X., Fukuyama, H., Yazawa, S., Mima T., Hanakawa, T., Magata, Y., Kanda, M., Fujiwara, N., Shindo, K., Nagamine, T., and Shibasaki, H. 1997. Functional localization of pain perception in the human brain studied by PET. NeuroReport, 8/ 555-559.

Banquet Address: The Many Sides of the Wild Trout Issue

Thomas McGuane

INTRODUCTION

When asked to come to this event, I felt a sort of trepidation and not just because I am unaccustomed to public speaking. I was aware that many of you are scientists and professional resource managers and I seriously questioned the pertinence of my experience in speaking to you. As an angler, I have spent my life as the complaining but non-consumptive user of aquatic recreation. I have served on environmental boards whose reason for being was research and found that my services were welcome in either fund raising or, because I am a writer, advocacy. I am a great fan of real research and pure science but in our increasingly out of control work, I have come to think that our hope, particularly comradeship between all the players, high and low, who have the well-being of our waters at heart.

I come to all things as an angler. It is not so much an obsession as it is the air I breathe. My first dream of being an ichthyologist evaporated when I learned through my classes in biology that the wholly poetic and mythological and romantic view I held of life astream was not particularly in the service of quotidian truth. For many years, I accepted my limitations, happy just to be happy. I had nothing to pass on to the public about fish and waters: I was satisfied to be *with* them. Some plans I abandoned as unrealistic; for example, the excavated bedroom with a picture window opening into a streambank. I substituted a ten gallon aquarium and went to sleep gazing at guppies for more than a decade. Over the years, and as my society came to be dominated by other anglers, I realized that there was something universal in our passion; and that, more importantly, we were powerful.

And yet: in the early 1990s my home state of Montana had the strongest water quality standards in the West. Now they are among the weakest in the nation. It is one thing for anglers to wax poetic over A River Runs Through It and quite another – more disquieting – thing when so many who are dependent upon pristine waters allow this to happen.

In the year of the Yellowstone floods, several things occurred to give me pause about the vision of nature possessed by the average angler. It was the age of unbounded riprap, as everyone from ranchers, streamside homeowners to trailer park operators hurled themselves into bank stabilization. Any inclination to resist the armoring of the Yellowstone was forgotten in the race to protect the pay fisheries on the Livingston Spring creeks. Some fly shops were advertising the virtues of riprap as reliable fish habitat. One authority stated publicly that the work of American Rivers and other organizations to stop the armoring of the Yellowstone was misguided. He had just had great dryfly fishing on a section of riprapped bank. Therefore, mechanically stabilized banks were in the best interest of wild rivers!

A previous speaker at this proceeding noted that anglers can identify their quarry and even the complex families of invertebrates that their quarry prey on but the commonest inhabitants of the stream which are not among their targets are completely unknown. I remember when the sculpin was first widely "discovered" by anglers upon learning that trout liked to eat them. It reminds me of bird hunters who call non-game species, "shit birds" or "chi-chi-birds". This might include peregrine falcons. An exception would be the bald eagle, as sportsmen tend to be patriotic.

Of course, all this must change if sportsmen are to be true partners in managing the wellness of our wild lands.

And what about the research scientist who watches his efforts disappear into some archival black hole with nothing to show for it but a promotion or a mild increase of self-esteem. Wouldn't it be better to see positive change as a result of his work? Perhaps, he should be aware of his need for allies in the non-scientific world. When I talk to my friend Carl Bock, a distinguished fire ecologist, I am relieved to find that he is such a driven fisherman that he wears out his waders annually. I suspect his science and his ostensibly useless but poetic passion will strengthen

his pragmatism. Aldo Leopold was a *feverish* sportsman and Roderick Haig-Brown saw conversation and angling as two sides of the same coin.

I observed something recently which spoke of the many sides of wild trout issues. I had just parked my car in a Bozeman Costco parking lot, an expanse of asphalt that seemed at least by local standards to be bound only by the horizon. In the near distance, the earth was being opened to accommodate a new motel, one that could be viewed from the interstate in a blizzard. Near the parking lot was a small stream, small enough that you could straddle it. It seemed a very forlorn location for moving water of any kind but in Montana it was liable to be a trout stream. Uniformed employees of Montana Fish, Wildlife and Parks were working their way along this sad piece of water electroshocking it for a fish survey. Gloomy curiosity sent me their way to observe: trout were rolling up to the surface in astonishing numbers and their form indicated an ample prey base. But the scene suggested that nature was being bounteous well beyond the call of duty, if indeed nature *has* a duty to us. This stream was something of a diamond in the rough and, frankly, deserved better than a parking lot and a new motel; and yet there is something encouraging about the scene, encouraging in the accommodations of nature, the examination and concern of the fisheries technicians, the incredible vitality of our fisheries. While the big box store fuelled the consumer and the new motel housed the rootless spillover from the interstate, somehow the little stream kept doing its millennial work.

We are increasingly aware of the precariousness of the very idea of wildness. One of the strangest experiences I've ever had was steelhead fishing on the Nehalem River in Oregon where bright, strong hatchery fish return in considerable volume. Our pleasure at our success began to diminish as we detected signs of management: these fish didn't linger along the riverway on their return to the place of their origins like wild fish: they bee-lined their way to the hatchery offering limited opportunities, limited that is, on their first trip up the river. The solution to this problem was to truck them back to tidewater, over and over again, hole punching first the left gill plate, then the right. The adipose fin was already removed to identify them as hatchery stock. Each trip to tidewater set them out on another gauntlet to the hatchery, providing "angler opportunities" along the way.

I don't have to burden you with a description of what was missing. What was missing was everything.

But where is the line where light handed and effective management stops short of eradicating wildness? The very concept of "management" is problematical for me. It suggests that "WE" will provide a set of controls for "THEM". Ideally, in ecosystem based approaches to management it's "US" and "US". Otherwise, all is enforcement. And as we watch the gradual erosion of Mother Earth before the rapacity of development, it becomes clear that we can't expect too much from enforcement, as there can never be quiet *enough* enforcement to shore up the retreating frontiers of the natural world. As wispy as this may sound, we're going to have to change, evolve and improve spiritually or we're going to lose the whole thing. We're going to have to learn to *care*. Since charity begins at home, my sense is that those anglers and scientists, to whom these aquatic realms matter so deeply will have to have values larger and more overarching than that which is on the plate in front of them, whether the glories of recreating in the natural world or the pure pursuit of scientific knowledge. Science and advocacy can no longer be separated any more than conservation and sport fishing. Everybody will have to do both if we're to have a chance. *If we're to have even a chance.* In these realms, pure science doesn't exist and recreation without its profound responsibilities is a sin.

I once was quail hunting as a guest in the South on what is called a plantation but which "plants" nothing. Halfway through the day, I noticed that the beakless quail we were shooting did not fly like wild birds, had lost their beaks grinding away for food in concrete runs, and I asked the manager – rather gently I thought – if the plantation contained any *wild* birds. "Mister McGuane, " said the manager very firmly, " as far as I'm concerned, a wild quail *is nothing but a management problem.*" Well, he was right about that. Wildness is management problem. But when we're talking about wildlife management, it's the *only* problem. Your job as wildlife managers is not to provide recreational opportunities; it is to provide wildness.

Everybody has to help. The angler who prides himself on his catch-and-release ethics should be asked *how many are you catching and releasing*. There is mortality connected to catching and releasing. The angler who releases that fifty fish he caught on a three

split shot indicator nymph rig is not *entitled* to congratulations. Moreover, some have plausibly argued that catch-and-release is cruel; native bands in Canada have closed rivers altogether rather than submit to catch-and-release which they view as immoral playing with the fish.

The answer is restraint and the elevation of our capacity for appreciating nature so that the catch rate doesn't have to bear *all* the weight of the experience.

When I was in Russia, in a district where the local game warden shipped 20 or 30 gall bladders a year to Asia from the bears he killed but was paid to protect, a despairing local biologist told me that wildlife populations were bound to crash because "nature can never survive democracy." Are we in North American so confident that nature *can* survive democracy? Is everyone entitled to consume wildlife? What alternatives do we have to polling special interest groups in devising management policies? *I wish I knew.* I suspect that the day will come when hunting, fishing and access to wildlands will not simply be a universal entitlement: somehow, you will have to earn it, or you will have to own it. It will not be the same as air. Limited access or even fee fishing on public waters will be hard sell. Many Americans, upon learning that it is not free, are going to be furious.

In my years on the American River board, I learned several things about water. The overriding issue for most citizens is whether or not they can drink their tap water. This does not, for some reason, imply a great respect for clean water but they want lots of it. Americans are among the only people on earth who wash their cars in drinking water. If you want to save trout in America, one pitch is: *the presence of trout MAY INDICATE that you can drink the water.* And don't count on the idealism of the public. The end of the Cold War did not liberate millions for conservation projects. It just fueled the bonfire of consumerism. Our only hope is that a new class of persons will emerge who don't want to go to their graves with these shabby values.

Good wildlife management will be fiercely controversial and not everyone can stand that kind of pressure. Those who can have *all* my sympathy and *all* my admiration.

Manage First For Wild Trout

Robert L. Hunt

Approximate remarks following receipt of the A. Starker Leopold Professional Award

I am optimistic about future possibilities to expand the number and quality of wild trout fisheries in North America, more optimistic than I was when I participated in the first Wild Trout Management conference held here in 1974. Since then, and in large part because of that conference and its predecessor symposia, two significant trends have evolved that have heightened my sense of optimism for the future of wild trout fisheries.

The first trend has been a greatly increased awareness by fisheries management biologists and their angler clientele that hatchery reared, inbred, domesticated strains of trout cannot provide fishing quality comparable to that provided by fisheries sustained by wild trout. Wild trout are now almost universally recognized by anglers as having an inherent experiential value in terms of observing, fishing for, and catching that domesticated trout cannot provide because of genetic and behavioral deficiencies.

The second trend has been an increased awareness of and appreciation for the fragile environmental qualities necessary to sustain wild trout populations. There is a real but hard to quantify add-on value to the experience of fishing a stream or pond that sustains all life stages of wild trout on a year-round basis.

As fisheries management professionals, I believe we need to capitalize more than we have done so far on these two experiential attributes associated with wild trout fisheries. I suggest that one way we could do so would be formulation of and support for a simple foundational principle that could guide management agencies (state, federal, tribal, or private) to more fully implement strategies favoring wild trout fisheries.

I propose the need for a principle similar to that which under grades another branch of applied science more important and much more complicated than our profession, namely the science of human

medicine. From the jungle witch doctors to the most prominent medical clinic specialists, a common ethic determines their treatment of patients seeking their help: First do no harm. These four simple words provide a unifying and universal bond of professional obligations that have contributed immeasurably to the ways in which medical science is applied and to the confidence that patients have in the doctors and nurses they submit to for medical care.

There is more than enough collective talent among us today to think up a comparable foundational directive we could promote to guide our evolving science of trout fisheries management toward greater emphasis on wild trout management simply because it is the right thing to do and best serves our clientele. I offer one such example as a starting point: Manage First For Wild Trout.

Here are three brief scenarios to which this guiding principle could be applied:

First, for the increasing number of fisheries adequately maintained by wild trout populations, management emphasis would be placed on preservation and protection of healthy watersheds and instream habitat qualities that allow wild trout to thrive, plus imposition of angling regulations that prevent excessive harvest. Just continue to vigilantly "manage first for wild trout".

Scenario two would apply my simple directive to those fisheries entirely dependent now on periodic stocking of domesticated trout. Reexamine each such fishery. Is stocking of domesticated trout the only option or is it simply done be- cause it is the easiest and cheapest option? Consider in each case this alternative: Manage first for wild trout by managing first with wild trout. Yes, they are harder and more expensive to culture for a few months, but poststocking survival can be expected to be several fold greater and, more importantly, pro- vide the add-on value that only wild trout can offer.

The third scenario would cover the potentially greatest option for increasing the number and quality of wild trout fisheries - doing what is necessary to restore trout habitat quality so that stocking of domesticated trout is not necessary or desirable. Field tested stream, riparian zone, and watershed rehabilitation techniques are "on the shelf and ready to go". What seems to be lacking is simply management agency fortitude to adopt, fund, and implement policies to "manage first for wild trout".

These three brief examples are not impractical , untried options. I am grateful that I have had a part in contributing to just such implementations in my home state of Wisconsin where the Dept. of Natural Resources now places first priority on managing the public trout streams and spring ponds to provide fishing for wild trout. I challenge each of you to go back to your agency and encourage , as best you can, adoption of a similar SOP. You can be the one to ask, "If not, why not?"

Robert L. Hunt with especially robust brown trout caught on Montana Creek in Montana.

2000 A. Starker Leopold Wild Trout Awards

Marty Seldon

Starker Leopold, world-renowned scientist, dedicated teacher, distinguished author, outstanding naturalist, beloved angling companion to many, and an influential speaker and participant at both Wild Trout I and II died on August 23, 1983. His death occurred a year before Wild Trout III at his home near the University of California Berkeley campus where he taught and was the retired head of the Zoology Department. Many of us still miss him and his counsel.

At the suggestion of Nathaniel P. Reed, former Assistant Secretary of the Interior, the federal official that first approved these Symposiums, the Sponsoring Committee established The Aldo Starker Leopold Wild Trout Award as a memorial to Starker in 1984.

A. Starker Leopold was born in Burlington, Iowa the eldest son of Aldo Leopold. Following in his father's footsteps, he became one of the worlds most influential and honored authorities on wildlife ecology and management. He attended the University of Wisconsin, Yale Forestry School, received his Ph.D. from the University of California at Berkeley in 1944 and retired there as Emeritus Professor of Biology in 1978.

Starker Leopold was heavily involved in public policy at the highest levels. In 1968 he chaired the Special Advisory Board on Wildlife Management of the Department of the Interior which led to significantly new national park and refuge policies. He was a member of the Advisory Committee on Predator Control and an international consultant on wildlife conservation policy. He served as a Director and President of the California Academy of Sciences, as a Director and Vice President of the Sierra Club and engaged in a broad range of public service activities.

A.S. Leopold

Leopold addressed the negative impacts of multiple use at Wild Trout I. At Wild Trout II he spoke about degraded wild trout populations and the need to give higher priority to land use patterns and the physical condition of our lakes and streams. The following year Starker told the Federation of Fly Fishers annual convention, "For my part, I believe that the limited budget available for trout management is largely misspent on trivial activities, of no present value, such as the catchable trout program. Unless we bite the bullet and attack the habitat problem with vigor, the future of quality trout fishing in America is unpromising."

Starker's main goal was a world suited to wildlife and therefore fit for people. His personality was characterized by eminent academic and scientific achievements, love of the outdoors, positive personal warmth, and sensitivity. A. Starker Leopold was a friend to fish and wildlife, and to all of us.

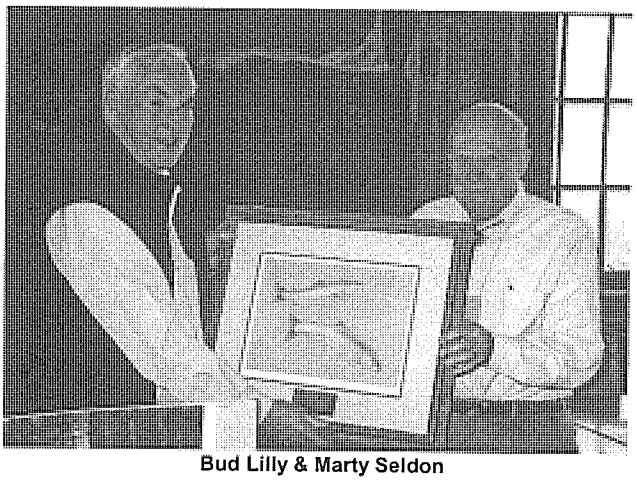
As a continuing memorial these awards are given at each Symposium to a professional and a nonprofessional who over time have made significant contributions to the enhancement, protection, and preservation of wild trout in North American. Prior to each symposium, nominations are solicited from the sponsoring organizations, biologists, administrators, and conservationists that attend these wild trout symposiums.

The first A. Starker Leopold Wild Trout Awards were made at Wild Trout III in September, 1984 to Martin M. Seldon, a long-time fisherman-conservationist, Sunnyvale, California and to Dr. Robert J. Behnke, Colorado State University, Fort Collins, Colorado, a noted trout biologist. The 1989 awards were made to Otto H. Teller, past President of Trout Unlimited, Glen Ellen, California and to Frank Richardson Lithonia, Georgia, retired U.S. Fish and Wildlife Service Assistant Regional Director and one of the initiators of these wild trout symposiums.

The 1994 A. Starker Leopold Awards at Wild Trout V were made to Gardner Grant, past President of the Federation of Fly Fishers and one of the initial orga-

nizers of these symposiums and to Ronald D. Jones retired U.S. Fish and Wildlife Service, Project Leader of the Fisheries Assistance Office at Yellowstone National Park, Wyoming. At Wild Trout VI in 1997 respected author and wild trout researcher Ernie Schwiebert was honored in the nonprofessional category and several-time Symposium Chairman Roger Barnhart received the Award in the professional category. We believe you will agree with the Awards Committee that the honorees at Wild Trout VII meet the high standards called for in the selection process.

The WT-VII Awards Committee is made up of former recipients including: Chairman Marty Seldon, Roger Barnhart, Robert Behnke, Gardner Grant, Ron Jones, Frank Richardson and Ernie Schwiebert.



Bud Lilly & Marty Seldon

WALDEN FRANCIS "BUD" LILLY

Bud Lilly is a fourth-generation Montanan who became a celebrated fly fishing guide, teacher, outfitter, and fisheries conservationist. He was born in Manhattan, Montana and grew up in an era when anglers filled their creels to capacity, but as his love and success at fishing grew; he was soon returning most trout to the river. Bud saw sea duty in the Atlantic and Pacific as an Ensign in the US Navy during World War II and then returned to Montana to continue his education. He received BS from Montana State University, an MS from the University of Montana, and taught high school science for 22 years.

During the summer, he ran the Bud Lilly Fly Shop in West Yellowstone, that in 1970 became a full time operation when he retired from teaching. During his 31 years in West Yellowstone, Bud met thousands of anglers, including international dignitaries and presidents. Bud was married to Pat Bennett until her death in 1984. They raised three children. His youngest son, Greg, a speaker at Wild Trout II, is a guide and runs a fly fishing shop in Sheridan, Montana. Bud is now married to the former Esther Simon, past Executive Secretary for TU and the FFF. They reside in Bozeman, Montana with Esther's two children. Bud is once again an outfitter, running his fishing lodge in Three Forks. Montana.

Bud was among the trout anglers that began questioning management policies and laws in the mid 50's and 60's. In 1961 he was a founder and first president of the Trout Unlimited chapter in Montana and continues to be an active force in its activities. He was a charter member of the Federation of Fly Fishers in 1964 and has been a FFF National Director and Senior Advisor. In 1984, Bud was the first curator of the International Fly Fishing Center established by the Federation of Fly Fishers in West Yellowstone and that same year received the FFF's most prestigious Man of the Year award.

Bud's impact on angling was noticed when in 1985 he was appointed a Montana Ambassador by Governor Swinden and then reappointed by the two subsequent governors. He received the Montana Governor's Ambassador Award three times for his efforts to improve trout fishing policy, conservation, and law. Bud is presently a Director at Large for both American Wildlands and the Montana Land Reliance, and is a member and former director of the Greater Yellowstone Coalition. When whirling disease was identified in the Madison River, Bud's "Home River" he immediately got involved as a member of the Governor's Task Force on Whirling Disease. He is also a founding Director of the Whirling Disease Foundation. Recently, the American Museum of Fly Fishing presented him with their highest recognition, the AMFF Heritage Award.

Bud is recognized as an icon in his own time, as one of the most important Montana trout conservationists. He has been profiled on CNN's "Portrait of America", on ABC's "Twenty- Twenty", and in the Wall Street Journal. He has often been the subject of other writer's stories. With Paul Schullery, he has coauthored, "Bud Lilly's Guide to Western Fly Fishing", and "A Trout's Best Friend". In the Guide, he writes, "You can't catch them if they're not there. The more of them you let go, the more of them will be there for the rest of us, and for you the next time you fish."

We are pleased to award the Wild Trout VII A. Starker Leopold Award in the nonprofessional category to Bud Lilly, a living testimony to its' standards.

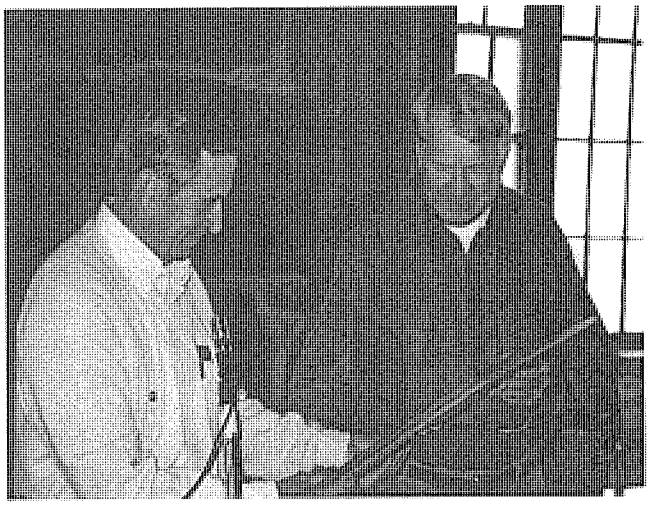
ROBERT L. HUNT

In his paper at WT-I in 1974, Robert L Hunt , the recipient of the A. Starker Leopold Award 2000 in the professional category, called for more rational programs to manage wild trout, involvement in the biopolitical process, and the initiation of new wild trout research projects. Twenty years later at WT-V, Mr. Hunt reported on a Wild Trout Management Survey he conducted of six midwestern states. He compared his findings to Lee Wulff's advice in 1980 at WT-II, and found a considerable commitment to improved wild trout management.

Robert L. Hunt received his formal education from the University of Wisconsin-Madison and served as a graduate student advisor. He was employed by the Wisconsin Department of Natural Resources for 33 years, retiring in 1992 as Leader of the Cold Water Research Group. Mr. Hunt is an American Fisheries Society Certified Fisheries Scientist and was elected to the AFS National Hall of Excellence in 1999. He has received a number of other awards including the 1982 Gulf Oil Conservation Award, served as a technical review consultant to four professional journals, and was an advisor to a Trout Unlimited scientific advisory board. His efforts generated public support for a State Inland Trout Stamp that generates $1,000,000 annually for trout habitat improvement.

Mr. Hunt promoted the use of trout stream habitat improvement as a management tool and conducted research that not only produced new instream structures, but clearly demonstrated their benefits to trout populations.

He pioneered evaluation of stream bank debrushing and the use of brush bundles and half-log structures. His wild trout research was done at a time when widespread indiscriminate stocking of hatchery trout was the major trout management thrust. His findings not only generated an awareness of the role of wild trout but resulted in the establishment of a trout stream classification system that recognized the wild trout component. Many streams were eliminated from Wisconsin's stocking roll. He spent his career researching the ecology, habitat relations, and management of wild trout populations and served as an international consultant.



Robert L. Hunt & Bob Behnke

In 1975, Mr. Hunt was co-chairman of the first Workshop on the Management of Brook Trout and helped organize a similar symposium on brown trout. In 1978 he organized the first North American Trout Stream Habitat Improvement Workshop, held every two years with international participation.

Robert L. Hunt published 46 papers and one stream habitat book, "Trout Stream Therapy". Two of his widely known bulletins are titled, "Production and Angler Harvest of Wild Brook Trout in Lawrence Creek, Wisconsin" and "Responses of Brook Trout to Habitat Development."

The Wild Trout Symposium is pleased to honor an outstanding fisheries scientist, Robert L. Hunt, for his long-term contributions to the cold-water fishery resource with its' A. Starker Leopold Award.

History of the Wild Trout Symposiums

Marty Seldon[1]

The first International Wild Trout Symposium was held September 25-26, 1974 at Mammoth Hot Springs Hotel in Yellowstone National Park. The event was cosponsored by Trout Unlimited and the Department of the Interior US Fish and Wildlife Service, based on an idea that originated with Frank Richardson, TU Executive Director and past FFF President Pete Van Gytenbeek, and John Peters of the EPA, at a 1973 luncheon in Denver. The concept received the enthusiastic support of the Assistant Secretary of the Interior for Fish, Wildlife and Parks, and past FFF Senior Advisor, Nathaniel P. Reed. The sponsoring group was joined and the Symposium hosted by Yellowstone National Park's Jack Anderson. Willis King was also on the Organizing Committee. Over 300 anglers, writers, students, and professionals from every trout region in the United States and Canada met on common ground to talk about wild trout and establish a new tradition. There were panels covering Anadromous Species, Water Quality and Quantity, Habitat and Species, Regulations and Politics, and a number of Special Sessions. Presenters included a number of familiar names such as Roger Barnhart, Gardner Grant, Ray White, Bob Wiley, and our good friend A. Starker Leopold. Dick Vincent presented his well-known paper on the effects of stocking catchables on wild trout populations and Wilfred Carter, head of the International Salmon Federation, discussed Atlantic salmon management.

The initial consensus was to hold these Symposiums every five years, and 1979 added the Federation of Fly Fishers as a cosponsor. John Townsley joined the Organizing Committee. Frank Richardson was Chairman. Gardner Grant and Mike Owen, the respective FFF and TU Presidents, were Assistant Chairmen.

Wild Trout-II, September 24-25, 1979, primarily focused on managing fish and anglers, with fewer papers on managing water and watersheds. WT-II emphasized the importance of genetic adaptations in strains of trout and that locally adapted populations have great ecological advantages. The distinguished Lee Wulff and others discussed the importance of preserving the quality of the angling experience as differentiated from the full-creel mentality, and there were perplexing reports documenting declining fisheries. Rupe Andrews and Gerry Taylor compared the similar problems of the great Alaska and British Columbia fisheries. Ron Marcoux and John Varley brought us up to date on the results of the major Catch-and-Release fishery studies on the Madison River and in Yellowstone National Park.

It was gratifying to see the very positive results. It all started in the Park with the major undertaking by Jack Anderson to save the cutthroat fishery in Yellowstone by closing angling at Fishing Bridge and establishing no-kill regulations. Starker Leopold asked that all administrators assign a high priority to the study of watershed relationships, such as grazing to trout populations. He said that better data to justify the conservation of riparian zones adjacent to streams is the real key to improved trout management.

At WT-III, September 24-25, 1984, the US Department of Agriculture shared sponsorship. Roger Barnhart was Chairman again assisted by Gardner Grant and Mike Owen. Frank Richardson headed Programs along with Bob Barbee on Logistics and Bob Hamre, Editorial. Keynote addresses by G. Ray Arnett, Assistant Secretary of the Interior, and John Crowell, Assistant Secretary of Agriculture, reminded us of the stark reality of a troubled resource, limited funding, competition among users, and the demanding effort we must all dedicate to the stewardship of our trout and salmon. Jackson Hole's Rev. Dan Abrams inspired us with a tale of the worth of a trout that extends far beyond nostalgia, sentimentalism, and winter dreams. Ben Dysart, President of the National Wildlife Foundation, dramatically pointed to the larger picture and how trout hatchery management solutions have changed to encompass complete watershed management.

---

[1] *Marty Seldon, Federation of Fly Fishers, member of the Organizing Committee since 1979, Sunnyvale, California.*

In August 1983, one year before WT-III, the entire wildlife community lost a dear friend and a strong advocate. A. Starker Leopold, an outstanding naturalist, teacher, author and effective public policy advisor, passed away at his home in Berkeley, California. It was a tragic loss to all. In recognition of his gentle eminence, the Sponsoring Committee established the A. Starker Leopold Award as a continuing memorial. Awards are given to a professional and a nonprofessional who over time have made significant contributions to the preservation of wild trout. The first awardees were Bob Behnke and Marty Seldon.

The mission of the Wild Trout Symposiums is to provide a forum for professional wild trout biologists and fishery conservationists to interact, to get to know each other in an informal setting, and to be exposed to the latest wild trout status, science, technology, and philosophy. These conferences equip participants to better preserve and restore this magnificent but declining resource. Although major national speakers and agency heads and administrators participate, this forum focuses on the needs of working level wild trout professionals and conservationists, not on the requirements and problems of agency or organization management. The originators hoped that each symposium would be a building block upon which the succeeding symposium could take hold and provide, in turn, insights and research which future sessions could use to advantage.

Wild Trout IV was held September 18-19,1989. Over the past 15 years, the Proceedings have grown from 102 pages to 233 pages as have the contents and scope of the presentations. The Environmental Protection Agency and the American Fisheries Society were added as cosponsors. Frank Richardson and Gardner Grant cochaired the symposium.

One of the major keynotes was by Nathaniel P. Reed who addressed the progress we made in the fifteen years that intervened since WT-I. He talked about our inability to explain ecosystem management to the public as was the case with the Yellowstone fires last year. He pointed out how Jack Anderson's restoration of the cutthroat trout with advice from Starker Leopold and Durward Allen made it possible to restore the Grizzly populations. Mr. Reed, as were many of us, said he was thrilled to see Luna Leopold with us this year and that we, as the caring vanguard, had fulfilled the constant need to better manage man's rapacious appetites in exceptional ways so that we can continue to save planet earth and the wild trout that seek to share it with us.

NWF's Benjamin Dysart joined us again as a Keynoter and although he approved of our scientific approaches to watershed, fishery and habitat restoration, he pointed out that something more was needed to really be effective. What is needed is to come up with projects that have scenarios where everyone wins. Win-win situations come about by working with right-minded developers, with the agencies, and with the anglers. The real challenge is to have desirable development that is done in a way that does not preclude public environmental quality values. When this takes place everyone can win.

Bob Behnke was the WT-IV Symposium Summarizer. He looked at our progress, including his observation that state and federal hatchery salmonid production had grown from a total of 169.4 million in 1958 of which 50.2 million were catchable trout, to 256.5 million salmonids in 1983 of which 78 million were catchable trout. The cost of each trout varied from $1.06 to $3.62 per fishing license sold creating an economic imbalance. Bob told us we could provide more angler days at lower cost by creating more wild trout opportunities and that more investigation is needed in this area. The 1989 A. Starker Leopold Award recipients were Frank Richardson and Otto H. Teller.

The organization of Wild Trout Symposiums normally include Sunday Registration and a speakers and committee meeting and reception. Monday morning starts with a plenary session usually with top-level agency speakers like the Secretary of the Interior followed by two and a half days of sessions on all aspects of wild trout. There is an awards luncheon and a banquet. WT-IV has panels including: the overall resource, fishery restoration, wildfire, drought and wild trout, fishery management, and fish economics, each with five to seven individual twenty minute presentations. The Symposium also includes poster papers and several exhibits. Well known author Richard Telleur reported on 25 years of no-kill regulations on New York's Beaverkill and Willowemoc rivers and an economic boom in Roscoe, New York that resulted from these special regulations. Similar results took place in Canada's five Atlantic seaboard provinces with no-kill Atlantic salmon regulations.

Wild Trout-V was held September 26-27, 1994 at the Symposium Headquarters at Mammoth Hot Springs Hotel in Yellowstone National Park. Roger Barnhart and Ron Jones were cochairman with the theme, "Wild Trout in the 21st Century." All three major arms of the Department of the Interior, The

National Biological Service, the Fish and Wildlife Service and the National Park Service joined the ranks of Symposium cosponsors.

Jay Hair, National Wildlife Federation President and CEO presented the message that our society desperately needs to return to a sense of place. Exhilarating wild trout fishing is an endangered experience.

Secretary of the Interior Bruce Babbitt reflected on his experiences with issues of trout and ecosystems. He spoke about water quality and grazing impacts and how new ESA, Section 404 of the Clean Water Act, and nonpoint pollution standards will protect our fisheries. He believed that the Forest Plan Management Act would help establish buffer zones in logging operations and that mining, urban expansion, water consumption, and road construction need similar attention and planning. "We can learn from the tragedies and mistakes of the past and begin to move toward an equilibrium upon the landscape."

There has been conflict for many years over these issues and it flares up in every generation. Our response has not been adequate to the Sagebrush Rebellion, The Great Fight, or the Wise Use Movement. There are far too many signs of the environmental movement and the classic sportsmen conservation groups drifting apart. We are losing too many sportsmen's groups and they are not pulling their weight as they should. Wild trout advocates need to bridge the gap between resource conservation and the sportsman tradition of Teddy Roosevelt. Good science is wonderful but in the final analysis it's political clout. We need to find our constituencies, and make certain they understand that everyone's concerns are tied together to get quality ecosystems. That understanding has to be translated into political action. 1994 Recipients of the A. Starker Leopold Award were Ron Jones and Gardner Grant.

WT-V also looked at the negative aspects of the animal rights movement and introduced the use of DNA analysis to track the movement and interactions of 26 cutthroat trout populations. This work offered better approaches to defining genetic diversity and indicated that we cannot draw valid conclusions from only looking at single isolated populations. Other papers included a view of New England Atlantic salmon restoration where populations in 28 rivers have declined from 1.1 million returning adults to less than 4,000. Ray White discussed why wild trout matter, we looked at wild trout management in British Columbia, and at a number of restoration projects.

Robert Martin summarized WT-V by pointing out that the greater public will determine the future of wild trout in the next century. It was about time we stopped pedantic discourses on "when is a wild trout a wild trout." There should be no dispute that in an environmentally balanced world wild trout would always be preferred over hatchery trout. Hatcheries represented only the need for temporary mitigation. The clarion theme of WT-V was that those involved in wild trout must convince the greater public of their value if they are to survive. Fishery management agencies must represent and protect the interest of the unorganized groups. Managers and advocates must stop arguing among themselves and share their passion for wild trout with the public. The other improvement that was instituted was to increase the symposium frequency from 5-years to 3-years to be better able to keep up with the more rapidly changing resource.

In an effort to overcome one of the difficulties, the limited capacity and accommodations at Mammoth Hot Springs, Wild Trout-VI was held at the excellent convention facilities of Montana State University, Bozeman, Montana. Pat Dwyer was Symposium Chairman. Attendance was limited by the American

Marty Seldon and Pat Dwyer with symposium participants.

Fisheries Society scheduling their conference on the West Coast the following week, but WT-VI presented one of the better technical sessions. The Symposium was organized into panels that included: Public Awareness and Education, What's a Wild Trout Worth (economics), Wild Trout Family Trees (genetics), Trout in Trouble (diseases and threats) and Trout on the Rebound (restoration projects). Each panel consisted of 5-10 papers; each limited to a 20 minute presentation and 5 minutes of questions. Papers ran from Monday morning, all day Tuesday and half day on Wednesday. The 1997 recipients of the A. Starker Leopold Award were Roger Barnhart and Ernie Schwiebert.

Wild Trout-VI focused on the formation of user group and agency partnerships, including ones for bull trout in Alberta, Canada, cutthroat trout in Colorado, and one with the University of Moscow to preserve Kamchatka Peninsula steelhead. It looked at improved management techniques, the latest developments in genetic research, and at the increasing public use of National Parks impacting all fish and wildlife. Examples of the value of wild trout included a $9 million annual economic contribution by anglers after the institution of barbless hook, Catch-and-Release fishing on the Beaverkill and Willowemoc watersheds in Upper New York State. New DNA analysis was used to confirm the discovery of new salmonid species/subspecies of New Mexico Gila trout, cutthroat trout in Colorado and Nevada, as well as three different groups similar to cutthroat trout in Kamchatca. Work in this exciting field is just beginning. WT-VI looked at the serious problems being caused by Lake Trout in Yellowstone Lake and the spread of Whirling disease. Possible threats from Global Warming and examples of the loss of more cold water habitat and rainbow-cutthroat trout hybridization in Idaho, Montana, and Ontario Canada were also presented.

Examples of successful restoration projects were highlighted by well known River Keeper Ron Holloway, who discussed how Great Britain's Itchen River wild brown trout fishery had been abused, destroyed, and then restored over the past three centuries. Consideration of the management of the total watershed rather just attacking problems at specific sites was one of the main factors. Man has the knowledge to "put the natives back into wild trout". What is needed is the will. Spencer Turner, WT-VI Summarizer, concluded that professionals, guides, and all the user groups have a lot in common including our love of wild trout and of the rich, cold, environs that support these wondrous creatures. We all need to continue to work together, but we have come light years since Wild Trout-I. The future of wild trout resources is quite optimistic.

A highlight at WT-VI was the legendary Ernie Schwiebert, who extolled the poetry of wild trout he loved as a child. "Everything about such wild trout is beautiful. The cold lakes and rivers that sustain them are beautiful. The methods of catching them are beautiful, the equipment we use is beautiful, and the flies we dress them with are beautiful. Fly fishing is both old and honorable. Its roots like in medieval chivalry itself, and we share a literature of sport more than five centuries old. It is filled with bright rivers tumbling swiftly toward the salty, the deft choreography of swifts and swallows working to a hatch of fly, and the quicksilver poetry of the trout themselves. And. In seeking their beauty, we may still discover that beauty itself is the most endangered thing of all."

Wild Trout-VII started the new millennium and brought us back to Yellowstone National Park, where these important meetings originated. Initial planning by the Organizing Committee for Wild Trout-VIII suggested a possible return to the 1904 Old Faithful Inn and Lodge and that it be held in 2004 to commemorate the 30th anniversary of these Symposiums. We hope you will join us in the land of the magnificent cutthroat around the geysers, the bison, the bugling elk, and the occasional bear and coyote. We need your contribution to meet our ever- pressing obligation to preserve and enhance what Ernie Schwiebert sees as the beauty of wild trout.

Resumption of a Limited Harvest Fishery for Bull Trout in Lake Pend Oreille, Idaho: Could We, Should We, ...Would We?

Charles E. Corsi and Christopher C. Downs[1]

Abstract—Lake Pend Oreille bull trout have long been recognized for their recreational fishery value, and the lake is generally recognized as supporting one of the more robust bull trout populations in the United States. Estimated annual harvest has exceeded 5, 000 fish, and the world record bull trout (14.5 kg) was taken from Lake Pend Oreille in 1949. In 1996, Lake Pend Oreille was closed to the harvest of bull trout, because it was unclear that the existing regulations (allowing harvest of one fish over 500 mm) were adequate to protect the population, and listing of the species under the federal Endangered Species Act was imminent. A subsequent, community based bull trout conservation planning effort identified providing for a harvestable surplus of bull trout as a recovery target. Is it possible to harvest bull trout without placing the Lake Pend Oreille population as a whole, in jeopardy? We examined three different harvest scenarios – a one fish per day bag limit, one fish per day bag limit with a minimum size restriction, and stock specific fishery targeting Trestle Creek fish. A long-term redd count data set (17 years) exists which suggests a relatively strong and stable bull trout spawning population using Trestle Creek. Recent population estimates conducted by the US Forest Service Rocky Mountain Research Station and the Idaho Department of Fish and Game indicate an annual spawning population of 1,100 to 1,400 fish utilizing only 11 km of Trestle Creek, at a density estimated at 185 to 235 fish per hectare. Recent genetic information from the University of Montana for Lake Pend Oreille bull trout indicates high fidelity of adult bull trout to their natal streams, suggesting a loss of fish from one tributary population is not likely to significantly influence refounding or bolstering of stocks in other tributaries. We believe the available information suggests a pre-determined number of post-spawning adults could be marked during out-migration to provide some harvest opportunity in the lake with no adverse consequences to either the Trestle Creek population or the lake as a whole. There appears to be potential to restore fishing opportunity, while continuing to strengthen weaker stocks of bull trout, and contributing to the overall recovery of the Lake Pend Oreille bull trout population.

INTRODUCTION

Located in the panhandle region of northern Idaho, Lake Pend Oreille (LPO) is Idaho's largest and deepest natural lake. It has a maximum depth of greater than 360 meters and covers a surface area of about 36,000 ha. LPO is classified as oligotrophic and drains the Clark Fork River watershed in western Montana (approximately 60,000 km^2). The Clark Fork River is the largest tributary to LPO, contributing approximately 92% of the total annual inflow (Frenzel 1991a).

Both inflow and outflow to LPO are regulated by hydroelectric facilities. Cabinet Gorge Dam, a modified run-of-river project constructed in 1952, regulates inflow except during periods of run-off. Construction of this dam blocked access to approximately 80% of the tributary habitat historically available to LPO bull trout. Albeni Falls Dam, also con-

[1]*Idaho Department of Fish and Game 2750 Kathleen Ave., Coeur d' Alene, ID 83815*

structed in 1952, controls the outflow and regulates the level of the lake.

The native salmonid fish fauna of LPO consists of bull trout *Salvelinus confluentus*, westslope cutthroat trout *Oncorhynchus clarki lewisi*, mountain whitefish *Prosopium williamsoni*, and pygmy whitefish *P. coulteri*. Kokanee salmon *Oncorhynchus nerka*, introduced to LPO from Flathead Lake during a 1933 flood event, provide an important forage base for bull trout as well as lake trout *Salvelinus namaycush* (introduced in 1925) and Gerrard rainbow trout *Oncorhynchus mykiss* (introduced in the 1940's) (Vidergar 2000).

Bull trout have historically provided an important sport fishery in LPO with harvest peaking at approximately 5,000 fish shortly after the closing of Cabinet Gorge dam in 1952. The current world record bull trout weighing 14.5 kg was caught in LPO in 1949. LPO fishing regulations became more stringent with time in order to conserve this valued sport fishery. Between 1946 and 1996 eleven different regulation changes were enacted to protect bull trout in LPO (Lake Pend Oreille Key Watershed Bull Trout Problem Assessment 1998). One of the most significant from a conservation perspective may have been the complete closure of all LPO tributaries to harvest of bull trout as early as 1964. Regulation changes to protect bull trout culminated in the complete closure to harvest of LPO bull trout in 1996 because managers were uncertain that the existing regulation (one fish per day, minimum size of 500 mm) would adequately protect bull trout.

Based on spawning ground surveys, LPO supports at least 17 different spawning populations of bull trout. A few relatively stable and strong spawning populations of bull trout are present, but the majority of the populations appear to have undergone substantial decline in recent decades (table 1). Trestle Creek, which supports the most robust and stable of the LPO spawning populations, underwent a large-scale watershed restoration program in 1994, and watershed conditions are generally described as good to excellent (USFS 1993). A number of spawning tributaries, including several in the Lightning Creek complex, have been subjected to intensive land management and runs have declined due to habitat related factors (Panhandle Bull Trout Technical Advisory Team 1998).

Recent genetic data suggests that individual LPO bull trout tributary stocks are highly differentiated (Neraas and Spruell 2000) with very low rates of straying between tributaries estimated at 1 fish/year (P. Spruell, University of Montana Wild Trout and Salmon Genetics Laboratory, personal communication). A strategy of protecting all stocks of bull trout in LPO in order to enhance weaker stocks through straying is unlikely to succeed given the low estimates of genetic exchange. Under the same scenario, loss of individuals from a strong LPO spawning stock is not likely to jeopardize the persistence of weaker stocks.

Harvest fisheries currently exist for bull trout in the Columbia basin both in Montana and in Oregon. There appears to be significant interest in restoring a harvest fishery in LPO, as evidenced by Restoration Target 2 of the Lake Pend Oreille Bull Trout Conservation Plan (Resource planning Unlimited 1999), which calls for restoration of a population sufficient to produce an annual harvestable surplus. We conducted an analysis of existing LPO bull trout population data to investigate the biological feasibility of providing a limited harvest fishery for bull trout in LPO. If annual recruitment to spawning age is adequate to maintain run strength and fully seed juvenile rearing habitat, perhaps a portion of the LPO bull trout population could be made available to anglers for harvest.

METHODS

We examined three options for providing a harvest fishery on bull trout in LPO. In order of their ease of enforcement and comprehension by anglers, they are:

1. One fish/day without size limits.
2. One fish/day with minimum size limit.
3. A stock specific regulation targeting the strongest LPO bull trout population, Trestle Creek.

Harvest options one and two were addressed through logical examination of current management objectives for bull trout in LPO. The Lake Pend Oreille Bull Trout Conservation Plan Recovery Target 1 calls for ensuring that at least six healthy spawning populations of spawning bull trout are well distributed around the basin, and that efforts are being made to maintain or improve all spawning stocks around the basin. Currently only three spawning populations meet the criteria for healthy, thus we analyzed the apparent impact exploitation would have on individual depressed stocks. We assumed an exploitation rate of 25 percent based on the findings of Paragamian and Ellis (1994), and then examined the immediate impact a 25 percent exploitation rate could have on spawning escapement into tributaries where stocks are depressed. We further as-

Table 1.— Number of bull trout redds counted per stream in the Lake Pend Oreille drainage, Idaho, 1983-1999.

Stream	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
CLARK FORK R.	--	--	--	--	--	--	--	--	--	2
Lightning Cr.	28	9	46	14	4	--	--	--	--	11
East Fork	110	24	132	8	59	79	100	29	--	32
Savage Cr.	36	12	29	--	0	--	--	--	--	1
Char Cr.	18	9	11	0	2	--	--	--	--	9
Porcupine Cr.	37	52	32	1	9	--	--	--	--	4
Wellington Cr.	21	18	15	7	2	--	--	--	--	9
Rattle Cr.	51	32	21	10	35	--	--	--	--	10
Johnson Cr.	13	33	23	36	10	4	17	33	25	16
Twin Cr.	7	25	5	28	0	--	--	--	--	3
Morris Cr.	--	--	--	--	--	--	--	--	--	--
NORTH SHORE										
Trestle Cr.	298	272	298	147	230	236	217	274	220	134
Pack River	34	37	49	25	14	--	--	--	--	65
Grouse Cr.	2	108	55	13	56	24	50	48	33	17
EAST SHORE										
Granite Cr.	3	81	37	37	30	--	--	--	--	0
Sullivan Springs	9	8	14	--	6	--	--	--	--	0
North Gold Cr.	16	37	52	8	36	24	37	35	41	41
Gold Cr.	131	124	11	78	62	111	122	84	104	93
Total 6 index streams	570	598	571	290	453	478	543	503	423	333
Total of all streams	814	881	830	412	555	478	543	503	423[1]	447

[1] Represents a partial count due to early snowfall.

Table 1. Continued.

Stream	1993	1994	1995	1996	1997	1998	1999
CLARK FORK R.	8	17	18	3	7	8	5
Lightning Cr.	2	5	0	6	0	3	16
East Fork	27	28	3	49	22	64	44
Savage Cr.	6	6	0	0	0	0	4
Char Cr.	37	13	2	14	1	16	17
Porcupine Cr.	6	1	2	0	0	0	4
Wellington Cr.	4	9	1	5	2	1	22
Rattle Cr.	8	0	1	10	2	15	13
Johnson Cr.	23	3	4	5	27	17	31
Twin Cr.	4	0	5	16	6	10	19
Morris Cr.	--	--	--	--	--	--	1
NORTH SHORE							
Trestle Cr.	304	276	140	243	221	330	260
Pack River	21	22	0	6	4	17	0
Grouse Cr.	23	18	0	50	8	44	50
EAST SHORE							
Granite Cr.	7	11	9	47	90	49	41
Sullivan Springs	24	31	9	15	42	10	22
North Gold Cr.	32	27	31	39	19	22	16
Gold Cr.	120	164	95	100	76	120	147
Total 6 index streams	529	516	273	486	373	597	548
Total of all streams	656	631	320[2]	608	527	726	712

[2] Observation conditions impaired by high runoff.

sumed that LPO is a mixed stock fishery, in that the exploitation rate would apply equally across stocks regardless of the size of the individual spawning population.

Option three required more detailed analysis, and we examined the potential effects to the Trestle Creek stock from harvest of post-spawn bull trout using several strategies. Initially, we examined Trestle Creek redd counts for trends in spawner escapement using the 17 year IDFG data set available for Trestle Creek. We chose the nonparametric rank correlation procedure Kendall's tau (Zar 1996) to look for correlations between year and redd count. A significant correlation would suggest a time based trend either of increasing or decreasing abundance. Kendall's tau was chosen over the Spearman rank procedure because it was used in a recent published analysis of LPO bull trout redd counts (Rieman and Myers 1997). We also used visual methods to look or trends. Trend analysis was conducted with the assumption that if the population appeared to be declining it would be unwise to place additional mortality loads on the population.

We also analyzed the frequency of repeat spawning, to assess the importance of repeat spawners in maintaining the population. Three hundred and seven adult bull trout were marked with adipose fin clips as part of a USFS population estimate during the spawning run in Trestle Creek in 1998. Based on the USFS population estimate of 1,400 adult spawners in 1998, approximately 22% of the spawning run was marked with adipose clips. We snorkeled Trestle Creek in both 1999 and 2000 to estimate the frequency of repeat spawning based on observation of fish with missing adipose fins. Individual snorkelers carefully made their way upstream observing individual adults for the presence/absence of adipose fins during August 1999 and 2000. We assumed no regeneration of clipped adipose fins, and that only fish marked by the USFS would have missing adipose fins. Bull trout without adipose fins were assumed to be repeat spawners from 1998.

We used Beamesderfer's (1987) MOCPOP fishery simulation model to analyze the potential effects of harvest on LPO bull trout. MOCPOP requires the following inputs to run: maximum age of fish, a Von Bertalanffy growth equation, a length-weight equation, a recruitment function, age at maturity, a length-fecundity equation, survival at different ages/life stages, sex ratios, and starting population size. We used both empirical data from Pend Oreille basin bull trout populations, and data reported in the literature, to describe these life history parameters (table 2). Where a range of literature values were examined, we chose to use the more conservative values in the range – i.e. those values least likely to

Table 2.—Input values for MOCPOP simulations of the Trestle Creek bull trout population.

Parameter	Parameter estimate
Years per run	25
Maximum age	8
Von Bertalanffy equation	Linf = 900; k = .177; Tzero = 0.0768
Length-weight equation	Intercept = 0.00008; Slope = 2.6813
Ricker values	Alpha = 0.77; Replacement abundance = 100,000
Age at first maturity	5
Proportion of females spawning at age: 5	0.1
6	0.9
7	1.0
8	1.0
Length-fecundity equation	Intercept = 0.2864; Slope = 1.403
Natural mortality rate age: 0 to 1	Random between 0.9965 and 0.9995
1 to 2	0.40
2 to 3	0.22
3 to 4	0.22
4 to 5	0.22
5 to 6	0.22
6 to 7	0.8
7 to 8	0.97

produce an artificially positive outcome to the population. For example, the length fecundity equation assumed that a 500 mm long female bull trout would produce 2000 eggs, which is at the low end of the reported range (Heimer 1965, Scott and Crossman 1973).

The Ricker stock-recruitment equation (Ricker 1975) was derived by using the annual redd counts, conducted since 1983, to represent spawner abundance. Number of redds represented stock and number of redds six years later represented recruits. Because the use of the Ricker curve demands that populations be influenced primarily by density dependent factors, we were only able to apply the approach to tributary populations where habitat conditions have remained relatively unchanged since 1983. Because some bull trout harvest was allowed in the lake prior to 1995, we assumed 25% fishing mortality (based on the creel data of Paragamian and Ellis 1994) and adjusted escapement estimates accordingly (Ricker 1975).

Estimated survival between age groups was derived using empirical data from Trestle Creek. Spawner abundance and egg deposition estimates were derived from redd counts, and mark-recapture population estimates conducted by the USFS (B. Rieman, personal communication of unpublished data). Estimates of juvenile abundance were made using the removal method (Zippin 1956). Based on these data points, we interpolated survival values for age classes in the lake. Survival for age-0 fish was estimated by interpolation, and randomly fluctuated between estimated high and low values to simulate variable survival, which may result due to the effects of periodic midwinter storms on incubating eggs (IDFG, unpublished data).

Sex ratios were derived based on observations made at a fish weir operated by the USFS during 1998. Age and growth data are from the LPO basin and were based on the work of Pratt (1984).

Each model run was set for 25 years. We made several preliminary runs of the model under a zero fishing mortality scenario, and made adjustments in input values until we could make the model behave in a fashion similar to what the empirical data indicates is occurring with the actual population. Only those values for which we had no empirical data were adjusted, we maintained the use of empirically derived inputs. The zero fishing mortality scenario was used as a baseline from which to compare population responses when fishing mortality was applied to different age groups (figure 1).

RESULTS

Option 1:

Under option one, a regulation would be in place that would allow for the harvest of bull trout from any LPO bull trout stock. Previous creel data for LPO bull trout (Paragamian and Ellis 1994) suggests we may encounter exploitation in excess of 25% under this regulation. Using redd count data and published spawner:redd ratios several stocks likely would be negatively impacted by losing even a few individuals to angling mortality (table 3).

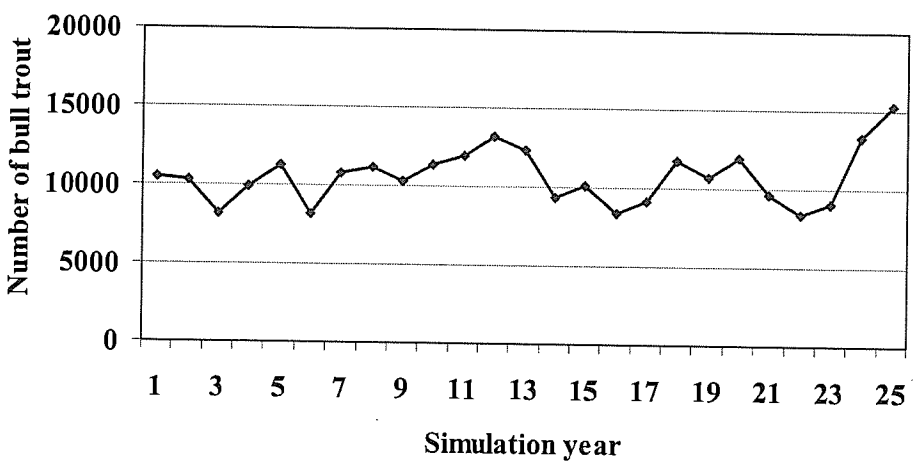


Figure 1.—MOCPOP simulation results for baseline (zero harvest) condition of bull trout spawner escapement in Trestle Creek, Idaho.

Table 3.—Estimated harvest of selected tributary stocks of Lake Pend Oreille bull trout under a general one fish limit.

Tributary	Mean number of spawners 1997-1999	Estimated harvest at 25% exploitation	Potential number of adults remaining to spawn
Trestle Creek	811	203	608
S. Gold Creek	343	86	257
Porcupine Creek	4	1	3
Rattle Creek	30	8	22

Option 2:

Based on length-frequency data (figure 2) for several LPO spawning stocks, a minimum size limit of 550 mm to 600 mm would allow most adult bull trout to spawn at least once. However, when the length-frequency plots of the spawning runs are compared, it becomes evident that we would be targeting weaker stocks with larger mean lengths, like Lightning Creek and the Clark Fork River and protecting stronger stocks like Trestle Creek which have smaller mean lengths.

Option 3:

Based on redd count and adult population data, Trestle Creek appears to be a relatively stable and strong bull trout population. Recent mark-recapture population estimates conducted in Trestle Creek in 1998 and in 2000 estimated strong annual spawning runs of 1,400 (USFS Intermountain Research Station, unpublished data) and 1,100 (IDFG, unpublished data) adult bull trout respectively. These spawners utilize approximately 11 km of stream, at an estimated density of 185 to 235 fish per hectare.

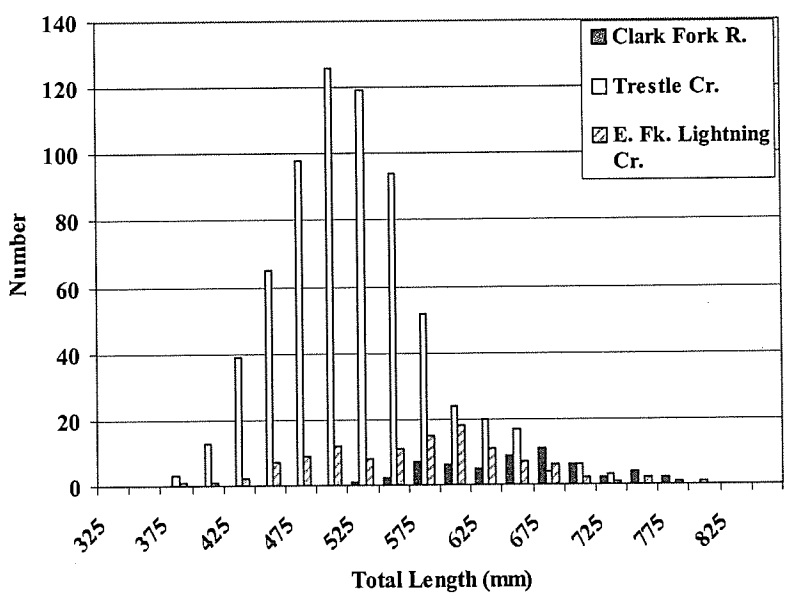


Figure 2.—Bull trout length frequency data for three Lake Pend Oreille tributary stocks.

Results of the correlation analysis performed on the Trestle Creek redd counts suggested no significant trend of either increasing or decreasing spawner abundance (tau-*b* = -0.007; p = 0.97). Visual observation of the redd count trend data supports the same conclusion (figure 3). This was not unexpected given that with current variability levels and redd count numbers observed in Trestle Creek redd counts, Rieman and Meyers (1997) estimated it would take more than 100 years to detect a statistically significant trend.

During snorkeling efforts in 1999 we observed 74 adult bull trout in Trestle Creek. Of these 74 adults, only one had an adipose clip indicating it had been marked the previous year. During snorkeling efforts in 2000, we observed 264 adult bull trout in Trestle Creek of which only 14 had adipose clips. Using the estimated marking rate in 1998 of 22%, we can estimate the true expected proportion of repeat spawning bull trout from 1998 contributing to the 1999 and 2000 spawning runs as 7% and 24%, respectively.

Analysis of the stock-recruitment relationship (figure 4), suggests room exists for harvest of even prespawn Trestle Creek bull trout. The data points that we utilized to estimate the stock-recruitment relationship fall close to, or above the replacement line. The distance between the recruitment curve we generated and the replacement line represents potential surplus production (Ricker 1975).

MOCPOP model outputs indicate that even with high natural mortality of post spawning adults, the Trestle Creek population can handle the additional mortality load of 25% exploitation on post-spawn bull trout. Results of the simulation indicated a

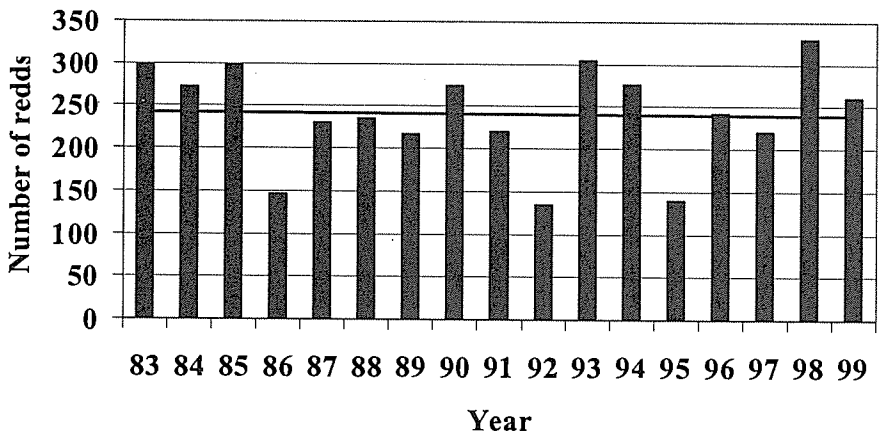


Figure 3.—Long-term redd count data for Trestle Creek, Idaho. Bold line is the trend line

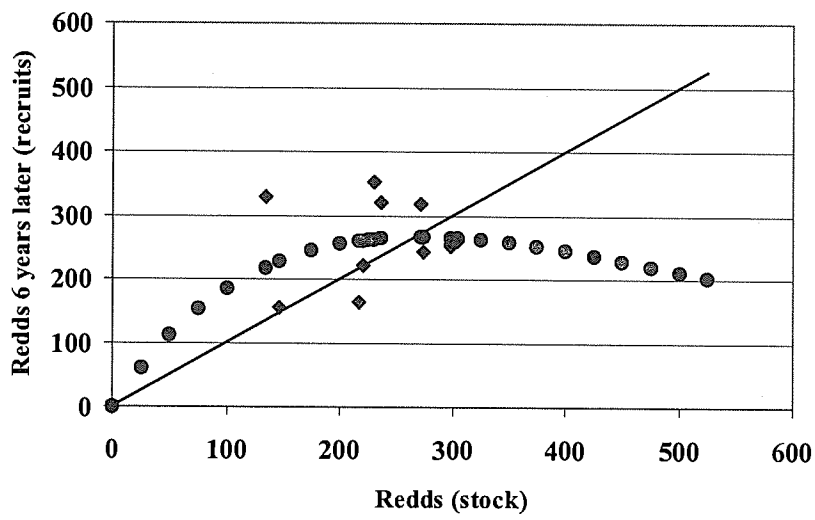


Figure 4.—Ricker stock-recruitment curve based on redd counts in Trestle Creek, Idaho 1983 – 1999.

population fluctuating in abundance, but with a stable long-term trend (figure 5). In adjusting the model to produce a simulated population response that closely resembles observed population responses based on redd counts, it was necessary to input high mortality values for egg to age 1and relatively low mortality values for juvenile and sub-adult fish in the lake. Adjustments in mortality rates for post spawning adults had little influence on long-term population response.

DISCUSSION

Our analysis suggests that fishing regulations placed on bull trout in LPO that allow harvest without regard for stock origin may pose a risk to long-term persistence of individual tributary stocks. Because several of the weakest spawning stocks also produce some of the largest fish, even a relatively high minimum size limit regulation poses some risk to weak populations at this time. This point was illustrated through application of a 25% exploitation rate on several different LPO bull trout stocks (table 3). Bonar et al (1997) summarized reported numbers of adults per redd for several bull trout populations, and showed a range of 1.5 to 3.2 adults per redd. USFS researchers estimate between 2.0 and 3.0 bull trout per redd in LPO tributaries, and estimated the sex ratio of females to males at 2.5:1 in Trestle Creek (USFS Intermountain Research Station, unpublished data). Even if the high end values for fish per redd are applied, in extreme cases where redd counts have declined, the lone male expected to return to a tributary in any given year may be harvested prior to spawning under this scenario. Porcupine Creek, formerly an important producer of bull trout, has had bull trout spawning activity decline precipitously and represents an instance where harvest of even one fish in some years may result in no reproduction.

In modeling the Trestle Creek population, we used some model inputs that were based on assumptions about the applicability of literature values to Trestle Creek bull trout. We also relied heavily on redd count data for our analysis, a methodology which may be subject to observer variability (Bonneau and LaBar 1997). However, redd count data have been conducted annually at the same time of year by experienced observers. In addition, some of the empirical information we used was derived from a limited data set. Where we were required to rely on outside data or limited information, we chose to use conservative model inputs, in the sense that we would limit the potential for an artificially positive population response. We then adjusted inputs to force the model to produce outputs, which appeared to closely resemble what the spawner escapement data indicated was occurring with the actual population. Based on this exercise, we are reasonably confident that our estimates of life history parameters are close to the actual life history parameters. A possible exception is that we likely underestimated post-spawn survival and the contribution of repeat spawners, based on recent data collected subsequent to the modeling effort.

We compared our data on bull trout repeat spawning to data reported by Baxter and Westover (1999). Baxter and Westover estimated 26% of bull trout marked in at a weir in the Wigwam River in British Columbia in 1996 returned to spawn two years later in 1998, compared to 24% from 1998 to 2000 in Trestle Creek. In contrast, the same Wigwam River data on repeat spawning reported 38% of the spawning run in 1997 was comprised of first year repeat spawners, compared to only an estimated 7% in Trestle Creek

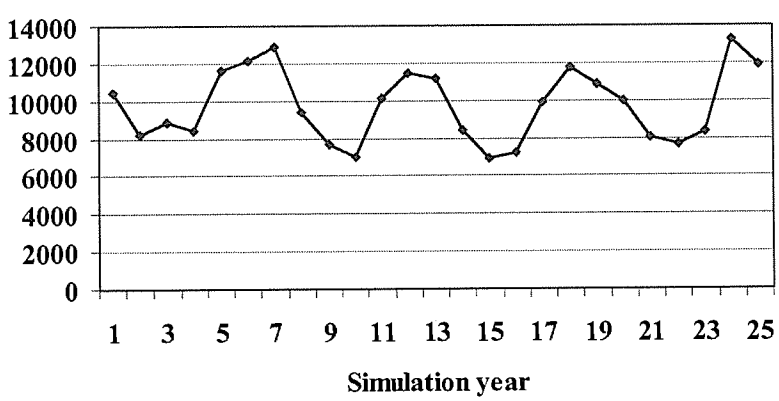


Figure 5.—MOCPOP results for simulated 25% exploitation of post-spawn bull trout in Trestle Creek, Idaho.

from 1998 to 1999. Our initial low percentage of first year repeat spawners had led us to believe that repeat spawning was not a major factor contributing to Trestle Creek run. The Trestle Creek repeat spawning data from 2000 caused us to rethink our earlier contention based on 1999 Trestle Creek data that repeat spawners may not account for a substantial proportion of the bull trout spawning run.

Perhaps repeat spawning is an important mechanism in supporting the Trestle Creek bull trout population. Mid-winter flooding in 1994-95 may have contributed to the apparently smaller spawning run in 2000, thus repeat spawners from a healthier year class would likely contribute a greater percentage of the run. Repeat spawning may also provide and important buffer for bull trout populations, like those in the LPO system which are found in climates conducive to winter rain-on-snow events. Winter rain-on-snow events may reduce the success of spawning and rearing for LPO bull trout and result in weaker year-classes (IDFG, unpublished data). However, given the high adult densities and vigorous recruitment observed in Trestle Creek, the potential value of repeat spawning does not necessarily preclude some level of limited harvest.

We modeled a 25% exploitation rate on post-spawn bull trout from Trestle Creek using MOCPOP. The model runs suggested that this harvest level was sustainable, even if natural mortality of post-spawn fish is high. If annual recruitment to spawning age is adequate to maintain run strength and fully seed juvenile habitat in Trestle Creek, there is an apparent opportunity to make post-spawn Trestle Creek bull trout available to anglers for harvest once they return to LPO. Harvest could be regulated to a degree that over-exploitation would be unlikely. It may be prudent to reduce the number of fish available for harvest when low spawning escapement is anticipated, due to the apparent negative effects of midwinter flooding on year class strength six years prior, but the model simulations suggest allowing some harvest of post-spawned fish is still feasible.

A complete weir will be operated on Trestle Creek for the next several years to assess emigration of juveniles and adults from Trestle Creek into LPO. A proportion of the outmigrating adult run could be marked with an easily recognizable tag or mark and made available for harvest in the lake. The number marked could be adjusted annually dependent on the number of upstream migrants, and an estimated 50% in tributary post-spawn mortality rate (USFS Intermountain Research Station, unpublished data). During years of lower adult escapement into Trestle Creek, potentially no fish would be marked.

By harvesting only post-spawn individuals, all Trestle Creek bull trout would have an opportunity to contribute genetically to the population. In addition, by removing only a pre-determined proportion of post-spawn individuals, the risk of over-exploitation is low. Because the genetics data indicate that straying rates between tributary populations are low, it seems unlikely that harvesting a percentage of post-spawn adult bull trout will significantly impact the potential for refounding of populations in nearby tributaries.

Other biological factors that need to be considered before restoration of a harvest fishery include the impact of exotic species on bull trout populations, and whether or not habitat quality is adequate to sustain bull trout. Donald and Alger (1993) observed that lacustrine populations of bull trout are almost always reduced or extirpated in the presence of lake trout. However, lake morphometry, or other factors, may be limiting the expansion of lake trout in LPO (Panhandle Bull trout Technical Advisory Team 1998).

Kokanee, an important forage item for bull, lake, and rainbow trout in LPO, have declined significantly in recent years due to operation of the Albeni Falls Dam (Maiolie 2000). To reduce the risk of predation virtually eliminating the remaining kokanee population, fishing regulations were adopted in 2000 allowing unlimited harvest of lake trout, more liberal limits on rainbow trout (6 fish per day), and closed the harvest fishery for kokanee (IDFG 2000).

Brook trout *Salvelinus fontinalis* are known to occur in some LPO tributaries, and in some cases are hybridizing with bull trout (P. Spruell and L. Neraas, Montana Wild Trout and Salmon Genetics Laboratory, personal communication). However, no brook trout have been documented in Trestle Creek, and the risk of brook trout negatively impacting the Trestle Creek bull trout population appears low.

We believe the data indicate there is biological potential for restoring a limited harvest fishery for bull trout to LPO, without jeopardizing weaker stocks of bull trout in the basin. The questions of whether or not a limited harvest fishery for bull trout would or should be resumed therefore becomes a question of social acceptability and the feasibility of administering relatively complex regulations. While there are no data to quantify angler or other public opinions on

the question of social acceptability, many anglers have expressed a desire to harvest bull trout. Likewise, the community developed Lake Pend Oreille Bull Trout Conservation Plan calls for restoring a harvestable surplus of bull trout to the lake.

Attempting to apply a regulation targeting only one spawning population of bull trout in LPO may create confusion for the public and difficulty in enforcement. However, anadromous salmonids are routinely managed this way, where hatchery raised salmon *Oncorhynchus spp.* and steelhead *O. mykiss* are marked with an adipose fin clip and made available for harvest (IDFG 2000).

Allowing the harvest of non-threatened stocks of anadromous fish has had the effect of helping to maintain angler interest in restoring anadromous fish runs. In the case of LPO bull trout, we believe that providing anglers with an opportunity to occasionally harvest a trophy sized bull trout could help accomplish the objective of improving angler support for restoring bull trout in the system. Maintenance of healthy bull trout stocks in the LPO basin appears to be largely tied to maintaining quality spawning and rearing habitat (Panhandle Technical Advisory Team 1998). Recognition by anglers that angling opportunity follows from protection and restoration of spawning and rearing habitats, and other measures, may serve to generate support for sometimes controversial restoration measures, such as road obliteration or removal of exotic species. If providing harvest opportunity in a biologically sound manner can be used as a means to gain support for the conservation of bull trout, the loss of a limited number of post-spawn bull trout to a harvest fishery may ultimately contribute to meeting bull trout recovery targets basin wide.

LITERATURE CITED

Beamesderfer, R.C. 1991. MOCPOP 2.0: A flexible system for simulation of age-structured populations and stock-related functions. Oregon Department of Fish and Wildlife, Clackamas.

Bonar, S.A., Divins, M., and Bolding, B. 1997. Methods for sampling distribution and abundance of Dolly Varden. Washington Department of Fish and Wildlife. Research Report RAD097-05. Olympia.

Bonneau, J. and G. LaBar. 1997. Inter-observer variability and temporal bull trout redd count variability in tributaries of Lake Pend Oreille, Idaho. Completion report. Department of Fish and Wildlife Resources, University of Idaho, Moscow, ID.

Donald, D.B., and D.J. Alger. 1993. Geographic distribution, species displacement, and niche overlap for lake trout and bull trout in mountain lakes. Canadian Journal of Zoology 71: 238-274.

Fraley, J.J. and B.B. Shepard. 1989. Life history, ecology, and population status of migratory bull trout *salvelinus confluentus* in the Flathead Lake and river system, Montana. Northwest Science 63: 133-143.

Frenzel, S.A. 1991a. Hydrologic budgets, Pend Oreille Lake, Idaho, 1989-90. USGS. Boise, Idaho.

Heimer, J.T. 1965. A supplemental Dolly Varden spawning area. M.S. thesis. University of Idaho. Moscow.

Idaho Department of Fish and Game. 2000. Idaho 2000 and 2001 fishing season rules including steelhead. Idaho Department of Fish and Game. Boise.

J.S. Baxter and W.S. Westover. 1999. Wigwam River bull trout—habitat conservation trust fund progress report (1998). Fisheries Progress Report KO 54. British Columbia Ministry of Environment.

Maiole, M.A., B. Harryman, and W.J. Ament. Lake Pend Oreille fishery recovery project, Idaho Department of Fish and Game. Annual report to Bonneville Power Administration, contract 94BI12917, Portland, Oregon.

K.L. Pratt. 1985. Pend Oreille trout and char life history study. Idaho Department of Fish and Game. Boise.

Neraas, L.P. and P. Spruell. 2000. Genetic analysis of bull trout from the lower Clark Fork Basin and Cabinet Gorge Dam. Report WTSGL00-101. Wild Trout and Salmon Genetics Laboratory, University of Montana, Missoula

Panhandle Bull Trout Technical Advisory Team. 1998. Lake Pend Oreille Key Watershed Bull Trout Problem Assessment. Lake Pend Oreille Watershed Advisory Group and the State of Idaho.

Paragamian, V.L., and V. Ellis. 1994. Kokanee stock status and contribution of Cabinet Gorge Hatchery, Lake Pend Oreille, Idaho. Idaho Department of Fish and Game completion report, Bonneville Power Administration, Portland, Oregon.

Resource Planning Unlimited. 1999. Draft lake Pend Oreille bull trout conservation plan. Lake Pend Oreille Watershed Advisory Group.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada Bulletin 191.

Rieman, B. E. and D. L. Meyers. 1997. Use of redd counts to detect trends in bull trout *salvelinus confluentus* populations. Conservation Biology 11: 1015-1018.

Scott, W.B. and E.J. Crossman. 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184, Ottawa.

USFS. 1993. Trestle Creek watershed improvement environmental assessment. Idaho Panhandle National Forest, Sandpoint Ranger District, Sandpoint, Idaho.

Vidergar, D. Population estimates, food habits, and estimates of consumption of selected predatory fishes in Lake Pend Oreille, Idaho. M.S. thesis. University of Idaho. Moscow.

Zar, J.H. 1996. Biostatistical analysis, third edition. Prentice-Hall, Englewood Cliffs, New Jersey

Zippin, C. 1956. An evaluation of the removal method of estimating animal populations. Biometrics 12:163-189.

Wild Trout Regulations and Natural Bait in North Carolina

James C. Borawa and Micky M. Clemmons[1]

Abstract— An experimental wild trout regulation allowing the use of natural bait (WBA) was implemented on 14 North Carolina streams following a regulation proposal eliminating the use of natural bait on many streams containing wild trout populations. The objectives of this study were to document changes in fish population characteristics, fishing effort, and harvest before and during the experimental regulation. Fish population sampling and creel surveys were conducted on 3 streams where natural bait had not been allowed for at least 10 years. After 2 years of monitoring, there were no significant changes in the densities or length-frequency distributions of trout >178 mm. The only noticeable change in fishing effort occurred immediately after the regulation change. While the percentage of legal-length fish harvested increased from 42-77% to ³88% pre- and post-regulation change, total numbers of fish harvested between 1994 and 1995 changed little. Although natural bait use went from 0% to >50% immediately following WBA implementation, total catch rates of trout varied little over the 2-year study and were comparable to rates on wild trout streams where natural bait is not allowed. We recommended removing the WBA regulation from experimental status and monitoring the fish populations to assess its long-term impact.

INTRODUCTION

The use of liberal versus conservative regulations to manage southern Appalachian wild trout populations has been the subject of much discussion over recent years among biologists. This is because infertile southern Appalachian trout streams (Webster and Wallace 1975) produce trout rarely exceeding 3 years of age or 200 mm length (Durniak and England 1986, Masterson 1991). Habera and Strange (1993) found most studies of trout management in the southeast concluded regulations did little to affect wild trout population characteristics. However, this conclusion was reached mainly by inference from trout population data comparing streams under differing regulations (Wingate et al. 1984, Durniak and England 1986) and not studies designed specifically to examine pre- and post-regulation change data. Additional disagreement existed over whether southern Appalachian trout populations can be overfished and if fishing mortality, particularly where natural baits are allowed, results in significant changes to trout population characteristics.

In 1991, the North Carolina Wildlife Resources Commission (NCWRC) proposed making wild trout regulations the default for 1,000 km of public trout streams. This change not only imposed a 178-mm minimum length limit and a reduced creel limit (seven to four fish), but also made the use of bait unlawful. Most waters where the new regulation would apply were located on the Nantahala and Pisgah National Forests in western North Carolina. The proposal was intended to minimize effects on recreational angling opportunities while limiting the potential for overharvest of wild trout (Fatora 1975, Washington State Department of Game 1984). It was initiated as a resource conservation measure to protect fishing quality given continued increases in angling popularity nationally (USDI and USDC 1993*a*, 1997) and specifically in the southeastern U.S. where the number of anglers has increased at a rate faster than the general population (USDI and USDC 1993*b*).

Some anglers of western North Carolina objected to the proposed regulation change charging it dis-

[1]*Fishery Biologists, North Carolina Wildlife Resources Commission, Division of Inland Fisheries, Raleigh, NC 27699-1721.*

criminated against anglers desiring to fish for wild trout using natural bait. These anglers stated trout populations had not declined in the last 20 years and creel limits of 4 fish/day did not make it worthwhile to fish wild trout streams. Most North Carolina trout anglers did not object to the proposed regulation. Such disparities in attitudes towards specific fishery management strategies by different user groups are not uncommon (Gigliotti and Peyton 1993) and public sentiment against changes in management strategies has influenced southern Appalachian trout management in the past. The reasons for this were aptly stated by Fatora (1976), "Trout management, more than any other fisheries program, has been clouded by the desires, demands, emotions, and ritualisms of trout fishermen."

In response to angler objections, the NCWRC implemented an experimental regulation allowing the use of natural bait on all or portions of 14 streams containing wild trout populations. This regulation, known as Wild with Natural Bait Allowance (WBA) retained the restrictive 178-mm length limit and 4-fish daily creel limit of the standard wild trout regulation, but allowed the use of natural bait, except live fish. This paper summarizes the results of a study designed to evaluate changes in angling effort, trout harvest, and trout population characteristics associated with the implementation of the WBA regulation (Borawa and Clemmons 1998).

METHODS

Study Streams and Regulations Background

Fish population sampling was conducted on 13 streams under the WBA regulation (Table 1). Creel surveys also were conducted on Kimsey, Park, and Buck creeks.

Table 1.—Mean density (number/ha) of trout >178 mm by species, stream, and year taken during an evaluation of a regulation allowing the use of natural baits in wild trout waters of North Carolina. All samples taken after 1 July unless otherwise noted.

Species Stream	Year 1991	1992	1993	1994	1995	1996
Brook Trout						
Chattooga R. (lower)		5			23[a]	
Fowler Creek				44		59
Scotsman Creek					33	21
Tellico Creek				33	14	
Turtle Pond Creek				3	37	7
Brown Trout						
Buck Creek (lower)			37	28/15[b]	17	14
Chattooga R. (lower)		69	160	85[c]	125[a]	146
Fowler Creek				157	229	81
Jarrett Creek				95	87	
Kimsey Creek	128	160	175	118/124[c]	162	111
Park Creek (spring)	[d]	188	125	128	153	84
Park Creek (fall)	176	145	122	130	71	[e]
Scotsman Creek				39	33	42
Tellico River						7
Turtle Pond Creek				45	71	59
Rainbow Trout						
Buck Creek (lower)			88	49/68[b]	58	42
Deep Creek			166	129	140	31
Jarrett Creek				53	87	30
Kimsey Creek	32	30	35	42/13[c]	11	13
Long Creek				29	88	42
Park Creek (spring)	[d]	5	29	10	19	11
Park Creek (fall)	5	48	39	19	29	[f]
Tellico Creek				28	17	15
Tellico River				136	102	105
Turtle Pond Creek				19	27	61

[a]Sample site 1 (lower) shortened because water levels very high; sample site 2 (upper) not sampled.
[b]Samples taken in June and October.
[d]Samples taken in June and August.
[e]No samples taken in spring 1991.
[f]No samples taken in fall 1996.

Kimsey, Park, and Buck creeks had been managed under the standard wild trout regulation (or its predecessor known as native waters) for over 10 years. This regulation limited the daily harvest to four fish with a minimum length limit of 178 mm and only allowed the use of single-hook artificial lures. The previous native waters regulation further restricted the creel to include only 1 fish >254 mm. The remaining streams in the study were under the hatchery-supported regulation until 1 October 1992, but had not been stocked in at least 7 years. The regulation applied to these streams imposed a daily creel limit of seven fish, no minimum length limit, and no bait restrictions. Furthermore, these streams were under the wild trout regulation from 1 October 1992 to 1 July 1994 when the WBA regulation went into effect.

Fish Population Monitoring and Data Analysis

Kimsey, Park, and Buck creeks were targeted for more intense sampling because at least two years of baseline data under the wild trout regulation were available. The U.S. Forest Service (USFS) (M. Seehorn, USFS, personal communication) provided data collected for Park Creek prior to 1993; 1993-96 data were jointly collected. At least three fish population samples were collected from each stream using the three-pass depletion method (Armour et al. 1983). The USFS Coldwater Research Unit sampled Overflow Creek during 1990-92 and 1996 using basinwide survey techniques. These data were statistically analyzed and reported independently (Dolloff et al. 1993, 1997). Conclusions from that study are incorporated into this paper.

For Kimsey (1993 vs. 1996), Park (1993 vs. 1995), and Buck creeks (1993 vs. 1996) mean densities of brown trout and rainbow trout >178 mm were compared using t-tests.

Length-frequency distributions were calculated by year, stream, and species. Distributions of brown and rainbow trout >178 mm for Kimsey, Park, and Buck creeks were compared by species and stream with Kolmogorov-Smirnov (KS) tests. Individual fish length data for available pre- (1991-93) and post- (1994-96) WBA regulation years were combined and compared only after tests for differences between years in each group were determined to be nonsignificant. All statistical tests were conducted at $\Delta = 0.05$. Numbers of trout >178 mm within each study stream were estimated by proportionally expanding the number of fish captured in fish population samples (based on sample length).

Creel Survey Design Criteria and Data Analysis

Uniform probability roving creel surveys (Robson 1991) were conducted on Kimsey, Park, and Buck creeks from 1 April to 15 November 1994 and 1995. Fishing trip data were collected during instantaneous counts. Days were stratified into weekends and weekdays, with morning and afternoon work periods having equal probability of selection. Generally, all weekend days and holidays and three weekdays of each week were included in the schedule. Creel data collected during interviews included time spent fishing, number, size group (δ178 mm or >178 mm), and species of all fish caught, types of bait used, residency, and trip rating.

Expanded estimates of fishing effort, catch, and harvest of trout were made using instantaneous counts, interview data, and a creel analysis computer program designed at the North Carolina State University Institute of Statistics. For 1994, separate statistics were estimated for the periods before and after the WBA regulation became effective (1 July). Fishing pressure (hours/km) was calculated using estimated effort and total study reach length for each stream. Catch rates were computed for each individual angler interview and averaged to obtain estimates by species and time period.

Fishing effort, pressure, and trout harvest during 1994 and 1995 were matched with fish population characteristics to identify trends resulting from the WBA regulation. The WBA regulation, with its associated changes in fishing effort and harvest, was considered to have a negative impact to trout resources in Kimsey, Park, and Buck creeks if statistically significant decreases were found in the densities and size structures of trout >178 mm. Because of the varied regulations on the nine other streams in the study, pre- and post-regulation change statistical tests were not possible on those data. However, the data were examined for changes in trout population structure. Details of all sampling procedures can be found in Borawa and Clemmons (1998).

RESULTS

Fish Population Sampling

Pre- and post-WBA regulation comparisons of fall mean densities of brown and rainbow trout >178 mm from Kimsey, Park, and Buck creeks (Table 1) revealed only the density of rainbow trout in Buck Creek was significantly lower ($P < 0.05$) in the post-WBA regulation period. Similarly, no consistent or conclusive trends in brown and rainbow trout (>178 mm) densities in the nine less intensively sampled streams (Table 1) were seen. Dolloff et al. (1997) found similar results for trout in the Overflow Creek drainage. Brook trout were not found in sufficient numbers in any study stream to make comparisons or conclusions.

No significant differences in pre- and post-WBA regulation length-frequency distributions of brown or rainbow trout >178 mm were found for Kimsey, Park (fall samples), or Buck creeks. Similarly, little change occurred in the length-frequency distributions of brown or rainbow trout collected from Park Creek in spring, Overflow Creek (Dolloff et al. 1997), or the nine less intensively sampled streams where natural bait had been previously allowed under the hatchery supported regulation. Brook trout found in Fowler, Scotsman, Tellico, and Turtle Pond creeks also showed no evidence of change.

Creel Surveys

No more than 102 anglers were interviewed on a given stream either in 1994 or 1995. Total estimated seasonal effort ranged from 50 hours on Park Creek in 1995 to 865 hours on Buck Creek in 1994. About 50% of the total seasonal fishing effort on Buck Creek occurred immediately following the 1 July 1994 effective date of the WBA regulation. There were no similar peaks in fishing effort on Kimsey or Park creeks during this time. Estimated total seasonal angling pressure on streams under the WBA regulation ranged from 74 to 234 hours/km in 1994 and 19 to 188 hours/km in 1995.

Catch was dominated by trout δ178 mm which was consistent with the abundance of small trout found in the fish population samples. Estimated annual catch of legal-length trout was highest for Kimsey Creek in 1995 at 339, while only 65 legal-length trout were caught from Park Creek in 1995. No brook trout were reported caught.

For streams under the WBA regulation, we estimated that between 1 April-30 June 1994 (pre-WBA regulation) anglers harvested 65% of all legal-length brown and rainbow trout caught. During the 1 July-15 November 1994 (post-WBA regulation) they harvested 93% of the legal-length trout caught. For all of 1995, 66% of legal-length fish caught were harvested. In comparison, on a portion of Buck Creek where natural bait was not allowed, 81% and 60% of all legal-length trout were harvested during 1994 and 1995.

Although the total number of legal-length trout harvested by anglers from a given stream in either year was <250, this did not reveal how harvest was related to the number of legal-length trout available for capture. We found the estimated number of legal-length trout harvested often equaled or exceeded the estimated number present in fall samples. The ratios of these estimates (number harvested:number present), by species, were not consistent among streams. For example, the ratio for brown trout in Kimsey Creek was about 1:4 in both years, whereas for brown trout in Buck Creek it was 2.2:1 in 1994 and 2.8:1 in 1995.

The proportion of anglers using natural bait increased from 0% to >50% pre- and post-WBA regulation in 1994, whereas in 1995 this proportion ranged between 35% and 50% among the three streams surveyed. The proportion of local, non-local, and non-resident anglers using these waters varied considerably between years with no consistent patterns discernible among waters. Before the 1994 effective date of the WBA regulation, 53-91% of anglers rated their trip as fair or good. In late 1994 and 1995 fair-good trip ratings for individual streams ranged from 65-100%. There was no obvious pattern of improved trip rating between pre- and post-WBA regulation periods in 1994, however, the proportion of good ratings increased for all streams in 1995.

In the two years of this study, total catch rates varied from 0.92 to 3.73 trout/hour on Kimsey, Park, and Buck creeks. Total catch rates were higher in 1995 than 1994 for all three streams under the WBA regulation. The only decrease in catch rate from 1994 to 1995 occurred for rainbow trout in Buck Creek, dropping from 0.86 to 0.77 trout/hour.

DISCUSSION

Pre- and post-WBA regulation monitoring of fish population characteristics on 13 of 14 streams clarified the short-term impact of the WBA regulation. For all but one stream, both where natural baits were and were not previously allowed, there was little evidence of a significant change in the densities of brown or rainbow trout >178 mm. Only in Buck Creek was a significantly lower density of rainbow trout found, but the decline cannot be conclusively linked to the WBA regulation. Contradictory evidence suggests the apparent decline in rainbow trout density in Buck Creek by fall 1996 was more likely the result of natural population variation rather than any effect of the WBA regulation. The data reveal that mean density of rainbow trout >178 mm in Buck Creek was only marginally higher (49/ha) in June 1994, immediately before the WBA regulation was effective, than in fall 1996 (42/ha). In addition, fishing effort and rainbow trout harvest were higher before the WBA regulation took effect in 1994 than in a similar period in 1995. The late season harvest (July-November) were similar in both years (65 vs. 53 fish) even though fishing effort increased for three weeks following the effective date of the WBA regulation. Similar patterns of change in rainbow trout densities were also seen in May samples from Park Creek (Table 1). Thus, it appears that over the short-term, densities of brown and rainbow trout were not impacted by the WBA regulation.

Although mean densities of trout >178 mm showed little change, it is possible length-frequency distributions could be altered if natural bait use resulted in increased harvest of larger fish from the populations (Mongillo 1984). We found no visual evidence in the length-frequency distributions that larger trout were absent under the WBA regulation even considering that the statistically nonsignificant results may be an artifact of low sample sizes. Rainbow trout >250 mm were rarely encountered in our samples before or after the WBA regulation. Sub-legal rainbow trout were abundant and probably recruited to legal lengths quickly as other legal-length rainbows were removed. Legal-length brown trout were generally more abundant than rainbow trout (Table 1) and fish >250 mm were common. However, even with their higher abundance, brown trout catch rates were often equal to or lower than rainbow trout catch rates indicating brown trout were more difficult to catch. We concluded that over the short-term, the WBA regulation had little effect on wild brown or rainbow trout length-frequency distributions.

The large increase in fishing effort on Buck Creek following the effective date of the WBA regulation suggests anglers' believed trout had been protected under the standard wild trout regulation and would be available for harvest with natural baits. However, anglers apparently quickly realized this was not the case and, after three weeks, effort returned pre-WBA levels. The absence of similar increases in fishing effort on Kimsey or Park creeks was indicative that Buck Creek was targeted by local anglers. This is partly substantiated by the 9% increase in local anglers using Buck Creek between early and late 1994. No similar changes on local angler use were seen on Kimsey and Park creeks due to the presence of a large developed USFS campground that attracts non-local residents.

The variability in total catch rates both pre- and post-WBA regulation and between streams in this study (0.92-3.73 trout/hour) is similar to streams under the standard wild trout regulation. Borawa et al. (1995) found catch rates of 3.25 and 1.06 trout per hour for Looking Glass Creek and South Toe River in 1993. They also found trout δ178 mm dominated the catch, identical to what was found in this study. Regardless of baits allowed, total catch rate does not appear to be affected by the WBA regulation.

The 19-234 hours/km angling pressure on streams surveyed in this study were comparable to pressure on other easily accessible wild trout streams where natural bait was not allowed. Borawa et al. (1995) found angling pressure was 187 hours/km on Looking Glass Creek and 923 hours/km on South Toe River in 1993. Except for the 3-week increase in pressure on Buck Creek immediately following implementation of the WBA regulation, we concluded that allowing the use of natural bait to catch wild trout did not increase total seasonal fishing pressure in the short term. However, expansion of recreational facilities in the vicinity of the streams under the WBA regulation could cause increased fishing pressure over the long term, ultimately resulting in impacts to the wild trout population (Ratledge 1967). While overall fishing pressure did not increase, 40-50% of anglers opted to use natural baits over artificial lures when it became legal to do so.

Although it appeared the number of trout harvested post-WBA regulation did not affect trout population characteristics, there was evidence that higher fishing effort by bait anglers may be related to the

increased percentage of legal-length trout harvested. Between 1 July and 15 November 1994, when fishing pressure and percentage of bait anglers were highest, 88-100% of legal-length trout caught were harvested. During the same period in 1995, when the proportion of anglers using bait was 35-50%, only 47-80% of those caught were harvested. The overall estimated annual percentages of legal-length trout harvested in this study (53-77%) are high when compared to the 15% and 11% harvest of legal-length fish caught under standard wild trout regulations from Looking Glass Creek and South Toe River in 1993 (Borawa et al. 1995). This large difference may be explained by differences in anglers' motivations for fishing. Anglers using natural bait are more likely to harvest fish (Gigliotti and Peyton 1993).

The addition of a natural bait fishing option had little effect on how anglers rated their fishing trips. Less than 5% of anglers rated their trips as excellent both before and after the WBA regulation was effective, whereas 53-100% rated their trips as fair or good. A higher proportion of anglers (73-91%) rated their trips as good or excellent (Borawa et al. 1995) on Looking Glass Creek and South Toe River. Generally, more local anglers (>50%) fished in this study than in the Looking Glass Creek (26%) and South Toe River (12%) studies. These differences are likely a reflection of anglers' motivation to fish, their expectations for their trip, the location of streams being fished, and the regulation in effect. Looking Glass Creek and South Toe River contain or are near wild trout streams managed under catch-and-release regulations and attract large numbers of non-local anglers interested in that type of fishing. Differences among anglers in the two studies also reinforces the concept that anglers can be classified into different user types based on their reasons for fishing and that the proportions of these groups can vary greatly between streams.

SUMMARY

Based on fish population monitoring and creel surveys, the initiation of the WBA regulation did not have any short-term impacts to the densities or length-frequency distributions of brown or rainbow trout >178 mm. Fishing pressure did not increase between 1994 and 1995 and was comparable to levels found on streams managed under the wild trout regulation where natural bait was not allowed. The percentage of legal-length fish (>178 mm) harvested increased following the start of the WBA regulation in 1994, but in 1995 the percentage declined to approximately pre-WBA regulation levels. These levels were still much higher than found on streams managed under the standard wild trout regulation. The percentage of anglers using natural bait increased substantially immediately following its implementation in 1994, but fell in 1995. Most anglers rated fishing trips as fair or good both before and after being allowed to use natural bait in the study streams. The majority of anglers interviewed during the creel surveys were local residents. Total catch rates of trout varied little over the two years of creel surveys and were essentially the same as catch rates on North Carolina wild trout streams where natural bait was not allowed.

This study has shown the allowance of natural bait to harvest wild trout has no short-term impacts to rainbow or brown trout populations in low fertility waters where fishing pressure is average. Anglers preferring to use bait were provided additional fishing opportunities with little detectable effects to the fish populations. However, this study did not address the long-term effects of the WBA regulation and it contained insufficient data to assess the impacts to brook trout populations. Continued monitoring of trout populations under the WBA regulation will be necessary to determine if long-term changes occur.

RECOMMENDATIONS

1. Take the WBA regulation out of experimental status.
2. Place streams under the WBA regulation only after establishing management objectives and considering the species present and potential fishing pressure and associated harvest.
3. Monitor populations of streams under the WBA regulations to determine the long-term trout population trends following implementation of the WBA regulation.

ACKNOWLEDGEMENTS

We thank Jeanne Riley, Monte Seehorn, and others of the U.S. Forest Service (USFS) and Steve Moore and others of the National Park Service for their assistance in the collection of the fish population data. A thanks also goes to Andy Dolloff of the USFS Coldwater Fisheries Research Unit for his independent collection, analysis, and reporting of fisheries

data from the Overflow Creek drainage. Dr. Kevin O'Brien of East Carolina University and Mr. David Turner were consulted for statistical analyses and creel designs. This study was funded under Federal Aid in Sport Fish Restoration Project F-24.

LITERATURE CITED

Armour, C. L., K. P. Burnham, and W. S. Platts. 1983. Field methods and statistical analyses for monitoring small salmonid streams. U.S. Department of the Interior, Fish and Wildlife Service Western Energy and Land Use Team Publication FWS/OBS-83/33.

Borawa, J. C., C. J. Goudreau, and M. M. Clemmons. 1995. Responses of wild trout populations to supplemental feeding. North Carolina Wildlife Resources Commission Division of Boating and Inland Fisheries, Raleigh.

Borawa, J. C. and M. M. Clemmons. 1998. Evaluation of a wild trout regulation with a natural bait allowance. North Carolina Wildlife Resources Commission Division of Inland Fisheries, Raleigh.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. U.S. Department of Agriculture, Forest Service Southeastern Forest Experiment Station General Technical Report SE-83. Asheville, North Carolina.

Dolloff, C. A., K. N. Leftwich, and M. K. Underwood. 1997. The effects of fishing regulation changes on fish populations in Overflow Creek, North Carolina. U.S. Department of Agriculture, Forest Service Southeastern Research Station Coldwater Fisheries Unit and Center for Aquatic Technology Transfer, Virginia Polytechnic Institute and State University, Blacksburg.

Durniak, J. P. and R. H. England. 1986. Dynamics of rainbow trout populations in small headwater streams. Georgia Department of Natural Resources, Game and Fish Division, Atlanta.

Fatora, J. R. 1975. The planning approach to trout management. Pages 107-110 *in* Anon., ed. Symposium on trout habitat research and management. U.S. Department of Agriculture, Forest Service Southeastern Forest Experiment Station, Asheville, North Carolina.

Fatora, J. R. 1976. Stream trout fishery management in the southeastern United States. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 30:280-284.

Gigliotti, L. M. and R. B. Peyton. 1993. Values and behaviors of trout anglers, and their attitudes toward fishery management, relative to membership in fishing organizations: a Michigan case study. North American Journal of Fisheries Management 13:492-501.

Habera, J. W. and R. J. Strange. 1993. Wild trout resources and management in the southern Appalachian Mountains. Fisheries 18(1):6-13.

Masterson, S. K. 1991. Age and growth characteristics of rainbow trout (*Oncorhynchus mykiss*) in Little River watershed, Great Smoky Mountains National Park. Masters Thesis. Tennessee Technological University, Cookeville.

Mongillo, P. E. 1984. A summary of salmonid hooking mortality. Fisheries Management Division, Washinton Department of Game, Olympia.

Ratledge, H. M. 1967. The impact of increasing fishing pressure upon wild and hatchery-reared trout populations. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissions 20:375-379.

Robson, D. S. 1991. The roving creel survey. Pages 19-24 *in* D. Guthrie et al., eds. Creel and angler surveys in fisheries management. American Fisheries Society Symposium 12. Bethesda, Maryland.

USDI and USDC (U.S. Department of Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census. 1993*a*. 1991 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Government Printing Office, Washington, D.C.

_____. 1993*b*. 1991 National survey of fishing, hunting, and wildlife-associated recreation - North Carolina. U.S. Government Printing Office, Washington, D.C.

_____. 1997. 1996 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Government Printing Office, Washington, D.C.

Washington State Department of Game. 1984. A basic fishery management strategy for resident and anadromous trout in the stream habitats of the state of Washington. Fish Management Division, Olympia.

Webster, J. R. and J. B. Wallace. 1975. Productivity of southeastern stream ecosystems. Pages 64-77 *in* Symposium on trout habitat research and management. U.S. Department of Agriculture Forest Service, Southeastern Forest Experiment Station. Asheville, North Carolina.

Wingate, P. J., R. J. Brown, J. H. Davies, J. H. Mickey, W. R. Bonner, and H. M. Ratledge. 1984. Effects of fishing regulation changes on lotic wild trout populations. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 35:654-660.

Management History and Angler Behavior in a Northeast Oregon Trout Fishery with Implications for Setting Wild Trout Regulations

William J. Knox[1]

Abstract—The Wallowa River in northeast Oregon supports popular sport fisheries for rainbow trout and summer steelhead. Most angler effort is in the section from Rock Creek to Minam State Park where the river is easily accessed from Oregon Highway 82. Historically, the trout fishery was supported by natural production and stocking of catchable (20-25 cm. total length) hatchery rainbow trout. Development of a large hatchery steelhead program in the late 1980's and increasing concerns about interactions of hatchery and wild fish resulted in changes in stocking programs and angling regulations. Catchable trout are no longer stocked, regulations now require release of wild trout, and residual hatchery steelhead support consumptive fishing. Results of creel surveys in 1979, 1995, and 1998 suggest that while angler effort has remained at a similar level, trout harvested (kept) by anglers has decreased significantly. Angler compliance with wild release regulations has been good. Conversely, efforts to encourage harvest of residual hatchery steelhead have been less successful because of voluntary release by anglers. Further analysis of creel survey data suggests that additional regulations (gear restrictions) would provide little benefit to the wild trout population.

INTRODUCTION

Providing consumptive and non-consumptive angling opportunities while maintaining and enhancing wild salmonids is an ongoing challenge for fishery managers. Stocking programs have been used to support consumptive fisheries and mitigate habitat alterations. However, concern about the effects of such programs on wild salmonids is a source of increasing discussion and controversy (Waples 1999). Managers have developed a variety of angling regulations to address demands on fishery resources. Several biological and social factors must be considered when developing angling regulations to achieve management goals (Wright 1992), including the potential effects of angler behavior (Clark 1983). In this paper, I review management history and results of creel surveys used to evaluate management strategies for a trout fishery on the Wallowa River in northeast Oregon. I also discuss implications of the results related to angling regulations designed to protect wild trout.

STUDY AREA

The Wallowa River is a major tributary of the Grande Ronde River in the Snake River basin of Northeast Oregon (Figure 1). Creel surveys were conducted in the "canyon" reach between Minam State Park (river kilometer 13) and Rock Creek (river kilometer 29.5). Oregon Highway 82 parallels the Wallowa River through the majority of the study reach and provides ready access to the river for anglers. Areas upstream and downstream of the study reach receive less use because of private land ownership upstream of Rock Creek and a lack of road access downstream of Minam State Park.

[1]*Assistant District Biologist, Oregon Department of Fish and Wildlife, Enterprise, OR 97828*

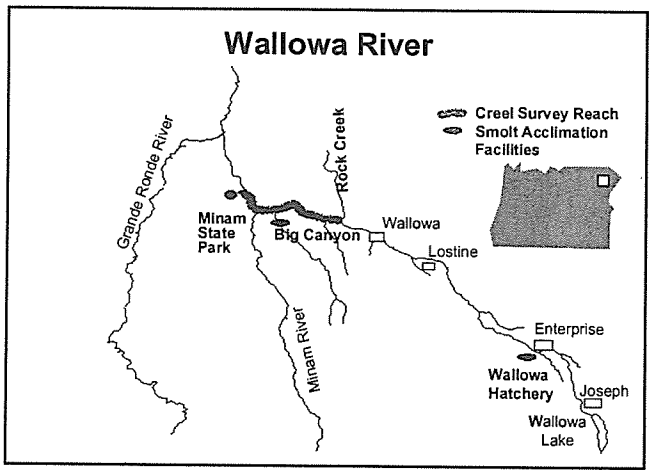


Figure 1.— Map of Wallowa River

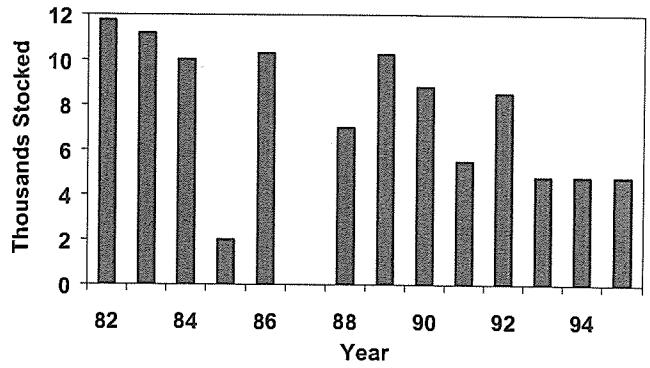


Figure 2.— Number of catchable rainbow trout stocked annually in the Wallowa River from Rock Cr. to Minam State Park, 1982-1995.

MANAGEMENT HISTORY

ODFW has stocked hatchery rainbow trout (Oncorhynchus mykiss) to supplement high use fisheries in northeast Oregon for many years. ODFW stocking records indicate 4,000 to 46,000 catchable rainbow trout stocked annually into the Wallowa River at various locations from 1950 to 1995. Prior to the early 1980's, exact stocking locations were not recorded, only totals for the Wallowa River that include areas in addition to the canyon. Figure 2 displays catchable rainbow trout stocked into the Wallowa River canyon from 1982 through 1995.

The stocking program for the Wallowa River canyon was evaluated in 1979 to assess angler effort, harvest, and exploitation of stocked trout (Anderson 1982). Anderson (1982) concluded that stocking of 10,000 to 11,000 catchable trout per year should continue because the program supported catch rates greater than one fish per angler hour and exploitation of stocked hatchery trout was greater than 60%. The stocking program continued as recommended until the early 1990's when Endangered Species Act (ESA) listing of several Snake River salmonid stocks heightened concerns about interactions of wild and hatchery salmonids. No catchable rainbow trout have been stocked in the Wallowa River canyon since 1995.

Additional releases of hatchery fish into the Wallowa River have occurred during implementation of the Lower Snake River Compensation Plan (LSRCP). The LSRCP summer steelhead program for the Grande Ronde basin began achieving its production goal of 1,350,000 smolts in the mid-1980's following construction of new facilities. Facilities included adult trapping and smolt acclimation facilities on Spring Creek at Wallowa Hatchery (completed in 1985) and at the Big Canyon facility located at the mouth of Deer Creek (completed in 1987; Figure 1). A central rearing facility, Irrigon Hatchery, was completed near Irrigon, Oregon, in 1986 (Whitesel et al. 1998).

Most LSRCP steelhead production for the Grande Ronde basin has been released into the Wallowa River system. Primary release sites have been smolt acclimation facilities with some releases directly into the Wallowa River (Figure 3). An unexpected result of the LSRCP steelhead program has been the numbers of residual steelhead (hatchery smolts that are released but do not migrate out of the basin). Abundance of residual steelhead has not been estimated in the Wallowa River, however, Viola and Schuck (1995) estimated that 3.1% to 17.7% of steelhead smolts released from acclimation facilities in the Tucannon River, Washington, residualized in the river. If hatchery steelhead residualize at similar rates in the Wallowa River their numbers could be substantial (Figure 3). Studies of steelhead residuals in the Grande Ronde basin found they are most numerous near release sites, tend to distribute downstream over time, are mostly males, can persist and grow, and may contribute substantially to sport fisheries (Jonasson et al. 1994).

Earliest records of angling regulations for the Wallowa River are from 1910 when the bag limit for trout in Oregon was 75, six inches or larger. The bag limit changed to 20 pounds from 1924 through 1934, 15 pounds from 1935 through 1941, 15 fish from the 1942 through 1946, ten fish from 1947 through 1979, and to the current five fish bag limit in 1980. The six-

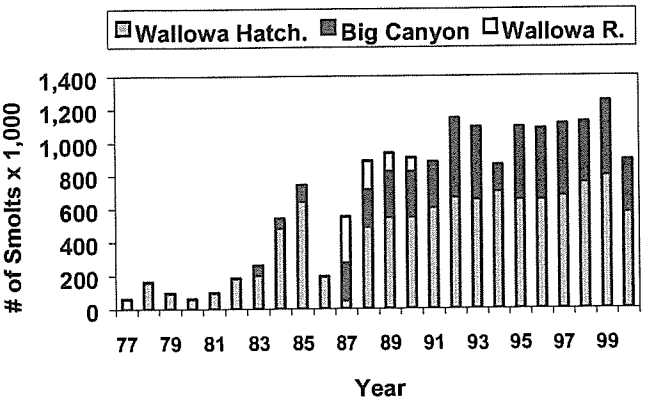


Figure 3.—Annual releases of summer steelhead smolts into Wallowa River, 1977-2000.

inch minimum size persisted until 1997 when the regulation increased to eight inches throughout Oregon.

During development of 1994 angling regulations ODFW received a proposal from a local fishing club to change trout regulations in the Wallowa River to prohibit harvest of wild (unmarked) rainbow trout and prohibit use of barbed hooks and bait. ODFW reached a compromise with those proposing the change. As a result, angling regulations for the Wallowa River from Rock Creek to the mouth allow anglers to keep only adipose fin-clipped trout. Barbless hooks were required from 1994 through 1996 but the regulation was eliminated following state-wide review of barbless regulations in 1997. Bait is allowed in the Wallowa River. The objectives of the compromise regulations are to conserve wild trout while encouraging harvest of hatchery trout and residual hatchery steelhead. The fishing club cooperated with ODFW managers and Wallowa High School shop class to build sign boards at several access points in the Wallowa River canyon and post notices alerting anglers to changes in regulations.

Creel surveys in the Wallowa River canyon in 1995 and 1998 were designed to evaluate success of new regulations by:

1. Estimating angler use, catch, harvest, and exploitation of hatchery trout and comparing results to those obtained in 1979;
2. Comparing relative contribution of catchable rainbow trout (1995 only), residual hatchery steelhead, and wild trout to total catch and harvest and over time through the season; and,
3. Measuring angler compliance with regulations requiring release of wild (unmarked) trout.

ODFW received additional proposals to restrict the use of bait in several northeast Oregon streams in 1996. In response, a combination of Wallowa River creel survey results and information on hooking mortality from the literature were used to examine potential effects of additional restrictions on the fishery and wild trout populations in the Wallowa River. In the following sections, I describe creel surveys and additional analyses and discuss their implications.

CREEL SURVEY METHODS

Methods used to estimate angler effort, catch and harvest in the 1979 survey are described in Anderson (1982) and were similar to those described below for surveys conducted in 1995 and 1998. A stratified cluster sampling approach (Scheaffer et al. 1979) was used in all surveys. Sampling strata included weekdays and weekends/holidays. Clusters were randomly selected days within each stratum with some adjustments for a 40-hour week for personnel conducting surveys. Sampling began in July, after spring run-off had receded, and ended October 31, the end of fishing season.

On each sampling day, counts of anglers were made every two hours. Starting time (0700 or 0800) and location (Minam State Park or Rock Creek) were selected randomly. Counts were made in as short a time period as possible and direction of counts alternated throughout the day. A total of six or seven counts were made each sample day, depending on length of daylight.

Angling parties were interviewed between counts with the following information collected:

1. Number of anglers in party;
2. Time spent fishing to the nearest ½ hour and whether or not they had completed their fishing trip for the day;
3. Number of fish kept (harvest) by species, 2-inch size class, and mark (fin clip);
4. Number of fish caught and released (catch) by species and mark; and,
5. Type of gear used (bait, fly, lure, or combination).

Estimates of angler effort, catch, and harvest were calculated using methods described by Scheaffer et al. (1979) for stratified cluster sampling. Bounds on the error of estimation (bound) were calculated for effort, catch and harvest estimates to approximate a 95% confidence interval (Scheaffer et al. 1979).[1]

[1] Details of methods used to analyze creel survey data will be provided by the author upon request.

Catchable rainbow trout stocked in 1995 were marked with adipose and right ventral fin clips (Ad-RV) so they could be distinguished from residual hatchery steelhead that were marked with either adipose fin clips (Ad) or a combination adipose and left ventral fin clips (Ad-LV). In 1998, only wild rainbow trout and residual hatchery steelhead were available to anglers.

When interviewed, some anglers provided numbers of each mark group caught and released, some reported only unmarked and Ad-marked (recorded as Ad-?), while others reported only numbers of rainbow trout (recorded as Rb-?). I first partitioned the Ad-? group based on the proportion of Ad, Ad-LV, and Ad-RV in the harvested fish observed in the total of all interviews. Angling regulations required release of all unmarked rainbow trout so estimates of marked and unmarked rainbow trout in the Rb-? group were made using proportions of marked and unmarked reported released by anglers who kept track of marked fish. Marked fish were then apportioned as above. I did not estimate bounds on these proportions.

Estimates of Catch and Harvest by Gear Type

Proposals to restrict bait in several northeast Oregon streams prompted a closer look at gear types in Wallowa River creel surveys. Gear type data were used to assign each party interviewed to bait, fly, lure, or other categories. The "other" category was used for anglers who changed gears throughout their fishing trip. Anglers using baited lures or baited flies were assigned to the "bait" category. I then compared effort, catch, and harvest estimates as well as fishing trip characteristics among gear types.

Total effort estimates were apportioned among gear types for each stratum by angler hours recorded for each gear type in interviews. Interview data were also used to compare angler numbers and length of time spent fishing by gear type. Apportioning catch and harvest required additional steps to adjust for Ad-? and Rb-?, recorded as caught and released, among gear types. The composition of the angling population as well as the relative numbers of marked and unmarked rainbow trout in the population likely changed over the angling season. To account for changes over time, I estimated monthly marked and unmarked proportions from all interviews and then calculated monthly adjustments, by gear type, for Ad-? and Rb-? records. Monthly adjustments were incorporated into interview data, by gear type and stratum, prior to calculating estimates of total catch and harvest of each mark group. I also used monthly estimates to assess temporal trends in catch rate and catch composition as indicators of abundance of wild trout and residual hatchery steelhead through the season.

Estimates of numbers of wild rainbow trout caught and released by gear type were used in conjunction with mean hooking mortality rates from Wydoski (1977) to estimate potential hooking mortality of wild rainbow trout. The hooking mortality rates I used were 25% for bait, 4% for flies, 6% for lures and 15% for other. I did not estimate bounds on estimates of catch, harvest and hooking mortality by gear type.

RESULTS

I compared results of creel surveys conducted in the Wallowa River canyon in 1979, 1995, and 1998 and found similarities as well as differences (Table 1). Estimates of angler effort were similar among the surveys (6,595, 6,488, and 5,418 angler hours in 1979, 1995, and 1998, respectively), however, the 1979 survey ended in early September while recent surveys continued through October 31 (Table 1). The greatest difference among surveys was numbers of fish kept by anglers. Anderson (1982) reported harvest of 8,361 total fish in 1979 including 6,748 hatchery rainbow trout. The 1979 hatchery trout harvest was much greater than recent estimates of 2,300 in 1995 and 1,566 in 1998 (Table 1). Anderson (1982) did not report estimates of fish caught and released. Anderson (1982) reported an exploitation rate of 61.1% on 11,000 catchable rainbow trout stocked in 1979. In 1995, 4,800 catchable rainbow trout were stocked and anglers harvested only 968 for an exploitation rate of 20.2 %. Total catch (harvest + catch and release) of catchable hatchery rainbow in 1995, was 3,028, or 63.1% of the number stocked. Catch and release of residual hatchery steelhead was more than double harvest in 1995 and more than six fold greater than harvest in 1998 (Table 1). Catch rates and total catch estimates were much greater for residual hatchery steelhead in 1998 than they were in 1995 (Table 1).

More wild rainbow trout were caught and released in 1995 and 1998 than were harvested in 1979 and total catch rates were greater in the 1990's surveys than harvest rate in 1979 (Table 1). Total catch rates for wild rainbow trout were similar in 1995 and 1998 (0.47/hour and 0.36/hour, respectively; Table 1).

Table 1.—Estimates of angler effort, harvest, catch, and catch rates from creel surveys conducted on the Wallowa River.

	1979[a]	1995		1998	
Inclusive Dates	July 3 – September 9	July 21 – October 31		July 15 – October 31	
Total Angler Hours (Bound)	6,595	6,488	(±377)	5,418	(±347)
Harvest (Bound)					
Catchable Hatchery Rainbow	6,748	968	(±232)	b	
Residual Hatchery Steelhead	b	1,210	(±268)	1,457	(±382)
Wild Rainbow	1,547	95	(±59) c	94	(±63) c
Mountain Whitefish	66	27	(±20)	15	(±20)
Total Harvest	8,361	2,300	(±466)	1,566	(±403)
Catch and Release (Bound)					
Hatchery Rainbow (Ad-?)		3,101	(±724)	8,121	(±1,889)
Unidentified Rainbow (Rb-?)		2,502	(±612)	967	(±522)
Wild Rainbow		1,968	(±455)	1,693	(±459)
Mountain Whitefish		590	(±256)	376	(±283)
Bull Trout		15	(±20)	0	
Total Catch and Release		8,176	(±1,406)	11,157	(±2,259)
Adjusted Catch and Release					
Catchable Hatchery Rainbow		2,060		b	
Residual Hatchery Steelhead		2,571		8,921	
Wild Rainbow		2,940		1,860	
Harvest Rates					
Catchable Rainbow/Hour	1.0	0.15		b	
Residual Steelhead/Hour	b	0.19		0.27	
Wild Rainbow/Hour	0.3	0.01	c	0.02	c
Total Fish/Hour	1.3	0.36		0.29	
Total Catch (Kept+Released) Rates					
Catchable Rainbow/Hour		0.47		b	
Residual Steelhead/Hour		0.58		1.92	
Wild Rainbow/Hour		0.47		0.36	
Total Fish/Hour		1.61		2.36	

[a] *Bounds and catch and release estimates were not reported for the 1979 survey.*

[b] *Residual hatchery steelhead were not present in 1979 and catchable hatchery rainbow were not stocked in 1998.*

[c] *Illegal harvest*

Monthly catch rates for wild rainbow trout and residual hatchery steelhead increased in October in 1995 and 1998 (Figure 4). While wild rainbow trout catch rates were similar in both years, monthly catch rates for residual hatchery steelhead were three to four times larger in 1998 (Figure 4). In 1995, monthly trends in composition of total catch (harvest + catch and release) were similar to catch rates, with percentage of residual hatchery steelhead and wild rainbow trout increasing late in the season (Figure 5). Contribution of catchable rainbow trout declined markedly in October of 1995. In 1998, residual hatchery steelhead dominated the catch throughout the season (Figure 5). However percentage of residual hatchery steelhead in total catch declined while wild trout increased as the season progressed (Figure 5).

Angler compliance with regulations requiring release of wild rainbow trout was very good. In 1995, 23 of 869 (2.7%) anglers interviewed kept one or more wild rainbow trout. Results were similar in 1998 when 14 of 612 (2.3%) anglers interviewed kept a wild rainbow trout.

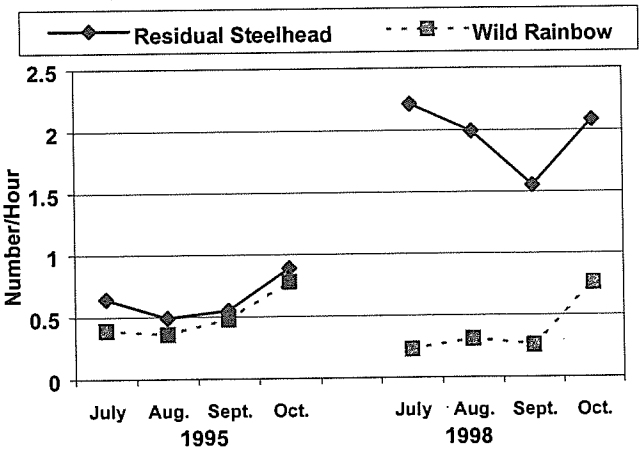


Figure 4.—Monthly catch rates for residual hatchery steelhead and wild rainbow trout in 1995 and 1998.

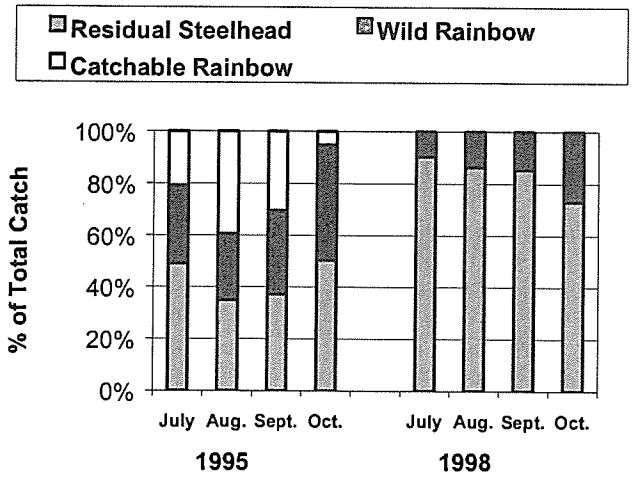


Figure 5.—Monthly composition of the total rainbow trout catch (harvest + catch and release) in 1995 and 1998.

Table 2 displays average hours per angler, by gear type, for completed trips and for all anglers interviewed (complete and incomplete trips) in 1995 and 1998. In both years, average hours per angler were greatest for fly anglers. Another indicator of disproportionate effort among gear types is comparison of relative number of anglers versus total angler hours from interviews. In 1995, we interviewed 866 total anglers with the following percentages by gear type: 36.7% bait, 36.0% fly, 11.7% lure, and 15.6 % other. Percent of angler hours by gear type was 32.4% bait, 43.9% fly, 9.5% lure, and 14.2% other. In 1998, gear type distribution of 612 anglers interviewed was 37.4% bait, 47.4% fly, 14.2% lure, and 1.0% other, while angler hours were 33.1% bait, 54.5% fly, 11.3% lure, and 1.1% other.

Table 2.—Average length of angling trip, by gear type, from Wallowa River creel surveys in 1995 and 1998.

Avg. hours/angler	1995 (# anglers)	1998 (# anglers)
Complete trips:		
Bait	1.99 (68)	1.79 (66)
Fly	3.40 (76)	2.28 (60)
Lure	1.55 (21)	1.87 (26)
Other	3.02 (29)	1.00 (2)
All interviews:		
Bait	1.73 (318)	1.48 (229)
Fly	2.39 (312)	1.92 (290)
Lure	1.60 (101)	1.33 (87)
Other	1.79 (135)	1.83 (6)

Number of wild rainbow trout hooked per angler and per angler hour was greatest for fly anglers and least for bait anglers in both 1995 and 1998 (Table 3). Conversely, number of hatchery rainbow trout harvested per angler and per angler hour was greatest for bait anglers and least for fly anglers (Table 3). These relationships among gear types hold for total catch and harvest estimates with fly anglers hooking the largest numbers of hatchery and wild trout but releasing most of their catch while bait anglers accounted for the majority of hatchery trout harvested (Figure 6).

Table 3.—Wild rainbow trout catch rates and hatchery rainbow trout (catchable trout and residual steelhead) harvest rates, by gear type, from Wallowa River creel surveys in 1995 and 1998.

	1995		1998	
	#/angler	#/hour	#/angler	#/hour
Wild Rainbow:				
Bait	0.47	0.27	0.38	0.26
Fly	1.69	0.71	0.81	0.41
Lure	0.53	0.33	0.44	0.33
Other	0.44	0.24	0.50	0.26
Hatchery Rainbow:				
Bait	1.04	0.60	0.93	0.62
Fly	0.21	0.09	0.16	0.08
Lure	0.73	0.46	0.22	0.16
Other	0.74	0.41	0.17	0.09

Estimates of hooking mortality of wild rainbow trout caught and released were 1.6 and 2.1 times greater for bait anglers than for fly anglers in 1995 and 1998, respectively (Figure 7). Total estimated hooking mortality was less than 10% of total wild trout caught and released by all anglers in both years (Figure 7).

DISCUSSION

Easy access to the Wallowa River makes it a relatively high use fishery compared to other trout fisheries in northeast Oregon. However, fishing pressure measured in these surveys is approximately 300 to 400 angler hours per kilometer per year or 150 to 200 angler hours per hectare per year, about half the fishing pressure reported by Thurow and Schill (1994) for the Big Wood River in Idaho. Schill (1992) reported that 35% of waters managed under general regulations in Idaho received over 200 angler hours per hectare per year of effort. When compared to other trout fisheries in the western United States, the Wallowa River canyon receives moderate fishing pressure.

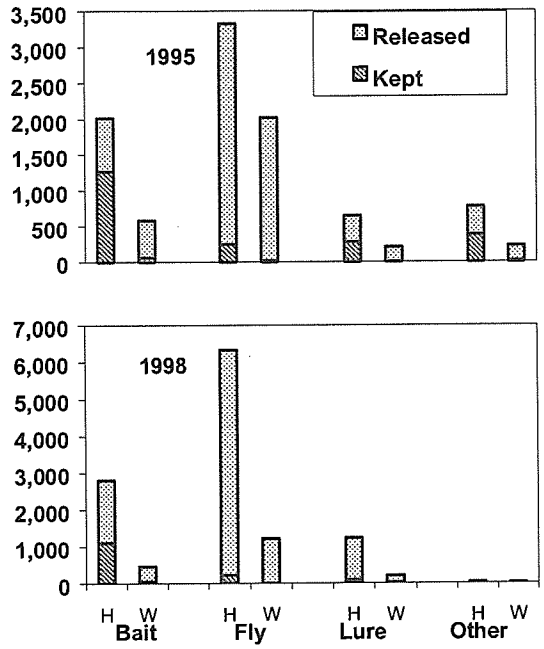


Figure 6.—Estimates of total hatchery and wild rainbow caught and released by gear type in the Wallowa River, 1995 and 1998. Note the difference in y-axis scales.

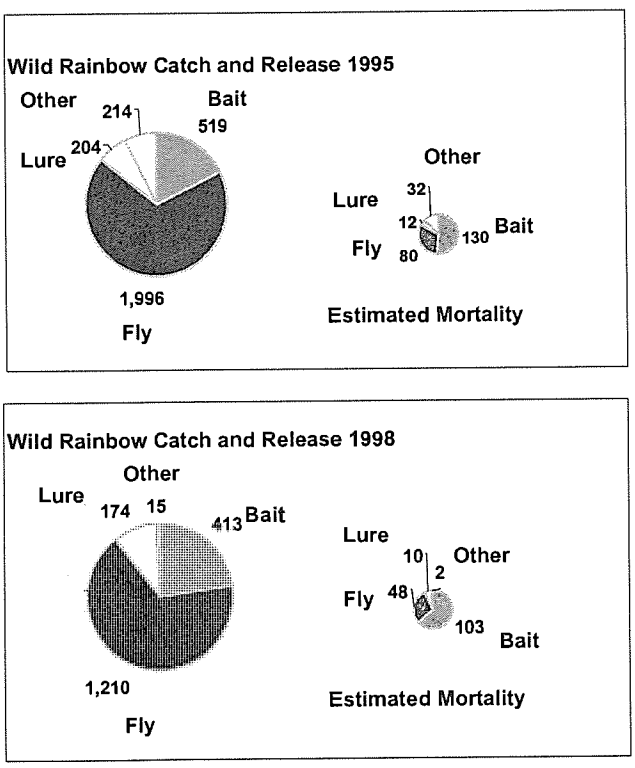


Figure 7.—Estimated catch and release of wild rainbow and hooking mortality by gear type in the Wallowa River, 1995 and 1998. Hooking mortality rates: Bait-25%, Fly-4%, Lure-6%, and Other-15%, from Wydoski (1977).

Wild trout have persisted in the Wallowa River canyon in spite of a long history of general, consumptive fisheries. Angling regulation changes in 1995 increased protection of wild rainbow trout while encouraging harvest of hatchery rainbow trout. While comparisons of wild rainbow trout status among the 1979, 1995, and 1998 surveys are confounded by regulation changes, there is no evidence of significant decline. However, we have no other measures of wild rainbow trout abundance to corroborate results of creel surveys.

Catch rates for wild rainbow trout and residual hatchery steelhead actually increased late in 1995 and 1998 seasons. While it is likely that changes in the angler population following the end of local tourist season contributed to increased catch rates, results do not suggest a significant decrease in abundance over time. Residual hatchery steelhead comprised 90% of the total catch in July and decreased to 73% by October in 1998. High catch rates and dominance of the total catch suggest residual hatchery steelhead were abundant throughout 1998.

Angler awareness and acceptance of wild-release regulations was very good with compliance rates greater than 97% in both 1995 and 1998. Information about regulations posted at access sites and presence of creel survey personnel undoubtedly contributed to angler awareness. Attempts to use regulations to encourage removal of hatchery trout that may compete with wild salmonids appear to be only partially successful. Exploitation of hatchery trout decreased appreciably since 1979, apparently a result of voluntary catch and release by anglers.

Reduced exploitation by anglers and apparent abundance of residual hatchery steelhead supported our decision to eliminate stocking of catchable rainbow trout. Angler success, measured by total catch rates (Table 1), actually increased in 1998 after stocking of catchable hatchery rainbow trout was discontinued, primarily because of high catch rates for residual hatchery steelhead.

Public proposals to prohibit angling with bait in several northeast Oregon streams prompted further evaluation of 1995 and 1998 creel survey results to estimate wild rainbow trout hooking mortality. Ideally, evaluations of effort, catch, and harvest by gear type would be incorporated in initial design of creel surveys by treating gear types as separate strata. In this case, analyses of differences among gear types were done "after the fact" and contain many assumptions. For example, I assumed angler accounts of fish

caught and released were accurate and anglers using each gear type gave equally accurate responses. I also assumed angler interviews accurately represented relative effort among gear types and mean mortality by gear type reported by Wydoski (1977) provided reasonable estimates for the Wallowa River fishery. I did not attempt to test the validity of these assumptions or quantify precision of resulting estimates. In spite of these shortcomings, I believe the results are informative.

Estimates of total wild rainbow trout hooking mortality (all gear types combined) were less than 10% of total wild rainbow trout caught in the Wallowa River canyon in 1995 and 1998 (Figure 4). Hooking mortality rates less than 10% are small when compared to 30% to 60% natural mortality rates in wild trout populations in Oregon and Idaho (Schill 1991; Schroeder and Smith 1989). Some authors have reported evidence of compensation for angling mortality in natural mortality rates (Schroeder and Smith 1989). If such compensation occurs in the Wallowa River, angling mortality rates of less than 10% would be relatively insignificant to the wild trout population.

Results of Wallowa River creel surveys illustrate that angler behavior must be considered when applying results of hooking mortality studies to management decisions. During discussions of angling regulation proposals, frequent reference was made to four to six fold greater hooking mortality when angling with bait compared to flies. However, these relationships imply equal effort and success among gear types. In Wallowa River evaluations fly anglers spent more time angling (Table 2), generally moved more and fished more of the area available, and caught and released more wild trout than bait anglers (Figure 3). When hooking mortality rates from Wydoski (1977) were applied to wild trout catch estimates, bait anglers accounted for more mortality than fly anglers but estimates of mortality were 1.6 times greater in 1995 and 2.1 times greater in 1998 (Figure 4). These differences are much less than would be expected from results of hooking mortality studies alone.

Another consideration in setting angling regulations to protect wild trout in the Wallowa River is the fishery's potential to reduce numbers of competitors, such as residual hatchery steelhead. Studies in the Yakima River system, Washington, found evidence of displacement of wild salmonids by residual hatchery steelhead (McMichael et al. 1999) and reduced growth of wild rainbow trout in the presence of residual hatchery steelhead (McMichael et al. 1997). Large numbers of hatchery steelhead are likely to continue to be released in the Wallowa River system because of mitigation responsibilities of LSRCP and production agreements with tribal co-managers. Attempts are being made to reduce numbers of residual hatchery steelhead through volitional smolt release strategies as recommended by Viola and Schuck (1995). However, success of these efforts is uncertain and we are likely to continue to encourage anglers to harvest residual hatchery steelhead in the trout fishery.

Bait anglers were the only group harvesting significant numbers of residual hatchery steelhead in 1995 and 1998 surveys. Bait anglers kept approximately 5 times as many hatchery trout as fly anglers, both on a per angler basis (Table 3) and in estimates of total harvest by gear type (Figure 3). Bait anglers accounted for 58.2% and 76.9% of total hatchery trout harvest in 1995 and 1998, respectively (Figure 3).

Review of past and recent creel survey results have brought managers of the Wallowa River trout fishery to the following conclusions:

1. Effort has remained relatively consistent since the late 1970's;
2. Catch rates remain high (>1 fish/hour);
3. Harvest in recent years is much less than recorded in the late 1970's, primarily because of voluntary catch and release by anglers;
4. Residual hatchery steelhead have effectively replaced catchable hatchery rainbow trout to support the consumptive angling;
5. Angler awareness of and compliance with wild release regulations has been very good (>97%); and,
6. Additional regulations to restrict bait are unlikely to provide additional benefit to wild trout populations and may be detrimental because of reduced exploitation of residual hatchery steelhead.

ACKNOWLEDGMENTS

I'd like to thank Brad Smith and Bruce Eddy for their encouragement and support. John Gordon, Katy VanDis, and Shelley Ringo collected and summarized field data. I'd also like to thank Brad Smith, Tim Walters, and Bob Hooton for their reviews of draft manuscripts. Funding for creel surveys was provided by U.S. Fish and Wildlife Service, Sport Fish Restoration Program.

LITERATURE CITED

Anderson, G. A. 1982. Catchable rainbow trout studies for the Lostine, Imnaha, and Wallowa Rivers. Oregon Department of Fish and Wildlife Information Report Number 82-9. Portland, Oregon.

Clark, R. D. Jr. 1983. Potential effects of voluntary catch and release of fish on recreational fisheries. North American Journal of Fisheries Management 3:306-314.

Jonasson, B.C., R. W. Carmichael, and T. A. Whitesel. 1994. Residual hatchery steelhead: characteristics and potential interactions with spring chinook salmon in northeast Oregon. Annual Progress Report, Oregon Department of Fish and Wildlife Fish Research Project number 14-48-0001-93538. Portland, Oregon.

McMichael, G.A., C.S. Sharpe, and T.N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Transactions of the American Fisheries Society 126:230-239.

McMichael, G.A., T.N. Pearsons, and S.A. Leider. 1999. Behavioral interactions among hatchery-reared steelhead smolts and wild *Oncorhynchus mykiss* in natural streams. North American Journal of Fisheries Management 19:948-956.

Scheaffer, R.L., W. Mendenhall, and L. Ott. 1979. Elementary survey sampling. Duxbury Press, North Scituate, Massachusetts.

Schroeder, R.K. and L.H. Smith. 1989. Life history of rainbow trout and effects of angling regulations, Deschutes River, Oregon. Oregon Department of Fish and Wildlife Information Report Number 89-6. Portland, Oregon.

Schill, D.J. 1991. Wild trout investigations. Idaho Department of Fish and Game. Job Performance Report. Project F-73-R-13. Boise, Idaho.

Schill, D.J. 1992. Wild trout investigations. Idaho Department of Fish and Game. Job Performance Report. Project F-73-R-13. Boise, Idaho.

Thurow, R.F. and D.J. Schill. 1994. Conflicts in allocation of wild trout resources: an Idaho case history. Pages 132-140 *in* R. Barnhart, B. Shake, and R.H. Hamre, editors. Wild Trout V: Wild Trout in the 21st Century. Yellowstone National Park, Wyoming.

Viola, A.E. and M.L. Schuck. 1995. A method to reduce abundance of residual hatchery steelhead in rivers. North American Journal of Fisheries Management. 15:488-493.

Whitesel, T.A., R.W. Carmichael, M.W. Flesher, and D.L. Eddy. 1998. Summer steelhead in the Grande Ronde river basin, Oregon. Pages 21-31 *in* Lower Snake River Compensation Plan Status Review Symposium, U.S. Fish and Wildlife Service, Boise, Idaho.

Waples, R.S. 1999. Dispelling some myths about hatcheries. Fisheries 24(2):12-21.

Wright, S. 1992. Guidelines for selecting regulations to manage open-access fisheries for natural populations of anadromous and resident trout in stream habitats. North Americn Journal of Fisheries Management 12:517-527.

Wydoski, R.S. 1977. Relation of hooking mortality and sublethal hooking stress to quality fishery management. Pages 43-87 *in* R.A. Barnhart and T.D. Roelofs, editors. Catch-and-release fishing as a management tool. California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California.

The Effects of Hook Size on Hooking Mortality of Juvenile Summer Steelhead, *Oncorhynchus mykiss*, Captured on Adult Summer Steelhead Gear

Greg A. Taylor[1], Mary A. Buckman[2], and David V. Buchanan[3]

Abstract—Releases of juvenile non-native summer steelhead, *Oncorhynchus mykiss*, have occurred in the Willamette Basin (Oregon) since the 1960's. These releases have produced large hatchery runs of adult summer steelhead for angling. However, many of these same streams have declining runs of wild adult winter steelhead. Regulations governing most streams allow the use of bait in the adult summer steelhead fishery. Because of the threatened status of Willamette winter steelhead, concern over the potential impact of bait fishing has grown. We examined hooking mortality of juvenile steelhead trout captured on standard adult summer steelhead gear; baited single hooks and treble hooked lures with three different hook sizes. We captured 823 juvenile steelhead and mortality was 4.3 % for all six hook size and terminal gear combinations tested. There was no significant difference in mortality between gear types (bait 3.6%, lure 4.4%) ($p > 0.05$), but a significant difference between hook sizes ($p < 0.05$). Small hooks had a significantly higher catch rate than large hooks ($p < 0.05$), and there was a significant difference between gear types (bait, lures) ($p > 0.05$). We believe that a minimum hook size regulation is a conservative approach and may reduce the catch rate of juvenile steelhead on adult terminal gear, but may not alter total mortality associated with incidental take of juveniles in adult steelhead fisheries.

INTRODUCTION

Steelhead, *Oncorhynchus mykiss*, are generally classified into two separate races summer and winter steelhead (Withler 1966, Smith 1960, 1969; Everest 1973). Summer steelhead enter streams between April-October, hold for several months in deep pools, attain sexual maturity, and generally spawn in January or February. Winter steelhead enter streams sexually mature from November-March and generally spawn from January-April. Currently, many streams in the Willamette Basin (Oregon) support large hatchery produced runs of adult summer steelhead (e.g. Clackamas, Molalla, Sandy, and Santiam). However, many of these same streams have declining runs of wild adult winter steelhead. To date, regulations governing most streams allow the use of bait in the adult hatchery summer steelhead fishery. Because of the sensitive status of wild winter steelhead, concern over the potential impact of bait fishing on juvenile winter steelhead has grown. Mongillo (1984) found hooking mortality associated with bait typically ranged from 23-35% for wild resident rainbow trout caught on standard gear. No data has been collected on juvenile steelhead, however, Mongillo (1984) believes it is extremely likely that data pertaining to resident rainbow and cutthroat trout is applicable to juvenile steelhead.

To minimize the potential impact of bait on wild juvenile winter steelhead, a minimum hook size regulation was implemented. Anglers using bait are restricted to single point hooks #1 or larger (7/16″ gap), multiple point hooks #4 or larger (3/8″ gap) year round (ODFW 1999). Few studies have assessed

[1] EBA, ODFW, Springfield, OR
[2] *Biometrician, ODFW, Corvallis, OR*
[3] *NRS 3 (Retired), ODFW, Corvallis, OR*

hook size as it relates to hooking mortality in salmonids. Shetter and Allison (1955) found that #4 and #8 single hooks baited with worms killed significantly more brook trout > 175 mm than #2 hooks. Hulbert and Engstrom-Heg (1980) found higher mortality associated with #4 hooks than with #2 or #6 hooks. No studies have directly assessed juvenile steelhead hooking mortality associated with adult steelhead terminal gear.

We examined hooking mortality of juvenile steelhead trout caught on standard adult summer steelhead terminal gear; baited single hooks and treble hooked lures with three different hook sizes. The goals of the experiment were to determine the overall mortality rate of juvenile steelhead captured on adult summer steelhead terminal gear and to identify an optimal hook size, which would allow an adult summer steelhead fishery while minimizing juvenile steelhead mortality.

STUDY SITE

We conducted this study at Leaburg Hatchery located on the McKenzie River Leaburg, Oregon. The hatchery cultures summer steelhead, catchable rainbow trout, and cutthroat trout (*O. clarki*). This facility has 39 concrete raceways that were maintained at 7-9 θC during experimental angling. We conducted experimental angling in a single raceway 30.5 m in length, 6.1 m wide, and 1.1 m deep. The raceway contained approximately 3,000 fish (mean FL=23 ρ 0.1 cm) and feeding was suspended eight days prior to fishing. Juvenile steelhead caught during the experiment were held in an identical raceway for observation.

METHODS

We conducted experimental angling using 26 volunteer anglers on 18-19 May 1998. All anglers used standard adult summer steelhead spinning and bait casting gear. Terminal gear consisted of 3/8 oz. Bangtail Spinners with size #2, #4 and ¼ oz. with #6 treble hooks and single hooks size #4, #1, 2/0 baited with salmon roe or worms.

Six three-person teams (2 anglers, 1 recorder) conducted angling. Each angler was assigned a number that corresponded to a pre-determined random sampling schedule. Anglers fished all six gear and hook size combinations for an equal amount of time. After hooking a fish, anglers lifted fish from the raceway into a five-gallon bucket, marked it with a standard paper punch (Figure 1), removed the hook and released it into the bucket.

Bait						Lure					
Single Hook						Treble Hook					
#4		#1		2/0		#6		#4		#2	
C	Nc	C	Nc	C	Nc	C	Nc	C	Nc	C	Nc

• Hook Placement: C = critical (eyes, gills, tongue, esophagus) Nc = non-critical (jaw)

Figure 1.—Marking scheme for juvenile steelhead trout captured on baited single hooks and lures with treble hooks of three different hook sizes. Fish captured on each of the six hook sizes were marked with a different shaped paper punch on the upper or lower caudal fin dependent on hook placement.

Fish were immediately transferred from the bucket to the holding raceway. We recorded the terminal gear used, hook type, hook size, hook placement and size (to the nearest cm) for each fish landed. Hook placement was classified as critical or non-critical. We defined critical areas as hook placement occurring in the eyes, esophagus, gills, or tongue and non-critical areas as hook placement occurring in the jaw or mouth (Mongillo 1984).

A control group of 104 juvenile steelhead were netted randomly, marked in the caudal fin with a paper punch, and held in the holding raceway. We observed the raceway for 48 hours following the completion of experimental angling. Mongillo (1984) found that 90-95% of hooking mortality occurs within 48 hours. Dedual (1996) found that 93% of total mortality of rainbow trout occurred within 26 h following release. Mortalities were recovered, measured, and recorded.

We used ANOVA to compare catch rates among anglers using different gear types and hook sizes. We used a chi-square test of independence to determine whether there were statistical differences in hooking mortality between hook sizes and gear type, and to determine if gear type or hook size had a significant effect on hook location. We chose an alpha level of 0.05 to determine statistical significance. The statistical software packages S-Plus (1995) and SAS were used to conduct the statistical analysis.

RESULTS

There was a significant difference in catch rate between hook sizes ($p < 0.05$) and between gear types (bait, lures) ($p < 0.05$). Bait with large hooks caught fish at less than half the rate as bait with small and medium hooks (Table 2). Catch rate for lures with large hooks was almost half that of lures with small hooks (Table 1).

Table 1.—Catch rate (Fish/hr) for 823 juvenile steelhead captured on baited single hooks size #4, #1, and 2/0 and lures with treble hooks size #6, #4, and #2 from Leaburg Hatchery, 1998.

Gear/Hook size	Catch Rate (Fish/Hr.)
Bait single hook/	
Small (#4)	10.4
Medium (#1)	11.5
Large (2/0)	4.8
Lure treble hook/	
Small (#6)	10.6
Medium (#4)	6.4
Large (#2)	5.3

Table 2.—Percentage of juvenile steelhead critically hooked for six adult steelhead gear combinations, 1998.

Gear/ Hook size		Critically Hooked (%)
Bait single hook/		
Small (#4)		27.3
Medium (#1)		28.9
Large (2/0)		22.2
	Average	27.1
Lure treble hook/		
Small (#6)		29.4
Medium (#4)		27.1
Large (#2)		26.4
	Average	28

Hook size did not influence hook placement ($p > 0.05$). Anglers captured 823 fish, hooking 230 in critical areas (27.5%) (Table 2).

Of these, 445 were captured using bait and 27.1% were critically hooked. Anglers using artificial lures captured 378 fish, hooking 28.0% in critical areas. There was no significant difference in hook placement between bait and artificial lures ($p > 0.05$).

We captured a total of 823 juvenile steelhead (mean FL = 233 mm) at water temperatures of 7-9 ℃. Overall mortality was 4.3% (35 mortalities) for all six hook size and terminal gear combinations tested (Table 1). There was no significant difference in mortality rate between gear types (bait 3.6%, lure 4.5%) ($p > 0.05$), but a statistically significant difference in mortality rate between hook sizes ($p < .05$) (Table 1). Large bait hooks produced the highest associated hooking mortality (10.3%) while medium bait hooks produced the lowest hooking mortality (0.5%). No mortality was recorded for the control group of 104 juvenile steelhead held in the holding raceway during the observation period.

Table 3.—The number of fish caught, mortalities recorded, and percent hooking mortality for 823 juvenile steelhead captured with six adult steelhead terminal gear combinations at Leaburg Hatchery, May 1998.

Gear/Hook size	Number Caught	Mortalities	Hooking Mortality (%)
Bait single hook/			
Small (#4)	171	7	4.1
Medium (#1)	196	1	0.5
Large (2/0)	78	8	10.3
Total	445	16	3.6
Lure treble hook/			
Small (#6)	178	4	2.2
Medium (#4)	114	9	7.9
Large (#2)	86	4	4.7
Total	378	17	4.5
Total	823	35[a]	4.3

[a] *35 total mortalities, 2 unidentifiable*

DISCUSSION

There was a significant difference in catch rate between hook sizes and between gear types. Large baited single hooks (2/0) caught less than half as many fish as small and medium baited single hooks. Lures with large hooks caught less than half as many fish as lures with small hooks. It appears that juvenile steelhead may be gape limited by large adult gear and this gear may considerably reduce catch of juvenile fish.

The percentage of fish critically hooked using baited single hooks was 27.1% well below rates reported by (Schisler and Bergersen 1996) for rainbow trout caught using bait (78.3%). The overall mortality rate was 4.3% for all six terminal gear and hook size combinations tested. The mortality rate for bait (3.6%) is low when compared to previous studies (Schisler and Bergensen 1996, Schill 1996, Klein 1974, Stringer 1967, and Shetter and Allison 1955). Mongillo (1984) found mortality ranged from 23-35% for rainbow trout captured with bait. The lower mortality rate may be a function of adult terminal gear entering critical areas at a lower rate than standard trout gear of the appropriate size. The overall mortality rate for lure-caught fish was similar to results reported in previous studies at the same water temperature (Titus and Vanicek 1988, Warner 1976, Klein 1965).

There was a significant difference in mortality rate between hook size. Large baited single hooks produced the highest mortality overall (9.9%). It is unclear why fish captured using large baited single hooks had a significantly higher mortality rate than fish captured on small and medium size baited single

hooks. It is possible that these large hooks cause more substantial injuries. In this study 15% of the fish hooked in a critical area by a small baited single hook died, but 33% of the fish hooked in a critical area by a large baited hook died. In addition, only three of the 35 mortalities recovered were hooked in non-critical areas, but two of the three were caught using large baited single hooks even though they accounted for the fewest number of fish caught.

Most important for management is to assess the total number of mortalities caused by each of the six hook size and gear type combinations tested. The total number of mortalities produced is a function of the catch rate of the terminal gear and percent hooking mortality associated with the terminal gear. Because the catch rate associated with smaller hooks was greater, even though the percent hooking mortality was lower the total mortality is nearly indentical to large hooks.

The results of this study may vary with changes in water temperature, capture of wild versus hatchery fish, and fishing in a river versus hatchery setting. Many studies have found that hooking mortality increases with increasing water temperature (Nuhfer and Alexander 1992, Dotson 1982, Titus and Vanicek 1988, Taylor 1998 unpub. data). Conducting this experiment at higher water temperatures could increase the overall rate of mortality. Mongillo (1984) found that wild salmonids have mortality rates 2 to 4 times higher than hatchery fish caught on artificial lures and flies, but simialr mortality rates when captured on bait. Fishing in a river setting may actually decrease the overall mortality rate for bait because the bait is fished actively with the current not passively on the bottom. Schisler and Bergersen (1996) found that artificial baits fished actively produced lower hooking mortality than artificial baits fished passively.

We believe these results are representative of wild juvenile steelhead hooking mortality in adult summer steelhead fisheries. We found hooking mortality of juvenile steelhead captured on adult steelhead terminal gear to be low (4.3%) under the conditions of the experiment. We believe that a minimum hook size regulation is a conservative approach and may reduce the catch rate of juvenile steelhead on adult steelhead terminal gear, but may not alter total mortality associated with incidental take of juveniles in adult steelhead fisheries.

LITERATURE CITED

Dedual, M. 1996. Observed Mortality of Rainbow Trout Caught by Different Angling Techniques in Lake Taupo, New Zeland. North American Journal of Fisheries Management. Vol. 16 357-363.

Everest, F.H. 1973. Ecology and Management of Summer Steelhead in the Rogue River. Oregon State Game Comm. Fish. Res. Rep. No. 7, Corvallis. 48pp.

Hooton, R.S. 1987. Catch and Release as a Management Strategy for Steelhead in British Columbia. Pages 143-156 in R.A. Barnhart and T.D. Roelofs, editors. Proceedings. Humboldt State University, Arcata, California.

Hulbert, P.J. and R. Engstrom-Heg. 1980. Hooking mortality of worm-caught hatchery brown trout. NEW YORK FISH AND GAME JOURNAL. 27 (1): 1-10.

Mongillo, P.E. 1984. A Summary of Salmonid Hooking Mortality. Washington Department of Fish and Game, Fish Management Division. 44pp.

Shetter, D.S. and L.N. Allison. 1955. Comparison of mortality between fly-hooked and worm-hooked trout in Michigan streams. Michigan Dep. Conserv., Inst. Fish Res., Misc. Publ. No. 9. 44p.

Smith, S.B. 1960. Racial Characteristics in Stocks of Anadromous Rainbow Trout, *Salmo gairdneri* Richardson. Ph. D. Thesis. University of Alberta, Edmonton, Alberta.

Smith, S.B. 1969. Reproductive Isolation in Summer and Winter Races of Steelhead Trout. Pages 21-38, In Symposium on Salmon and Trout in Streams. University of British Columbia. Inst. Fish. Vancouver.

Statistical Sciences, *S-Plus Guide to Statistical and Mathematical Analysis, Version 3.3*, Seattle: StatSci, a division of Mathsoft Inc., 1995.

Withler, I.L. 1966. Variability in Life History Characteristics of Steelhead Trout (*Salmo gairdneri*) Along the Pacific Coast of North America. J. Fish. Res. Board Can. 23 (3):365-393.

Biological and SocioEconomic Aspects of Natural State Catch and Release Regulations

John Stark[1], Stan Todd[2], Larry Rider[3]

Abstract—Catch and release requirements in Arkansas date to 1988, when the .5 mile long Dry Run Creek was opened to youth and disabled anglers. Catch and release has helped to ensure the continuance of 20 pound plus brown trout (Salmo trulla) spawning runs in the White River System. However, in some cases improper handling has led to mortality from secondary fungal infections and necessitated fishing closures. In the case of developing fisheries, catch and release regulations have been implemented to allow introduced rainbow trout (Oncorhynchus mykiss) to establish reproduction. The 1995 designation of 5 White River catch and release areas has had a profound biological and economic impact. Within 3 years, catch and release areas contained as many as 1,000x more 16 inch or larger rainbow than the pre-regulation state. Anglers were 6-8x more likely to catch 16-18 inch rainbow in designated areas and therefore the stretches received up to 2.6 times more use than non-catch and release areas. Catch and release areas have annually generated approximately $1,200,000/mi versus $400,000/mi in undesignated waters. However, despite the fact that 70% of surveyed anglers favor additional catch and release waters, it has been difficult to obtain new areas due to the opposition of influential interest groups.

INTRODUCTION

The implementation of catch and release fishing regulations have often been regarded by anglers as the ultimate answer for achieving trophy sized trout. Much of the enduring reputation for catch and release equaling trophy trout is due to the response of the fisheries in which they were first implemented. In particular, the early success in the Yellowstone area fisheries (Wells 1984) established the effectiveness of catch and release to increase numbers of quality sized trout. Increased numbers and size of trout have also been documented after the implementation of catch and release regulations in other parts of the country (Barnhard and Engstrom-Heg 1984, and Nehring and Anderson 1984).

Arkansas' experience with catch and release regulations extends over a 12-year period. During this period the Arkansas Game and Fish Commission has implemented catch and release fishing regulations to achieve a various goals including the maintenance of a phenomenal kids fishing stream conservation of the nation's premier trophy brown trout (Salmo trulla) populations, world-class tailwater rainbow trout (Oncorhynchus mykiss) fishing opportunities, and the establishment of a spring creek wild rainbow population.

MANAGEMENT HISTORY

In 1988, the previously closed Norfork National Fish Hatchery effluent stream (Dry Run Creek), was designated as catch and release fishing for youth under 16 years of age and licensed disabled individuals. During the public portion of the regulation process, many individuals expressed concern that if the .5 mile long stream were opened to fishing, many trout would be killed and thereby eliminate a "seed" source of large trout for the Norfork Tailwater. Conservative fishing tackle restrictions (single hook arti-

[1]*State Trout Biologist, Arkansas Game and Fish Commission, Mountain Home, Arkansas.*

[2]*Assistant Trout Biologist, Arkansas Game and Fish Commission, Mountain Home, Arkansas.*

[3]*Assistant Chief of Fisheries, Arkansas Game and Fish Commission, Little Rock, Arkansas.*

ficial lures) were implemented to reduce hooking mortality.

Pre-regulation samples indicated that the population of Dry Run Creek ranged from 14,000 too more than 19,000 trout per mile (unpublished data). Post-regulation electrofishing samples were conducted from 1988 through 1994 in order to access potential population changes. Post-regulation population numbers and size have shown no statistically significant decrease since the opening of fishing. Total numbers of trout consistently exceed 13,000 trout per mile approximately 10% of the population exceeding 16 inches in length (unpublished data). Individual trout as large as 15 pounds are consistently captured.

White River Brown Trout

Two variations of catch and release regulations have played a part in preserving arguable the greatest brown trout fisheries in the world. In 1988 the Arkansas Game and Fish Commission effectively mandated catch and release for all Beaver tailwater brown trout under 16 inches by implementing a 16 inch minimum length limit and a creel of 2 fish per day. The purpose of the regulation was to protect wild brown trout from harvest until they were three years of age and thus allow the these fish to spawn at least once before potentially being harvested (Hudy and Rider 1989). Survival of stocked trout more than doubled following the implementation of the 16 inch size limit.

The Beaver Tailwater size limit was extended statewide in 1990. Annual population sampling indicated that by 1998 wild brown trout comprised 90% of the Bull Shoals Tailwater population. Unfortunately the Little Red River (Greers Ferry Tailwater) with its consistently strong year classes was added administratively to the list of regulated waters despite the objections of the state trout biologist at the time. Within a few years as many as 10,000 (mostly 10-14 inches) brown trout per mile were present and many individuals were emaciated. Therefore a 16-21 inch protective slot limit with a four fish creel was implemented. Recent samples have indicated that overall numbers have declined and condition factors are within normal ranges. In other White River tailwaters, the regulation has been relatively ineffective in increasing wild brown trout numbers despite the regulation's desired impact of retaining sexually mature fish. Apparently environmental or bioenergetic conditions are not currently suitable for survival of young of the year trout (Pender 1998).

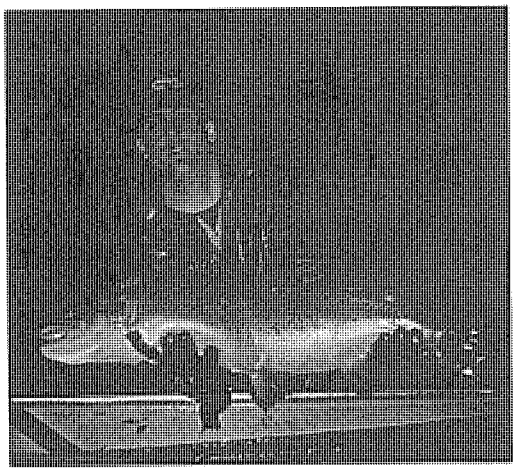


Figure 1.—Large White River spawning brown trout.

Bull Shoals and Greers Ferry tailwaters have historically produced consistently strong spawning runs with high numbers of brown trout between 5 and 20 pounds. Some of the spawning brown trout exceed 30 pounds (Figure 1).

During the spawning season, these large brown trout can move upstream at least 30 miles to known spawning shoals (Stark and Bowman 1995) and anglers historically have removed many as trophies. By 1990 the national reputation of these spawning runs had resulted in what appeared to be dangerously high harvest at the population level. AS a result, brown trout catch and release was mandated from November 1 through January 31 to allow for the spawning and dispersal of large trout. While this regulation has prevented harvest, at times noticeable population attrition has occurred from post-spawn fungal outbreaks.

In 1996, Bull Shoals Dam hydroelectric generation was minimal during the spawning and post-spawning period and an apparent jump in brown trout angling was noted. Improper handling led to post-spawn fungal lesions (often hand shaped) and alarming winter and early spring die-off. The number of 24 inch or larger brown trout in the spring of 1997 was approximately 50% of the spring 1996 samples (unpublished data). In the fall of 1997 favorable conditions of intensive angling were again present and a fishing closure on the largest and most well known Bull Shoals Tailwater spawning area (The first mile below Bull Shoals Dam) was passed to prevent a recurrence of the damage to the 1996 spawning run.

Other spawning areas where catch and release fishing is still allowed are currently being monitored to assure that handling stress and resultant popula-

tion damage does not reach the severity noted at Bull Shoals Dam. Should occurrences of high mortality take place, it is likely that additional fishing closures would be implemented for spawning shoals in the White River system.

Tailwater Rainbow Trout and Catch and Release

During the 1950s and 1960's Arkansas' White River tailwaters consistently produced 5 to 10 pound rainbow trout. However, large rainbow trout were nearly non-existent by the 1980s. During 1992 through 1993 growth and persistence of marked rainbow was monitored. Growth of stocked rainbow trout was within the historical levels of .5 to .5 inch/month. However, spring and summer stocked cohorts largely disappeared within 45 days of stocking. The rapid decline in rainbow trout cohorts was attributed to fishing impacts because much of Arkansas trout fishing occurs in spring and summer.

Based upon this information, on January 1, 1995 Arkansas entered the arena of quality rainbow trout management with the designation of 5 White River tailwater catch and release areas totaling 5.5 miles. The first areas were located so that each of the 4 Arkansas tailwaters in the White River system had at least one catch and release area. The 92 mile long Bull Shoals Tailwater received 2 catch and release areas totaling 2.3 miles. Permitted tackle in these areas are artificial lures (included flies) with single barbless, hook point. Within the areas, all trout have to be released although possession of trout from other areas is allowed as a concession to the float-fishing constituency. The goal of catch and release areas was/is to produce rainbow and cutthroat trout of at least 4 pounds. The biological and socioeconomic impacts of the catch and release fisheries have been profound.

Rainbow Trout Population Response

Within one year of catch and release designation, electrofishing samples indicated that in 4 out of the 5 areas phenomenal increases had occurred in the number of rainbow trout per mile, and 16 inch or larger rainbow (unpublished data). Specifically:

- Total numbers of rainbow trout were 2-3X greater than the pre-regulation state or in the surrounding normally regulated waters.
- Numbers of 16 inch or larger rainbow trout increased 5-58X.
- Anglers were 6-8X more likely to catch a 16 inch or larger rainbow trout than in non-catch and release areas.

By 1999, the four successful areas contained:

- Population levels 2-10X greater than that of the pre-regulation state or surrounding normally regulated waters (As great as 10,000 per mile).
- 10-58X more 16 inch or larger rainbow per mile (As great as 1,000 per mile).
- 15-200X more 20 inch or larger rainbow trout per mile (No 20 inch rainbow were found in the pre-regulation state or in surrounding normally regulated waters).
- Rainbow trout of at least 10 pounds in 3 areas with several in excess of 15 pounds (Figure 2).
- Noticeable wild rainbow trout populations in 2 of the areas.

An example of the rainbow trout population and size distribution response to catch and release is shown in Figure 3.

Figure 2.—Rainbow trout in excess of 10 pounds from a White River tailwater catch and release area.

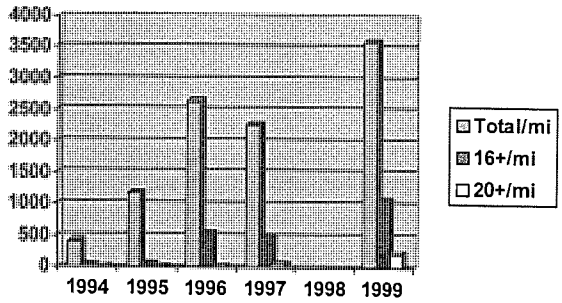


Figure 3.—1994 - 1999 Rainbow trout population indices from the Bull Shoals Dam catch and release area.

In the case of the one area (Little Red River) in which catch and release did not have an effect it was thought that the area either contained to much deep pool area to be productive and/or that designation of the previously lightly fished area resulted in greater fishing pressure (and therefore greater angling mortality than previously). It is planned to evaluate the fishery dynamics and trout behavior in the Greers Ferry Tailwater catch and release area to determine with certainty why the area has not been successful.

Angler Response

During the public meeting phase of the 1995 fishing regulation process little angler opposition was evident with 4 out of the 5 areas. However, nearly equal numbers of anglers/guides supported as opposed the Rim Shoals catch and release area located in Bull Shoals Tailwater. Much of the opposition to this area was from float-fishing guides and outfitters in the town of Cotter (located 7 miles upstream). The float fishing constituent of the fishery was/is primarily bait fishing and harvest oriented. After catch and release designation, an angler creel survey was conducted from early 1995 to early 1998 on Bull Shoals and Norfork tailwaters. (Todd, Stark, and Bivin, 1999). During the 3-year creel period it was determined that:

Generally, angling pressure (an indication of use) in the catch and release areas grew dramatically while use of non catch and release areas stayed the same or declined.

- The Bull Shoals catch and release areas received up to 2.6X more angling pressure than non catch and release areas.
- Anglers surveyed in the catch and release areas spent more time fishing than anglers surveyed in non-catch and release areas.
- Likewise anglers surveyed in catch and release areas had mean travel distances approximately 100 miles greater than their counterparts in non catch and release areas.
- Nearly 2/3 of the anglers in catch and release areas were non-residents.

Economic Impact

Information on average trip expenditures for residents and non-residents in 1994 (unpublished survey data) was combined with percentages of each type of angler fishing catch and release and non catch and release areas (Todd, Stark, and Bivin 1999). Economic figures generated for Bull Shoals Tailwater during the 1995-1998 creel survey indicated that:

- Over the 3 year period, catch and release areas were 1.8, 2.3, and 2.9X more valuable ($) per mile on a monthly basis.
- By 1997-98 catch and release areas were valued monthly at $96,864 per mile. Normally regulated areas at $33,257.
- Monthly values expanded equate to $1,162,370 and $399,081 per mile on an annual basis.

Current States of Tailwater Catch and Release Areas

Currently, there are 8 permanent catch and release areas totaling 9.6 miles in the 4 White River System tailwaters. Two of the additional catch and release areas were added to Bull Shoals Tailwater during 1997-98. A third new area (.5 mile long) was added to Greers Ferry Tailwater. A .5 mile long seasonal catch and release area has also been implemented in Narrows Tailwater downstream of Lake Greeson in southern Arkansas. The seasonal catch and release area is located in a portion of the otherwise cold weather only fishery that supports trout year-round. Catch and release is mandated from May 1 to October 15 and tackle restrictions during this period are identical to the year-round areas.

An aquatic users survey conducted by Responsive Management in 1999 indicates that over 70% of trout anglers favor additional catch and release areas (Duda 2000). However, it is unlikely that additional areas will be added for a number of years due to the opposition of politically strong interest groups.

Developing Fisheries

Most recently catch and release regulations have been utilized to protect a developing fishery in which managers hope to establish a completely self-sustaining wild rainbow fishery. Spavinaw Creek is an Ozark Region spring creek with water temperatures of less than 70°F in the head water portion. Because water temperature is not suitable for smallmouth bass, no native predators are present. Fish population surveys also revealed that no listed species were present. Therefore, a decision was made to introduce rainbow trout fingerlings and attempt to create a self-sustaining rainbow trout population.

Experimental rainbow trout stockings in the early 1990s had indicated that growth of stocked trout was extremely rapid. Therefore catch and release regula-

tions were implemented in January 1997 to protect introduced rainbow trout fingerlings from harvest and thus allowing them to reach sexual maturity. Hot Creek strain rainbow trout fingerlings were planted in the stream in May 1997. Samples in August 1998 indicated that although few adults were present, at least one strong year-class (approximately 1,000 per mile) had been produced from either the recently stocked trout or remnants of the earlier experimental stockings (Figure 4).

MANAGEMENT CONCLUSIONS

After 12 years of utilizing catch and release regulations in Arkansas several conclusions can be drawn about the application of the management technique. Overall the various applications of catch and release utilized in Arkansas have performed well.

In the case of small stream fisheries (Dry Run Creek) catch and release has served to conserve high density populations of memorable sized trout that are exposed to substantial numbers of anglers. Protection of introduced trout (Spavinaw Creek wild rainbow) is also an invaluable tool to the start-up of new fisheries while allowing anglers to enjoyment of fishing new waters.

Catch and release of sexually immature brown trout (< 16 inches) has proved to be critical for the continuance and expansion of the stellar wild brown trout fisheries of Arkansas. However it was also noted that catch and release fishing improperly applied to a strongly reproducing wild population (Little Red River brown trout) can actually bring about negative changes in conditions and size structure. Heavy angling pressure and improper handling can in fact defeat the conservatory goal of catch and release (Bull Shoals Dam brown trout spawning shoal example) and lead to limited fishery closures.

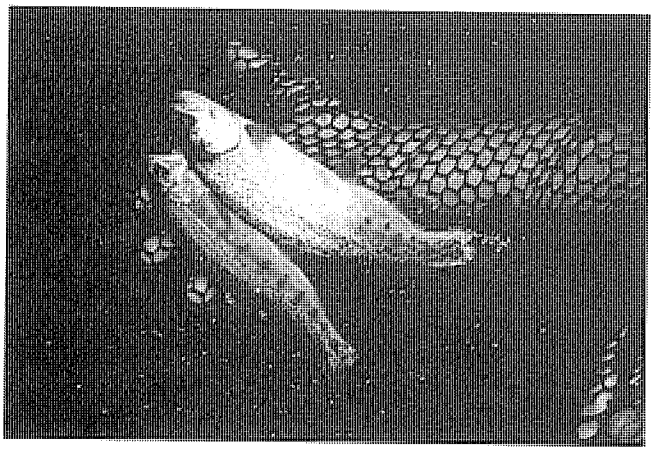


Figure 4.—Wild rainbow trout from Spavinaw Creek.

In most cases (4 of 5 areas), the application of catch and release regulations to stretches of the famed White River tailwaters has achieved some of the most dramatic transformations of a rainbow trout fishery ever documented. While most of the rainbow trout fishery is of stocked origin, two catch and release areas in Bull Shoals Tailwater have developed noticeable wild rainbow components. In the case of the Rim Shoals catch and release area, it appears that the rainbow population in this area may eventually become largely of wild origin.

Failure of catch and release regulations to effect positive change in one rainbow trout fishery (Little Red River) may be due to the selection of an area comprised largely of a deep pool that may be relatively unproductive. Additionally the area in the pre-regulatory state appeared to receive little angling pressure while the designation of other catch and release areas has resulted in documented increases in angling pressure. Increased fishing pressure may be great enough that hooking mortality may negate expected longer life expectancy of release trout. Further examination into the causes of the failed area may well yield definitive answers that will help refine the selection process in the future.

As Bob Benke said at Wild Trout Two "Such information as angling pressure, size, age structure, biomass, and production rates are needed to make sound decisions. How much angling pressure is required to catch 50% of a year-class in a fishery? Under most circumstances, unless we are dealing with a particular long-lived trout population with low natural mortality rates, special regulations will not work a dramatic change to produce older and larger trout if the annual angling kill is much less than 50% of the catchable size trout." Based upon the Arkansas experience it would be wise as well to add good trout habitat to the sage counsel of Dr. Benke.

It is clear that the various regulatory forms of catch and release fishing belong in the trout manager's "tool belt". Properly applied, catch and release can be used (often in spectacular fashion) to achieve many management goals. However it is also clear from the Arkansas experience that facts and logic often do not apply (either for or against) where catch and release is concerned.

LITERATURE CITED

Barnhart, G.A. and R. Engstrom-Heg, 1984. A synopsis of some New York experience with catch and release management of wild salmonids. Page 91-101 in Wild Trout III Symposium (Yellowstone National Park, Wyoming, Sept 24-25, 1984).

Duda, M.D. et.al, 2000. Arkansas resident anglers and non-resident anglers awareness of and attitudes toward fishing in Arkansas. Final Report to Arkansas Game and Fish Commission. Blacksburg, Virginia. 60 pp.

Hudy, M. and L.L. Rider. 1989. Brown trout management in the natural state. Pages 67-70 in Wild Trout IV Symposium (Yellowstone National Park, Wyoming, Sept. 24-25, 1984).

Nebring, R. B., and R. Anderson, 1984. Catch and release management in Colorado – what works? How, when, where, why? Pages 109 – 112 in Wild Trout III Symposium (Yellowstone National Park, Wyoming, Sept. 24-25, 1984).

Pender, D. R., 1998. Factors influencing brown trout reproductive success in Ozark tailwater rivers, M.S. Thesis. Arkansas Cooperative Fish and Wildlife Research Unit. University of Arkansas, Fayetteville, 146 pp.

Stark, J. D. and D. W. Bowman. 1995. Movement of resident trout in the Bull Shoals Tailwater in response to differing levels of dissolved oxygen and spawning. Project Report, Arkansas Game and Fish Commission, 21 pp.

Todd, C. S., J. D. Stark, and W. M. Bivin, 1999. Bull Shoals – Norfork tailwaters creel 1995 – 98. Final Report, Arkansas Game and Fish Commission. Little Rock, AR. 44 pp.

Wells, J. 1984. Restrictive regulations – the Montana experience, Pages 113 – 114 in Wild Trout III Symposium (Yellowstone National Park, Wyoming, Sept. 24-25, 1984).

Circle Hooks: Remedy for Bait Angling Mortality?

Steve Parmenter[1]

Abstract— A small but active number of anglers oppose the restriction of bait from most of California's growing list of special management trout waters. The California Department of Fish and Game recruited some of these individuals into a volunteer project to examine aspects of bait fishing. The cooperative project compared the performance of baited circle hooks and traditional 'J' hooks with respect to catchability, injury, and mortality of cultured rainbow trout. Results of the comparison do not suggest a difference in hook wound locations or trout catchability. Mortality was 19.0% in the 'J' hooked fish, which was significantly greater (p=0.01) than the 10.4% rate in circle hooked fish. Vascular injury was the probable cause of death in 77% of the hook mortalities. The geometry of circle hooks reduces the tendency to puncture deeply, diminishing the severity of wounds. The project helped educate and interest "bait-rights" advocates in the scientific basis of catch-and-release, focused interest on methods to reduce bait impacts, and reduced conflict. Results of this study do not support the admittance of baited circle hooks into regulated catch-and-release waters. Voluntary use of circle hooks gives individual bait and fly anglers who wish to release trout an improved means to do so.

BACKGROUND

In 1971 the California Fish and Game Commission adopted a Wild Trout Policy in response to staff advocacy and external lobbying. The policy establishes guidelines which encourage management for a "quality experience...in aesthetically pleasing and environmentally productive waters." To reduce harvest and encourage catch-and-release, the California Department of Fish and Game (Department) reduced bag limits and bait restrictions on eight California streams (Deinstadt, 1977). Angler survey data (Deinstadt and Parmenter, 1997) show following elimination of stocking in a 16 mile section of the Owens River, angler use declined from 17,500 hours per month to less than 7,000.

Institutional acceptance of special trout management was slow in California State government. Further advocacy by wild trout advocates led to passage of the Trout and Steelhead Conservation and Management Planning Act of 1979. This act codifies objectives for wild trout management, establishes a statewide inventory of trout waters, and requires the Department to annually recommend a minimum of 25 miles and one lake for reduced bag limits. The act defines catch-and-release fishing as a 0, 1, or 2-bag limit, but does not require exclusion of bait or barbed hooks.

The wild trout project has consistently made successful nominations to fill the expected quota of streams and lakes. Nomination is based upon an evaluation of each fishery's productivity, perceived need for harvest reduction, and the popularity of existing trout management programs such as "put and take." As a result of these parallel mandates, special management programs exist in a variety of combinations upon the State's most productive trout waters. California's coldwater resources have been estimated to include 18,000 miles of streams (Leopold et al. 1966). At present 1,054 miles of these have been placed into special management for wild trout. Of these, bait angling is proscribed from 913 miles, or 87% of the resource.

The traditional reluctance to include bait angling in wild trout areas stems largely from the high angling mortality rates demonstrated in the literature (Shetter and Allison, 1955; Mason and Hunt, 1967; Wydowski, 1977; Hulbert and Engstrom-Heg, 1980) and from case studies where harvest rates substan-

[1]*Associate Fishery Biologist, California Department of Fish and Game, Bishop, CA.*

tially affected population structure (Deinstadt and Parmenter, 1997). For 28 years, designation of waters for special management has emphasized highly accessible roadside waters in the middle elevations of California's mountain ranges. These select areas are perceived by most to possess the highest productivity, growth rates, and standing crops of the state's coldwater resources.

Designations have been preceded by conservative weighing of the biological, political, and even sociological ramifications of proposed management changes. A minority of highly eligible candidates for special designations have not been nominated, in favor of retaining existing, popular and successful put-and-take programs. The growth of special management areas has nevertheless spawned a reactionary sentiment in many individuals who profess a belief that the rights of a putative majority of anglers are infringed by the prohibition of bait. An aspect of this view is the perception that an organized minority of flyfishers have used the political process to incrementally disenfranchise a less cohesive (silent) majority of anglers who fish exclusively with bait.

As a representative of the Department's wild trout project I was asked to respond to complaints and allegations received individually, through the op-ed pages of newspapers, and via the state assemblyman's office. Elements of an effective response included defense of specific special regulations through data and documented case studies, explanation of the biological arguments for banning bait, and identification of areas of agreement.

Despite mutual misgivings about our respective values and aims, one key activist and I were able to agree that more information is needed about causes, and potential technical remedies for, bait angling mortality. Schill (1997) recommends evaluating the efficacy of circle hooks in reducing hooking mortality among resident trout. This recommendation became the basis for a cooperative study led by the Department of Fish and Game and supported by the efforts and participation of more than 20 volunteers from both sides of the bait question.

METHODS

Circle hooks were provisionally defined as hooks with a point which curves inward to aim approximately 90θ to the shank. Eight major hook manufacturers were contacted to determine the availability of circle hooks in sizes appropriate to the angling with bait for stream dwelling trout. No commercially available products were initially found which met these criteria. However, one manufacturer agreed to experimentally produce the desired hooks (Eagle Claw model L2050-12), which were then obtained for study. Commercially available bait hooks were evaluated to select a 'J' shaped hook would be closely match the experimental hook's in overall size and wire gage. For this purpose I selected a smooth barbed bait hook (Jorgensen Brothers model 960 size 8) for the study.

Fish injuries, mortality, and catchability were experimentally compared for the two hook types and a control group at Fish Springs State Hatchery, Inyo County, California. Twenty volunteer anglers of various ages and abilities supplied their own rods and reels to capture cultured rainbow trout from the hatchery raceways. Prior to fishing, technicians randomly affixed either a snelled 'J' or a snelled circle hook to a swivel on the angler's line, with one or more 0.3 gram lead sinkers attached above the swivel.

Hooks were pre-baited with one half piece of commercially obtained molded, scented artificial bait (Berkeley Power Chews) such that hook type was (at least initially) not observable by the volunteer. The volunteer anglers were requested to fish passively, self-time their efforts with a stopwatch, and submit each caught fish for initial inspection by a biological technician. Half of the fish were carried to the work-up tables suspended by the hook, a distance of 50 to 250 feet, with the remainder carried in water buckets.

Anglers were asked to try to keep each captured fish alive, and were provided hemostats and scissors to aid with fish "release." Technicians monitored the anglers; recorded data, monitored compliance with experimental protocol, and replaced baited hooks after each capture. Elapsed time required to catch each fish was self-timed by each volunteer with a stopwatch, although individual approaches were observed in how lost hooks and re-baiting were accounted for by some anglers. After each capture, the angler presented the fish to a waiting technician for an initial inspection to determine the hook type and location in the fish.

Locations were categorized as mouth, eye, gill, esophagus, stomach, and external (foul hooked). Following this, anglers simulated release by either removing the hook or cutting the line, at the angler's discretion, and placing the fish in a tub of water containing the anaesthetic ms 222. Technicians then

recorded individual fork lengths and weights, and affixed individually numbered stainless steel tags (National Band and Tag Co. style 893 size 3 monel) to the right opercula of sedated fish. Anglers caught 401 trout, of which 212 were caught using circle hooks and 189 using 'J' hooks.

A control group of 224 rainbow trout were obtained by long-handled dip net from the same raceways where fishing took place. Handling was intended to replicate the all the stresses treatment fish experienced, except hook related damage. Water temperature was 55ØF. Air exposure was similar in duration for all groups, as both hooked and control fish were carried on foot over the same route between the capture area and the recording stations. Anaesthesia, measurement, tagging, and revival of control fish was the same as for treatment fish.

After tagging, all treatment and control trout were released into a common 100' x 10' raceway for a 28 day observation period. Dead fish were collected daily from the holding area between October 6, 1998 and November 2, 1998. For each individual mortality, records were kept of tag number, evidence of external injury, and hook damage to the gills and gill arches. The fish were dissected to detect internal hemorrhage, and the location and status of any embedded hooks were noted. Cause of death was attributed to gill arch damage, internal hemorrhage, or unknown factors.

Surviving trout were individually checked for tag retention, measured, weighed, and checked for the presence or absence of embedded hooks after 26 days of observation. Embedded hooks were detected by probing the alimentary tract of anaesthetized trout with a finger, and/or by dissection.

Data were analyzed with the SAS (SAS Institute 1989) statistical program. Mortality rates and hook wound locations for each treatment were compared using a Chi-square test for equality of proportions.

RESULTS

Mortality and Injury

The mortality rate for circle hooks (10.4%) was significantly lower (p=0.01) than for 'J' hooks (19.0%).

Table 1.—Summary of Sample Size and Mortality Rates

treatment	caught	died	% mortality
circle	212	22	10.4
'J'	189	36	19.0
control	224	1	0.5

Table 2.—Distribution of Hook Wounds by Anatomical Site (%).

location	circle hooks	'J' hooks
mouth	48	46
gill	7	9
esophagus	38	39
stomach	5	2
foul	3	4

Deep hooking (gill, pharynx, and stomach) occurred in 50% of the circle hook captures, and in 49% of the captures with 'J' hooks. There were no significant differences in the anatomical distribution of hook wound locations caused by circle and 'J' hooks (p=0.49).

Autopsy revealed high rate of severe vascular injury. Of 60 autopsies conducted on trout from the treatment groups; 22.9% showed gill arch puncture or rupture, 43.8% presented large internal hemorrhages, 4.2% had both gill trauma and internal bleeding, and 27.1% had neither. No small hemorrhages were noted during the study. One out of 224 control fish died on day 18 of the observation period, with no sign of vascular injury. Of the treatment mortalities, 66.7% occurred on the first day, 86.7% within one week, and 98.3% within two weeks.

Forty-seven incidental notations were made on the data forms of bleeding fish within the treatment groups. Of the 47 reported bleeders, 29 fish, or 62% survived until the end of the observation period.

Angler Performance and Behavior

The mean time to capture one trout was 1.74 minutes, with a standard deviation of 0.94 minutes. Nineteen of 20 anglers had catch rates within 2 standard deviations of this rate. The slowest mean catch rate was 3 minutes 43 seconds per trout. The mean catch time for 'J' hooks was 1.6 minutes; for circle hooks it was 1.9 minutes, which was not significantly different (p=0.17). Individual anglers did not catch fish significantly faster with one type of hook (p=0.68, no interaction effect of angler and hook type in ANOVA).

The average mortality rate by angler was 14.5% with a standard deviation of 9.3 percent. One angler's fishing caused a 35% mortality rate, slightly higher than the mean plus 2 standard deviations. No significant relationship (correlation) was found between catch time and fish mortality per angler (p=0.93).

Anglers chose to clip the line and leave the hook embedded in a total of 35.5% of captured trout. The hooks most likely to be left in were those stuck farthest down the alimentary canal. In the stomach

100% of thirteen hooks were left in. In the esophagus 66 % of 169 hooks were left in. For hooks in the gills, 48% of 31 hooks were not removed. Ninety-eight percent 185 hooks lodging in the lip and mouth were left in place.

DISCUSSION

The specific circle hook design used in this study reduced the severity and associated mortality of bait hooking injuries. However, the circle design did not reduce the incidence of deep hooking.

Circle hooks are intended by design to reduce the frequency of deep hooking by allowing the engulfed hook to be pulled from the pharynx as the fish, not the angler, tensions the line. Unexpectedly, this study failed to show any difference in the hook wound locations between the two hook types. Despite virtually identical deep hooking frequencies, mortality rate associated with circle hooks was half of the 'J' hook rate. A plausible explanation is that the circle hook geometry causes the point to "bite" more shallowly.

Dissimilarities between the hook types selected for the experiment were not believed to have affected study outcomes. The 'J' hook had an up eye and gold color, while the circle hooks were ring eyed and black. These differences were accepted because it was felt more important to standardize the weight and bulk of the overall "package." The hooks were snelled to eliminate differences in how hooks rode on the line, and pre-baited to rule out reactions to hook color on the part of both fish and anglers.

A more important compromise was made in selecting the specific circle hooks model for the experiment. The smallest available production hooks were more than three times the size of typical bait hooks for trout. Custom manufacture of the hooks used in this study involved retooling and construction of custom dies. Technological limitations dictated the final style, which was not the precisely scaled-down version of larger circle hooks I had hoped for.

Future research using more circular shapes or different styles or might uncover designs which are effective at avoiding deep hooking. I have used an ingenious hook called the "Shelton Releaser" which can be removed from even deeply hooked trout without touching either hook or fish. The future holds many additional opportunities to reduce bait hooking mortality through innovative technology.

A majority of authors conclude that hook wounds, not handling stress, are the underlying cause of most angling mortality (Trotter, 1995). In this study the high rate of severe vascular injury among non-survivors, and the negligible loss of control fish, lead to the same conclusion. This markedly contrasts with advice about careful handling emphasized in typically distributed catch-and-release guidelines. Management agencies and conservation groups may wish to revise their message if the intended audience includes anglers using bait.

The survival of a majority of bleeding fish is anecdotal data and should be interpreted with reservation. External bleeding was not systematically sampled for, so there may be unknown bias in the observation and notation of bleeders on the data sheets. Warner and Johnson (1978) reported 86 percent mortality among bleeding fish in their study, and most anglers hold the belief that a bleeding fish is doomed. A more rigorous evaluation of bleeding and mortality should be undertaken before attempting to temper this common belief.

Volunteer anglers in this study were given a deliberately brief, one-time explanation of the hook's intended mechanism of action, and were requested to fish passively without setting the hook. Despite this, some anglers were observed actively "setting the hook," and the frequency of mouth and esophagus hooking differed significantly among anglers. Active fishing would be expected to increase the frequency of shallow hooking (Schill 1997) for 'J' hooks, but might actually increase deep hooking with circle hooks which have been swallowed. If so, active fishing would have contributed to the lack of differences in wound locations. Experience and skill could increase the rate of lip hooking with circle hooks, leading to higher trout survival, but this was not evaluated in the current study.

Extrapolation of these results from the hatchery setting to wild trout is risky. Low water temperature probably contributed to high overall survival of hooked trout, in comparison with similar studies. Differences in the feeding behavior of cultured and wild trout may result in different patterns of hook injuries. Further analysis could be more realistic if conducted on wild trout, or in less densely stocked waters. Recruitment of a diverse population of anglers strengthened the study by making the results more representative of behaviors and skill levels to be expected from the public at large.

Although this study was not designed to compare baited circle hooks with artificial lures or flies, some inference regarding this problem can be made. The death rate associated with baited 'J' hooks was lower than reported in the literature (Wydowski, 1977; Mongillo, 1984; Taylor and White, 1992; Schisler and Bergersen, 1996) despite rough handling and tagging. It is not known whether species, rearing history, angler behavior, or other aspects of the hatchery setting contributed to the low mortality rates. Taylor and White (1992) give a mean mortality rate for bait caught fish of 31.4 % in their review of published studies. Unknown factors such as fish species, rearing history, and fishing gear may have contributed to this difference.

If these differences were not present, one would expect higher mortality rates would have occurred in this study. If so, then 10.4 % mortality rate should be considered on the low end of expected mortalities for baited circle hooks. This rate compares unfavorably poorly with the adjusted mean mortality rates reported by Taylor and White (1992) for fly fishing (3.8 %) and artificial barbless lures (4.9%).

A hypothetical trout fishing regulation requiring circle hooks for bait can therefore not be equated with the protection levels offered by traditional "artificials only" requirements. However, circle hooks do substantially reduce hooking mortality. Voluntary usage of circle hooks can reduce mortality of bait caught (and released) fish. Potential disadvantages of popularizing catch-and-release with baited circle hooks include increased total mortality if bait anglers adopt this practice. This would be particularly likely if more bait anglers feel justified in "high-grading" as a result. On the other hand, fly fishers are legendary for seeking to eliminate even the smallest risk of death faced by fly-caught trout. Tying flies on circle hooks would save more fish, and as a voluntary recommendation it can be endorsed by all.

ACKNOWLEDGEMENTS

Mr. George Large of Wright McGill Co. brought a new line of trout hooks to market in response to my inquiry and the study needs. Calvin Chun provided expert assistance with sampling design and data analysis. This project was partially supported by Federal Aid in Sport Fish Restoration Act Program funds.

LITERATURE CITED

Deinstadt, J.M., 1977. Catch-and-Release Angling in California's Wild Trout Streams. Pages 119-124 *in*: R. Barnhardt, Editor; Proceedings of a national symposium on catch-and-release fishing. Humboldt State University, Arcata, CA.

Deinstadt, J.M. and S. Parmenter, 1997. Lower Owens River Wild Trout Area Management Plan. California Department of Fish and Game, 42 pp.

Hulbert, P.J. and R. Engstrom-Heg, 1980. Hooking mortality of worm caught hatchery brown trout. New York Fish and Game Journal 27 (1):1-10.

Leopold, A.S., T.L. Kimball, R.H. Stroud, M.B. Schaefer, and C.W. Buchheister, 1966. California Fish and Wildlife Plan. Calif. Dept. Fish and Game, 110 pp.

Mongillo, P.E., 1984. A summary of salmonid hooking mortality. Washington Department of Game. 44 pp.

Schill, D.A., 1996. Hooking mortality of bait caught rainbow trout in an Idaho stream and a hatchery: implications for special-regulation management. North American Journal of Fishery Management 16:348-356.

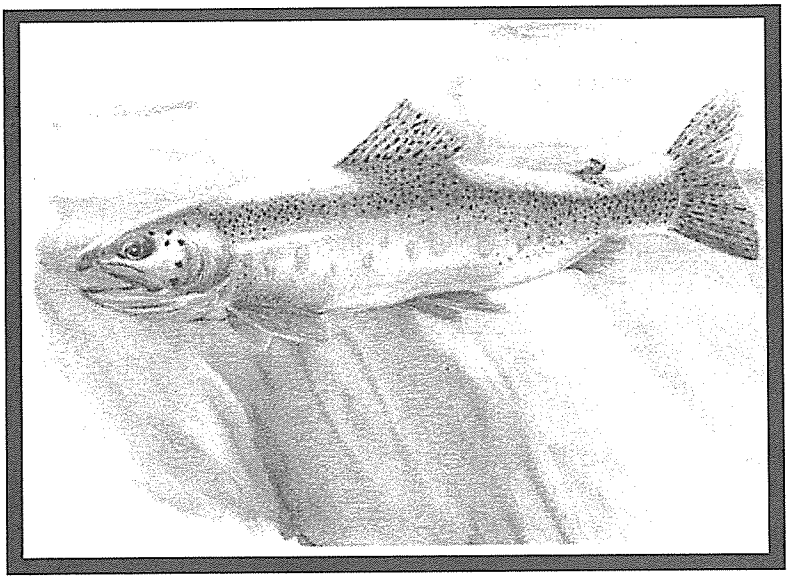
Schisler, G.J. and E.P. Bergersen, 1996. Postrelease Hooking Mortality of Rainbow Trout caught on released on scented artificial baits. North American Journal of Fishery Management 16:570-578.

Shetter, D.S. and L.N. Allison, 1955. Comparison of mortality between fly-hooked and worm-hooked trout in Michigan streams. Michigan Department of Conservation, Miscellaneous Publication No. 9.

Taylor, M.J. and K.R. White 1992. A meta-analysis of hooking mortality of nonanadromous trout. North American Journal of Fishery Management 12:760-767.

Trotter, P. 1995. Hooking Mortality of Trout. Fly Fisher Magazine, Federation of Fly Fishers, March issue.

Warner, K. and P.R. Johnson, 1978. Mortality of landlocked atlantic salmon (*Salmo salar*) hooked on flies and worms in a river nursery area. Transactions of the American Fishery Society 107: 772-775.



Artwork by Mimi Matsuda

An Overview of Endangered Species Act Processes

Michael M. Long[1]

Abstract—The Endangered Species Act (ESA) is a landmark piece of environmental legislation that is both widely known and widely misunderstood. This paper briefly discusses the process for listing threatened and endangered species, interagency consultation on listed species pursuant to section 7 of the ESA, prohibitions on taking of listed species and issuance of permits to allow take of listed species, the recovery process, and two tools to encourage voluntary landowner conservation measures.

INTRODUCTION

The Endangered Species Act of 1973 (ESA) is one of the most recognized pieces of legislation in America. While many are aware of the ESA and its general intent, few people understand its various provisions and requirements. This paper is intended to provide a general understanding of some of the major provisions of the ESA and the processes involved in their implementation.

THE ENDANGERED SPECIES ACT

Purposes and Definitions

The purposes of the ESA are to 1) provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved; 2) to provide a program for the conservation of such endangered species and threatened species; and 3) to take steps to achieve the purposes of various treaties and conventions (such as the migratory bird treaties with Canada, Mexico and Japan).

A few basic terms must be defined to facilitate an understanding of the ESA. An endangered species is any species in danger of extinction throughout all or a significant portion of its range. A threatened species is any species likely to become endangered in the forseeable future in all or a significant portion of its range. The term "proposed species" is used to denote species that have been proposed for listing as either threatened or endangered but for which a final listing decision has not been made. Proposed species receive only limited protection under the ESA. A candidate species is a species for which the U.S. Fish and Wildlife Service (Service) has on file sufficient information on biological vulnerability and threats to support proposals to list them as threatened or endangered. Candidate species are afforded no protection under the ESA.

The Listing Process

The first step toward protection under the ESA is listing as either threatened or endangered - a process described in section 4 of the ESA.. Listable entities are species, subspecies (including varieties of plants), and distinct population segments of vertebrates. Distinct population segments are determined based on discreetness of the population segment in relation to the remainder of the species to which it belongs, and the significance of the population segment to the species to which it belongs. It is the intent of Congress that distinct population segments be employed only sparingly in making listing decisions.

The listing process can be initiated in two ways - through a petition process or through an internal candidate species review process.

Petitions to List

Anyone may petition the Service (or the National Marine Fisheries Service for anadromous fish and certain marine mammals) to add a species to the list of threatened and endangered species, or to reclassify an already-listed species. Once a petition is received, the Service has 90 days to make a finding as to whether the petition presents substantial information that the listing *may* be warranted. If the Service's "90-day finding" determines that listing may be warranted, an in-depth status review of the species is initiated and announced in the Federal Register.

[1]*Field Supervisor, U.S. Fish and Wildlife Service, Cheyenne, WY.*

Data and other information concerning threats and population status of the species are solicited from States, other Federal agencies, species experts and the public. Timeframes and procedures for submitting information are spelled out in the 90-day finding in the Federal Register. The status review must be completed within 1 year of receipt of the petition, at which time the Service makes one of the following "12-month" findings and publishes the finding in the Federal Register: 1) listing is not warranted; 2) listing is warranted; or 3) listing is warranted but precluded by higher priority listing activities.

If listing is not warranted, the process ends. If a warranted but precluded finding is made, the Service must revisit such a finding annually on the anniversary of the petition's receipt until listing is proposed (when higher priority listing actions have been completed) or the petition is turned down as not warranted.

If listing is warranted, the Service must publish a proposal to list the species in the Federal Register within 30 days. Public comment is solicited on the proposal to list, the comments and any new data are evaluated, and either a final rule listing the species is published in the Federal Register (within 1 year) or the proposed rule is withdrawn. Though rarely employed, the proposal may be extended for an additional 6 months if there is substantial disagreement regarding the sufficiency or accuracy of the data.

Candidates for Listing

The Service's list of candidate species is published annually and assigns each candidate species a priority number based on the immediacy and magnitude of threats as well as taxonomic status (e.g., a monotypic genus would receive higher priority). The Service may propose a species from the list of candidate species to be listed as threatened or endangered. From the point when a proposal is published in the Federal Register, the listing process follows the exactly same steps described above for species proposed for listing as a result of a petition.

The Service's Listing Program budget is insufficient to allow the Service to work on all petitions received and to make diligent progress on proposals to list candidate species. Therefore, the Service developed Listing Priority Guidance that states the following are the priorities, in order, for the Listing Program: 1) emergency rules to list species faced with imminent risk to survival; 2) final decisions on species already proposed for listing; 3) new listing proposals for candidate species; and 4) listing proposals for species that are not currently candidate species (i.e., species for which petitions are received).

The Listing Factors

Section 4 of the ESA mandates that a determination be made whether any species is threatened or endangered because of any of the following five factors: 1) the present or threatened destruction, modification or curtailment of its habitat or range; 2) overutilization for commercial, recreational, scientific, or educational purposes; 3) disease or predation; 4) the inadequacy of existing regulatory mechanisms; 5) other natural or manmade factors affecting its continued existence. It is important to recognize that pursuant to the ESA, economics or other factors not listed above are not considered in making listing decisions. In making its listing decisions, the Service must use the best scientific and commercial data available, take into account all data made available during a status review and/or public comment periods, and must consider ongoing efforts to protect the species.

Critical Habitat

Critical habitat is the area that contains the physical and biological features essential to the conservation of the species and which may require special management or protection. Critical habitat may include areas that are not currently occupied by the species. The ESA requires that critical habitat be designated (by regulation) at the time a species is listed as threatened or endangered unless it is not determinable at the time of listing or such designation is determined to be not prudent (e.g., publication of such location-specific information could increase threats to the species from collection or malicious destruction). If found to be not determinable, critical habitat must nonetheless be designated within 1 year of listing the species based on data available at that time. Unlike the decision to designate a species as threatened or endangered, economic impacts must be evaluated in designating critical habitat.

Prohibited Acts and Legal Take

Section 9 of the ESA

Section 9 of the ESA prohibits several acts with respect to endangered species, including import/export, transport in the course of interstate or foreign commerce, offer for sale, and take. Federal regula-

tions extend these prohibitions to threatened species as well. The remainder of this section of the paper will focus on take.

For wildlife, take is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct." Take is defined quite differently for plants: "to remove and reduce to possession from, or maliciously damage or destroy on, areas under Federal jurisdiction" or "to remove, damage or destroy in knowing violation of State law." Prohibition on take of listed wildlife makes no distinction between Federal, tribal and non-Federal lands, whereas take of plants is generally not prohibited on non-Federal lands unless it violates a State law.

Section 10 Permits

The ESA does, however, provide several mechanisms to legalize take. Section 10 of the ESA provides for the issuance of two types of take permits. Section 10(a)(1)(A) allows permits to be issued for take for scientific research or to enhance the propagation or survival of the affected species.

Under section 10(a)(1)(B), incidental take permits can be issued to tribal and other non-Federal entities. *Incidental take* is take that is incidental to, but is not the purpose of, the carrying out of an otherwise legal activity. Incidental take permits can be issued only to non-Federal entities for activities where there is no Federal "nexus." A Federal nexus is established through Federal funding, permitting or licensing, or direct Federal agency involvement.

Along with an application for an incidental take permit, the applicant must submit a *Habitat Conservation Plan* (HCP). Habitat Conservation Plans range in scope and complexity from plans that address a single species for a single project, to county-wide or State-wide plans that cover many species. All HCPs must specify 1) the impact that will likely result from the taking of listed species; 2) steps the applicant will take to minimize and mitigate such impacts and the funding that will be available to implement such measures; and 3) alternative actions that would not involve take and why such alternatives are not being implemented.

The incidental take permitting process requires compliance with the National Environmental Policy Act and therefore may include preparation of an environmental assessment or an environmental impact statement. The Service also must give notice in the Federal Register of any proposal to issue such a permit to allow public review of the permit application. Prior to issuing an incidental take permit, the Service must ensure that the taking will in fact be incidental, and that the authorized take will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.

Habitat Conservation Plans also include a monitoring component to determine if impact minimization measures are working as expected. However, if additional mitigation measures are determined to be necessary, such measures will not be the primary responsibility of the permittee pursuant to the Service's "No Surprises" Policy. In essence, when the Service accepts an applicant's HCP and issues a incidental take permit, it is committing that a deal is a deal, and that it will not come back at a later date and require additional land or money from the permittee.

Section 4(d) of the Endangered Species Act

Section 4(d) of the ESA allows the Secretary of Interior to issue special regulations for the conservation of threatened species. Since threatened species are in less peril than endangered species, certain forms of take that would normally be prohibited under section 9 of the ESA may be exempted through the issuance of special rules (or "4(d) rules"). As examples, existing 4(d) rules allow killing of gray wolves in the act of attacking livestock, and killing grizzly bears in self defense. Special rules allow for some management flexibility when dealing with threatened species, and can garner greater support for conservation of the species in doing so.

Incidental Take Statements

Incidental take can also be legalized through issuance of an incidental take statement to a Federal agency. These statements are included in biological opinions developed through the consultation process laid out in section 7 of the ESA and are described in greater detail in the following discussion of the consultation process.

Section 7 Interagency Consultation Process

Section 7(a)(2) of the ESA requires Federal agencies to consult with the Service to insure that any agency action does not jeopardize the continued existence of threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. The consultation process is required whenever a Federal agency action may affect a listed

species. While section 7 does not apply to non-Federal entities, it is important to recognize that actions by non-Federal entities are subject to section 7 if there is a Federal "nexus" such as Federal funding(e.g., grants, loans), or Federal permitting or licensing (e.g., Clean Water Act section 404 wetland fill permits). There are two types of consultation - informal and formal (Figure 1).

Informal Consultation

Informal consultation is so named because there are no rigid timeframes for the steps involved or its completion and because there are less formal requirements for document preparation. The vast majority of consultations handled by the Service are informal.

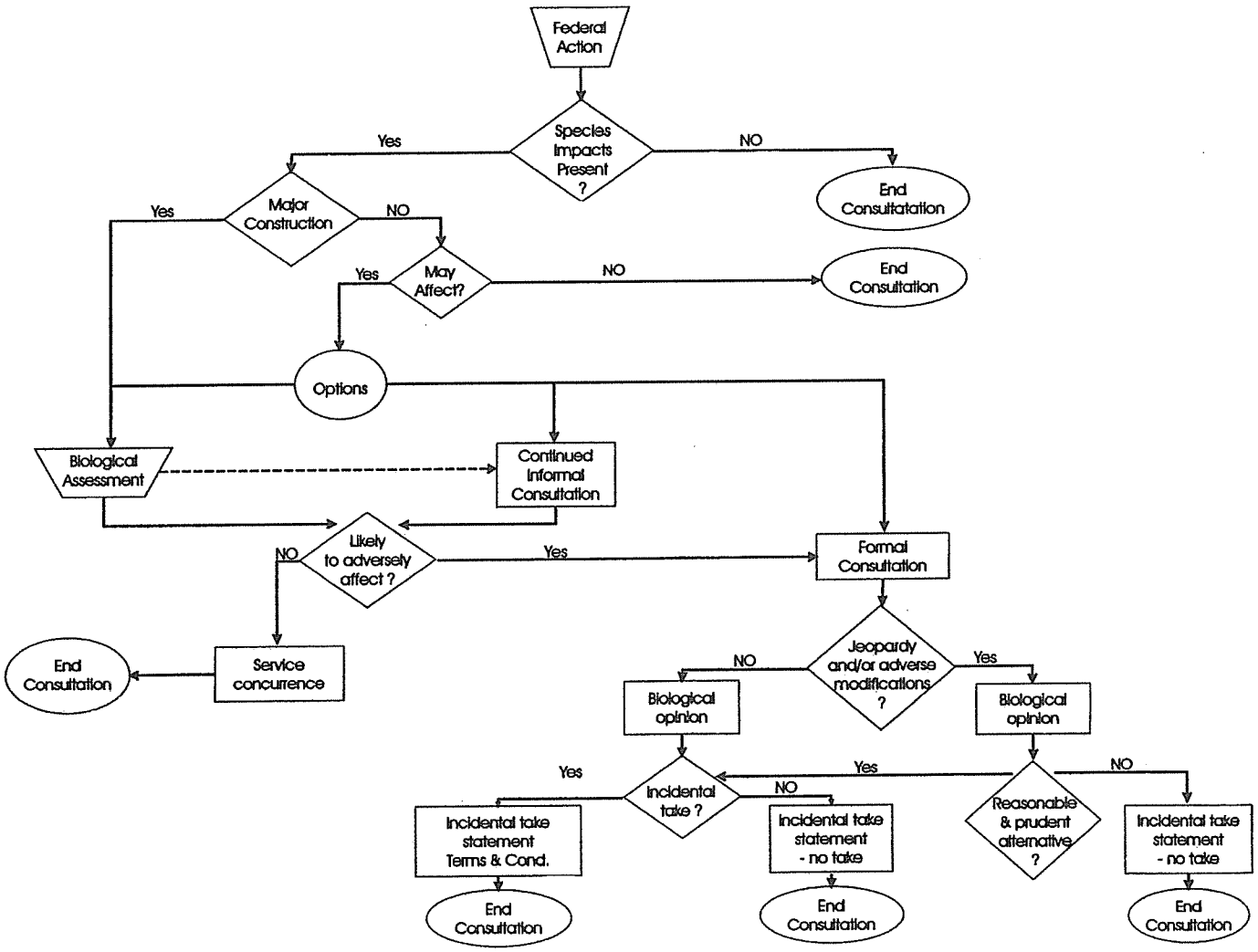


Figure 1.—Flow chart depicting the informal and formal consultation processes.

An agency contemplating an action (i.e., the action agency) typically initiates informal consultation by requesting a list of threatened and endangered species, and species proposed for listing, that may occur in the project area. The Service provides the "species list" (generally within 30 days) and usually supplements the list with information concerning the species' habitat requirements and life histories. The action agency must evaluate the potential impacts their action may have on listed species. This evaluation must take the form of a *biological assessment* for any action that is a major construction activity (generally any action that requires preparation of an environmental impact statement pursuant to the National Environmental Policy Act). Biological assessments should include results of on-site inspections; views of species experts; review of relevant literature; analysis of direct, indirect and cumulative impacts; and analysis of possible alternative actions. When biological assessments are not required, the action agency must nonetheless provide the Service with an account of the basis for evaluating the likely effects of the action on listed species. Based on the biological assessment or other effect evaluation, the action agency must then make one of the following effect determinations: 1) the proposed action will have *no effect* on listed species; 2) the proposed action *may affect, but is not likely to adversely affect* listed species; or 3) the proposed action *is likely to adversely affect* listed species.

If the case of a "no effect" determination, the agency's section 7(a)(2) obligations have been met and no further consultation is required. If the action agency finds that their action may affect but is not likely to adversely affect a listed species, the agency requests the Service to concur with their effect determination. If the Service concurs with this determination in writing, consultation is completed. It is noteworthy that the Service cannot provide a "conditional" concurrence, i.e., concurrence based on the project being modified in some way. The Service attempts to respond to requests for concurrence within 30 days.

Should the Service not concur, the action agency can work with the Service to revise their proposed action to eliminate adverse effects to listed species and again request concurrence from the Service with a "may affect but is not likely to adversely affect" determination. Alternatively, the action agency can request initiation of formal consultation on their proposed action.

Formal Consultation

Formal consultation is required when a Federal action is likely to adversely affect a listed species or critical habitat. When listed species are likely to be adversely affected, the action agency requests initiation of formal consultation with the Service and provides the Service with all relevant information necessary for the consultation (including the biological assessment for the project if one has been prepared). Once the Service has received all necessary information, it has 90 days to complete the consultation, and another 45 days to prepare its *biological opinion*. In certain circumstances these timeframes can be extended. During the consultation period, the Service discusses its review and evaluation of the project with the action agency and, if approved by the action agency, any project applicant. The action agency may request a draft biological opinion and provide comments to the Service on that draft.

The biological opinion prepared by the Service contains: a description of the proposed action, discusses status of the species, describes the environmental baseline, describes the effects of the proposed action on listed species, includes a conclusion as to whether the action is likely to jeopardize the continued existence of a listed species or adversely modify critical habitat, and conservation recommendations. The opinion includes an incidental take statement if the project will not jeopardize the continued existence of a species or adversely modify critical habitat but is expected to result in incidental take of listed species.

If the action is likely to jeopardize the continued existence of a listed species or adversely modify critical habitat, the Service issues a "jeopardy" biological opinion. Such opinions are very rare. A jeopardy opinion must include at least one reasonable and prudent alternative to the proposed action that would not result in jeopardy to the species. Reasonable and prudent alternatives must be consistent with the intended purpose of the action and with the scope of the actions agency's legal authority, and economically and technologically feasible. If no such alternatives are available, the Service must provide an explanation on the biological opinion. While rare, jeopardy opinions do make further pursuit of the proposed action problematic given the ESA's charge to Federal agencies to insure their actions do not jeopardize the continued existence of listed species or adversely modify critical habitat.

By far, most biological opinions are "non-jeopardy" opinions. If incidental take of listed animals [by definition there is no incidental take of plants] is anticipated, non-jeopardy opinions must include an incidental take statement. Incidental take statements describe the forms of incidental take anticipated, attempt to quantify the level of take, and include *reasonable and prudent measures* that are intended to minimize the amount or extent of incidental take. Reasonable and prudent measures (and the *terms and conditions* that specify how these measures are to be implemented) may involve only minor changes to the proposed action, and must be clear, precise and enforceable. Provided the action agency complies with the terms and conditions of the incidental take statement, any incidental take (up to the level anticipated in the incidental take statement) resulting from the proposed action is exempt from the take prohibitions of section 9 of the ESA.

Issuance of a final biological opinion concludes formal consultation on a proposed action. However, reinitiation of consultation is necessary if 1) the amount or extent of take specified in the incidental take statement is exceeded; 2) new information reveals effects of the action previously not considered; 3) the action is later modified in a way that causes an effect not considered in the biological opinion; or 4) a new species is listed or critical habitat designated that may be affected by the action.

Conferencing

Federal agencies are required to *conference* with the Service whenever an action they propose is likely to jeopardize the continued existence of a species that has been proposed for listing or would adversely modify proposed critical habitat. The process for conferencing is the same as that for consultation. The end product of formal conferencing is a *conference opinion* prepared by the Service. If the proposed species addressed in the conference opinion is listed as endangered or threatened, the conference opinion can be adopted as the biological opinion for the proposed action (assuming the proposed action has not changed by the time of listing). Incidental take statements in non-jeopardy conference opinions do not take effect until the conference opinion is adopted as the biological opinion.

In its conference opinion, the Service may concur that the proposed action is likely to jeopardize a propose species or adversely affect proposed critical habitat. The ESA does not preclude Federal agencies from taking actions that would have such adverse effects on proposed species or proposed critical habitat. However, the conference opinion will remind the action agency that should the proposed species be listed (or critical habitat become designated) prior to completion of the action, the agency may be required to modify or suspend the action until formal section 7 consultation is completed.

Recovery of Listed Species

The ultimate goal of the ESA is to recover species to levels where protection under the ESA is no longer necessary. Recovery is the process whereby the decline of a listed species is arrested or reversed, and threats reduced so that its survival in the wild can be ensured.

The first step in the recovery process is development of a recovery plan. Recovery plans describe, justify and schedule management and research actions necessary to recover the species. It is the policy of the Service to complete final recovery plans within 2½ years of the date of listing. Recovery plans may be prepared by a Service biologist, or by a recovery team formally appointed by a Service Regional Director. Teams may be comprised of species experts, Service biologists, affected citizens, and representatives of conservation organizations and local governments. The public is afforded the opportunity to comment on draft recovery plans to help reduce conflicts between conservation of the species and the affected communities.

Implementation of recovery plans is intended to be a cooperative effort between Federal, State and local agencies, researchers, conservation organizations, landowners and other individuals. Cooperation and coordination among all stakeholders is essential to an effective recovery program. To date, 12 species have been removed from the list of endangered and threatened species because they have been recovered. Critics charge this number is indicative of the ineffectiveness of the ESA. However, most listed species have suffered impacts from human activities for at least many decades, and reversal of these impacts is a long-term proposition.

Working with Landowners

Safe Harbor Policy

A 1995 General Accounting Office report showed that 712 listed species occurred on private lands. This figure underscores the importance of involving pri-

vate landowners in the conservation and recovery of listed species. However, many landowners have been reluctant to manage for listed species on their property for fear of possible land use restrictions that may follow. The Service's Safe Harbor policy was developed to address this issue. Under the policy, landowners who undertake voluntary conservation measures for listed species on their property can be issued an "enhancement of survival" permit (pursuant to section 10(a)(1)(A) of the ESA) that will allow them to take listed species in the future in order to return their property to the baseline conditions existing at the time of permit issuance. No land use restrictions over and above those in effect at the time of permit issuance will be placed on the landowner as a result of their conservation actions. Thus, the Safe Harbor policy removes disincentives for landowners wishing to conserve listed species.

Candidate Conservation

Ideally, species conservation measures should be implemented before species are in need of protection under the ESA. Candidate Conservation Agreements with Assurances are formal agreements between one or more parties and the Service wherein the participants voluntarily commit to implementing measures that will reduce or remove threats to a candidate or proposed species. In return, the Service provides assurances that no additional regulatory restrictions will be placed on the participants in addition to those agreed to in the agreement. In this way, landowners are provided regulatory certainty that should the target species eventually be listed under the ESA, they will incur no additional regulatory obligations. Similar to Safe Harbor agreements, the Service would issue an enhancement of survival permit to allow future take of the species (should it become listed) in association with returning the property to conditions agreed to in the conservation agreement. However, before the Service will approve a Candidate Conservation Agreement with Assurances, it must be confident the agreement will significantly contribute to elimination of the need to list the target species as threatened or endangered.

SUMMARY

The ESA is a highly recognized, but often misunderstood piece of environmental legislation. This paper provides only a general overview of some of the major provisions and processes laid out in the ESA and implementing regulations. All details and nuances of the ESA could not be covered in a paper of this length. Therefore, the reader is encouraged to refer to the following documents, many of which are available through the Service's web site at http://www.fws.gov. for a more thorough coverage of this paper's subject matter.

- The Endangered Species Act of 1973, as amended
- Part 402 of the Code of Federal Regulations
- Endangered Species Act Consultation Handbook
- Habitat Conservation Planning Handbook
- Making the ESA Work Better: Implementing the 10-Point Plan and Beyond

A Case History of the Jarbidge River Bull Trout Listing

Selena J. Werdon[1]

Abstract—Bull trout in the Jarbidge River watershed of northeastern Nevada and southwestern Idaho were proposed for listing as threatened in June 1998. An illegal partial reconstruction of a flood-damaged U.S. Forest Service road by Elko County, Nevada, shortly after this listing proposal caused the U.S. Fish and Wildlife Service to carry out a special emergency listing of this population as endangered. Subsequent substantial habitat restoration measures and other conservation commitments by Federal and State agencies, resulted in this population being listed as threatened in April 1999. Unregulated local efforts to rebuild the road have continued despite an ongoing Court-ordered mediation process to facilitate a settlement agreement and to develop public access alternatives. This bull trout listing and continued controversy associated with the road have had lingering adverse effects on working relationships among several local, State, and Federal agencies, and an environmental organization in Nevada. These entities must now cooperatively develop and implement actions to recover this bull trout population.

INTRODUCTION

Species listings under the Endangered Species Act (ESA) are sometimes controversial and may generate a wide spectrum of responses from Federal, State and local management entities, environmental organizations, and the general public. A recent controversial case involves the U.S. Fish and Wildlife Service's (USFWS) listing of a little known population of bull trout (*Salvelinus confluentus*) residing in the Jarbidge River watershed of northeastern Nevada and southwestern Idaho.

BULL TROUT LISTING HISTORY

The USFWS was petitioned to list bull trout as endangered throughout their range on October 30, 1992, by three Montana-based environmental organizations (Alliance for the Wild Rockies, Inc., Friends of the Wild Swan, and Swan View Coalition). A lengthy listing process then ensued involving numerous Federal Court rulings, which ultimately resulted on June 10, 1998, in the listing of the Klamath and Columbia River distinct population segments (DPS) as threatened and a proposal to list the three remaining bull trout DPSs in the United States as threatened (Coastal-Puget Sound, St. Mary-Belly River, and Jarbidge River DPSs).

Jarbidge River DPS Listing

The Jarbidge River is in the Snake River Basin and contains the southernmost habitat occupied by bull trout. This bull trout population is segregated from others by over 150 miles of unsuitable habitat and several impassable dams on the Snake River. The USFWS considers this population significant to the species as a whole because it occupies an unusual ecological setting and its loss would result in a substantial modification of the species' range.

Bull trout are known to occur in the East and West Forks of the Jarbidge River and seven tributaries (Cougar, Dave, Fall, Jack, Pine, Sawmill, and Slide Creeks), and at least seasonally in the upper mainstem Jarbidge River. The population as a whole is primarily composed of resident fish, with relatively low numbers of migratory (fluvial) fish. In records dating back to 1968, the Nevada State Record bull trout measured 22 inches (4 pounds, 6 ounces) and was caught from the West Fork of the Jarbidge River in 1985.

[1] *Fish and Wildlife Biologist, U.S. Fish and Wildlife Service, Reno, Nevada.*

Threats to the Jarbidge River DPS identified in the USFWS's June 10, 1998, proposed rule included habitat alterations from historical and/or ongoing land management activities such as mining, road construction and maintenance, timber harvest, grazing, stream channelization, and recreational developments; large woody debris removal; fishing overharvest; potential hybridization with brook trout; inadequate regulatory mechanisms and enforcement; and stochastic events including wildfires and debris torrents. Upon publication of the proposed rule, the USFWS opened a 120-day public comment period for written comments and held two local public hearings on July 21, 1998, in Jackpot, Nevada, to gather additional information on population status and threats.

South Canyon Road

South Canyon Road is the local name for a forest development road (#064) in the Humboldt-Toiyabe National Forest, Nevada. This 1.5-mile long spur road is one of seven unpaved roads providing vehicle access to the boundary of the 113,300-acre Jarbidge Wilderness. The road is located in a narrow canyon and parallels the West Fork of the Jarbidge River. During a rain-on-snow event in June 1995, substantial sections of this road were washed away where the river carved a new channel out of the roadbed and where debris torrents from two tributary gulches cut across the road. South Canyon Road has required major reconstruction at roughly 10-year intervals due to similar natural events since the 1940's. The road previously extended an additional 1.5 miles beyond the current wilderness trailhead, but that section was abandoned by the U.S. Forest Service (USFS) in the mid-1970's due to continued maintenance requirements and adverse effects on the watershed.

The USFS initially decided to rebuild the South Canyon Road again in 1997 after completing a biological evaluation comparing several access alternatives. However, this decision was appealed by Trout Unlimited relative to effects on fisheries and other resources. The appeal was upheld in part, and several additional alternatives for restoring public access were then evaluated. In June 1998, the USFS completed a new biological evaluation and selected construction of a hillside hiking/equestrian trail as the preferred alternative for public access to minimize impacts on the river and the bull trout population, which was proposed for listing as threatened that same month.

After meeting with the USFS and learning that they no longer intended to rebuild the South Canyon Road, the Elko County (Nevada) Board of County Commissioners issued a resolution on July 15, 1998, directing the Elko County Road Department (Road Department) to rebuild the road. On July 21, 1998, the day of the USFWS's listing hearings, the Road Department began rebuilding the South Canyon Road. Elko County failed to contact the appropriate State and Federal regulatory agencies before initiating this project and did not obtain necessary Clean Water Act permits or employ standard Best Management Practices (BMPs).

On July 22, 1998, the USFS observed and reported to State and Federal agencies that the West Fork of the Jarbidge River had been diverted, that portions of the channel had been filled, and that a sediment plume was visible for several miles downstream. As a result, the U.S. Army Corps of Engineers and Nevada Division of Environmental Protection (NDEP) issued cease and desist orders to Elko County on July 23, 1998.

During a site visit on July 23, 1998, the USFWS confirmed USFS reports of extensive riverine and riparian habitat damage (Fig. 1). The completed section of new river channel was approximately 1,000 feet long, with essentially no cover in the form of pools, boulders, woody debris, undercut banks, or riparian canopy (Fig. 2). Water depths were approximately 3-5 inches and further seasonal flow decreases were expected. The USFWS was concerned

Figure 1.—Habitat damage to the West Fork of the Jarbidge River from Elko County road construction in July 1998. Note the new roadbed (extreme left) and the former river channel partially-filled with dirt and fallen trees (center).

Figure 2.—New channel constructed for the West Fork of the Jarbidge River by the Elko County Road Department in July 1998.

that the river channel constructed by the Road Department did not provide adequate passage for bull trout migrating between upstream spawning habitats and downstream overwintering habitat. Although the exact timing of spawning in the Jarbidge River DPS is unknown, bull trout typically spawn from late August to early November (Montana Bull Trout Scientific Group 1998).

The new channel was also elevated above the loosely-filled former channel, creating concerns that during spring high flows, the river would again seek the flood channel filled by the Road Department and deposit substantial quantities of additional fill material into the river.

Emergency Listing - Endangered

On August 11, 1998, the USFWS emergency listed the Jarbidge River DPS as endangered due to impacts to bull trout in the West Fork of the Jarbidge River from road reconstruction by the Road Department and the threat of further unauthorized reconstruction of the South Canyon Road. Continued reconstruction would result in additional direct and indirect impacts to as much as 14.5 miles of known bull trout habitat in the West Fork of the Jarbidge River and potentially downstream in the mainstem Jarbidge River. The emergency listing was effective for the standard period of 240 days.

Habitat Restoration

After extensive Federal and State agency evaluations of the area impacted by the unauthorized road reconstruction, remedial actions prior to spring runoff were deemed essential. The USFS contracted a fluvial geomorphologist with stream restoration expertise to design a restoration plan and oversee implementation. The plan involved both river channel reconstruction and floodplain/road reclamation. After interagency coordination was completed and permits were obtained, work began in November 1998 and was completed in mid-December 1998.

The river channel was reconstructed where the Road Department had relocated it due to erosion concerns along the hillside/road alignment. The new channel was in the approximate location of the pre-1995 flood channel. Prior to any instream work, fish were captured and moved into undisturbed habitat upstream of the project area. The river was then diverted into a lined, temporary by-pass channel designed to provide fish passage and eliminate downstream sediment transport. Numerous other BMPs were also implemented to protect the project area and associated fish and wildlife habitat.

Around 1,000 feet of channel were excavated and reconstructed to approximate the sinuosity, substrates, channel dimensions, and instream cover found in river reaches immediately upstream and downstream (Fig. 3). A mix of large boulders representative of adjacent streambanks was used for channel stabilization. Numerous step pools and a low flow channel were built into the design. Remaining riparian vegetation and exposed root masses were incorporated into the channel realignment to provide cover. In addition, woody debris was salvaged from the floodplain and placed in the reconstructed channel. Clumps of native willows and willow poles from a local rural highway ditch were planted on the streambanks to supplement remaining riparian vegetation.

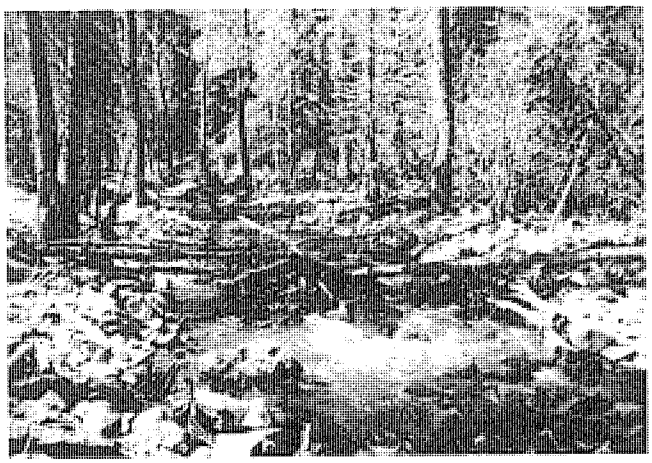


Figure 3.—Reconstructed channel with woody debris on the West Fork of the Jarbidge River on July 1, 1999.

Material excavated from the channel was screened and fine substrates were removed for use as fill to reclaim the road cut and to reconstruct floodplain features. The road cut was filled to match the general slope and topography of the affected hillside, seeded, and covered with erosion control fabric. Several rock abutments were also created on the floodplain along the base of the hillside to deflect future flood flows away from the slope. Vehicle access to the restored area was restricted by placing three large boulders across the former road entryway.

The total cost of this restoration project was approximately $400,000. Upon project completion, the U.S. Department of Justice requested Elko County to reimburse the government for repairing the habitat damaged by the road reconstruction. Elko County refused to pay any restitution and further claimed that they had a right-of-way for this road construction across public lands under Revised Statute (R.S.) 2477. The Federal Land Policy and Management Act repealed R.S. 2477 when it was enacted in 1976, but it did not terminate existing claimed rights-of-way. Elko County has never filed an official R.S. 2477 claim for the South Canyon Road.

Final Listing - Threatened

During the 240 days the Jarbidge River DPS was emergency listed as endangered, the above major habitat restoration project was completed and several other species conservation commitments were made by both State and Federal agencies. The Nevada Division of Wildlife (NDOW) agreed to no longer annually stock several thousand 8-10 inch rainbow trout (*Oncorhynchus mykiss*) in the West Fork of the Jarbidge River. NDOW and the Idaho Department of Fish and Game (IDFG) agreed to develop a joint bull trout conservation and management plan to ensure uniform management of the species throughout the Jarbidge River watershed. Both States also stepped-up local angler education efforts by posting informational signs on bull trout identification and catch-and-release regulations. The USFS and Bureau of Land Management also consulted with the USFWS under section 7 of the ESA and began implementing several watershed projects with potential beneficial effects for bull trout habitat including mine reclamation, riparian fencing, and off-stream livestock watering projects.

As a result of the habitat restoration project and other beneficial actions, the USFWS determined that the Jarbidge River DPS fit the definition of a threatened species under the ESA and listed it as such on April 8, 1999.

LITIGATION, MEDIATION, AND SOUTH CANYON ROAD REOPENING

Since the Jarbidge River DPS was listed, there have been repeated attempts by Elko County residents, local politicians, and out-of-state supporters to physically reopen the South Canyon Road. The first organized attempt took place October 9-11, 1999, by a group of individuals calling themselves Citizens United for South Canyon Road (CUSCR). Although the government obtained a temporary restraining order prohibiting any work on the road by this group (United States v. Carpenter, *et al.*), numerous private individuals carved out a narrow trail by hand along the base of the restored hillside.

In an attempt to resolve the temporary restraining order, the U.S. District Court ordered the three leaders of the CUSCR group into mediation with the USFS, USFWS, and U.S. Environmental Protection Agency on October 21, 1999. The Court also joined Elko County as a defendant in the case to resolve trespass issues and Clean Water Act violations, and NDEP later joined the mediation of their own volition. Negotiations began after a mediator was jointly selected in March 2000 under the auspices of the Congressionally-established U.S. Institute for Environmental Conflict Resolution.

Despite the ongoing mediation process, another citizen group was formed called the Jarbidge Shovel Brigade (Brigade). The Brigade gathered approximately 10,000 shovels from supporters across the country and raised over $50,000 to support their efforts to reopen the South Canyon Road on July 3-4, 2000. Although attendance fell far short of the expected 5,000 participants, several hundred individuals did remove one of the three boulders blocking access to the restoration area and shoveled out a narrow road atop the previously-restored hillside (Fig. 4). This provided access to the entire habitat restoration area for four-wheel drive and all-terrain vehicles (ATVs).

Although the Brigade also attempted and failed to successfully divert the river around the first road washout encountered upstream of the restoration area, ATVs have since been driving through the river in several locations to access more of the South Canyon. The USFWS and USFS have been monitoring use of the South Canyon area and documenting resource impacts.

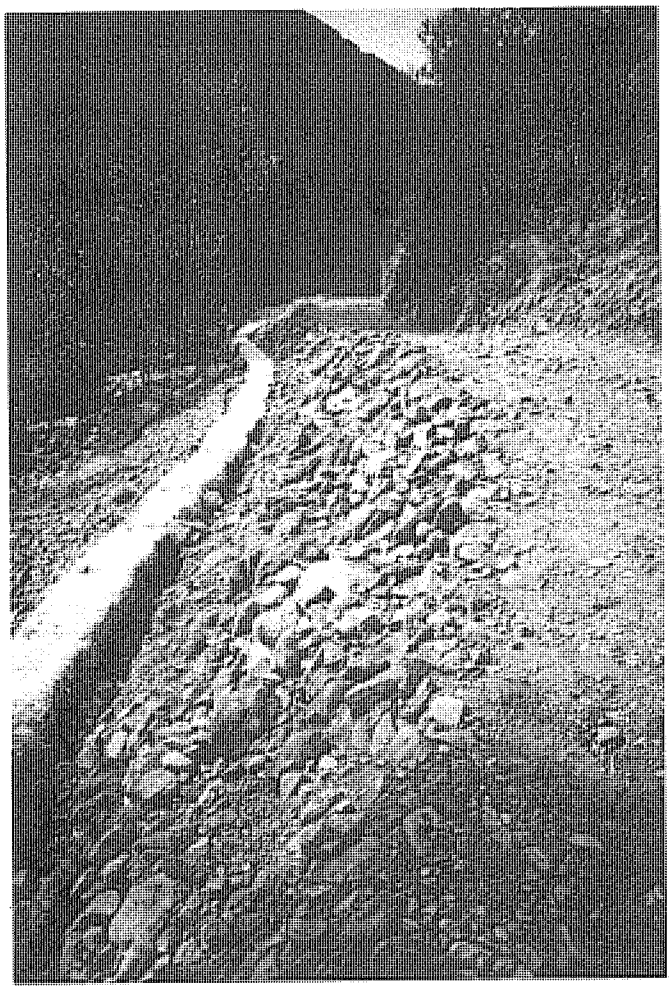


Figure 4.—Road constructed through the USFS hillside restoration site by the Jarbidge Shovel Brigade in July 2000. The Brigade placed straw bales along the toe slope of the road as a BMP to capture sediment.

Notwithstanding the Brigade's concurrent activities, after several months of mediated negotiations among the involved parties, a settlement agreement was jointly developed in July 2000. It is uncertain whether Elko County will ultimately sign the agreement.

BULL TROUT POPULATION STATUS

In the proposed, emergency, and final rules listing the Jarbidge River DPS, the USFWS has maintained that this

bull trout population warrants protection under the ESA. This determination was based on an evaluation of all available data on population status and threats. Much of the data on these two issues used in decision-making by the USFWS was provided by external sources, namely the States of Idaho and Nevada and Federal land management agencies.

Interagency Differences

Hoping to avert a final listing of the Jarbidge River DPS, State and Federal agencies were actively gathering additional bull trout population and habitat data, as well as implementing actions to conserve bull trout since 1992. Given their recent conservation efforts, all of these agencies were understandably disappointed when this population was listed. However, no agency has opposed this bull trout listing as strongly as NDOW.

NDOW has maintained that this bull trout population is stable or increasing and free from imminent threats. These statements have been based primarily on data gathered for two NDOW bull trout population status reports (Johnson and Weller 1994, Johnson 1999). In these reports as well as in official comments submitted to the USFWS on the proposed and emergency listings, NDOW acknowledges that population densities are low and that fish distribution and suitable habitat are limited. However, they contend that the population has never been numerous, that distribution and abundance are an artifact of natural watershed conditions which cannot be changed, and that rarity alone does not justify listing in the absence of threats. In addition, NDOW considers recent population genetics data to support the existence of a metapopulation in the Jarbidge River DPS, and therefore, inherent reduced population risk. The USFWS previously addressed these and other issues in the responses to public comments section of the final rule published on April 8, 1999 (64 *Federal Register* 17110).

The USFWS determined that available population data from NDOW and others were not sufficient to make statistically rigorous inferences about current bull trout abundance, trends in abundance, or distribution in the Jarbidge River watershed. Historical and recent collections have consisted of a few, sporadic presence and absence-type surveys occurring years and even decades apart. Given the variety of sampling methods used to obtain these population data, the limited extent of all surveys, and data extrapolation for population estimations, the USFWS considered assertions of stable or increasing population size and distribution to be flawed.

All reported historical bull trout collections in the Jarbidge River watershed occurred after a long period (1909 to 1932) of extensive habitat degradation

resulting primarily from extensive gold mining and milling operations. Therefore, the USFWS has also rejected unsubstantiated generalizations that the abundance and distribution of this bull trout population have always been limited and remain limited due to natural watershed conditions.

Genetic testing of bull trout fin clips collected in 1998 indicated that the Jarbidge River DPS as a whole is distinct from other bull trout populations (Paul Spruell, University of Montana, pers. comm. 1998). It also indicated that fish in the East and West Forks of the Jarbidge River are highly differentiated. Although current known bull trout distribution within this watershed suggests the existence of a metapopulation, the samples collected to date indicate that exchange of genetic material among occupied streams is infrequent at best.

Bull trout distribution in several remote headwater tributaries does confer some measure of security to the population. However, the apparent lack of fish movement among these streams despite access opportunities indicates that natural recolonization of any lost tributary populations could take years and indeed might never occur. Thus, maintaining bull trout in these individual streams and ensuring continued opportunities for genetic exchange to occur naturally is essential.

Without question, the USFWS considers there are threats to bull trout in the Jarbidge River DPS. The level of threat represented by any single activity is certainly debatable. However, USFWS biologists have personally observed impacts to bull trout habitat in the watershed from road construction and maintenance, livestock grazing, historical mining operations, flood control, recreation, large woody debris removal, natural debris torrents, and inadequate regulatory protection.

American Fisheries Society Peer Review

Due to continued controversy over the status of bull trout in the Jarbidge River DPS and the merits of the listing, Trout Unlimited requested an independent peer review of NDOW's 1999 status report (Johnson 1999) by the Western Division of the American Fisheries Society, which was completed in April 2000. The two anonymous reviewers comments generally supported the USFWS's decision to list the species. They also identified specific concerns with the report including sampling methodologies and data analysis. In summary, the reviewers found little evidence to support NDOW's conclusions that the population is stable or secure, that bull trout were never more widely distributed in the watershed, that present distribution is the maximum extent allowed by natural conditions, or that the population is free of imminent threats.

BULL TROUT RECOVERY PLANNING

The USFWS has convened a Bull Trout Recovery Team consisting of representatives from State and Native American Tribe natural resource agencies and USFWS personnel from throughout the species range. The Nevada Fish and Wildlife Office of the USFWS and IDFG are participating on this team to represent the Jarbidge River DPS; NDOW has declined to participate at this rangewide level to date. This team is developing overall recovery objectives and delisting criteria for the species, as well as dividing DPSs into smaller, more manageable "recovery units" for recovery planning purposes where appropriate.

Recovery Unit Teams are also being established locally to develop objectives, criteria, and recovery actions specific to each recovery unit. Membership on these teams includes local representatives from the above natural resource agencies, other State and Federal agencies, and local industry and environmental organizations.

Jarbidge River Recovery Unit Team

The Jarbidge River DPS is considered a single recovery unit, and a recovery unit team will be established in late 2000. Full participation, open communication, and coordination among all team members will be essential to ensure the timely completion and success of this planning effort. The USFWS considers the recovery planning process for the Jarbidge River DPS as an opportunity for a fresh start on Federal-State and Federal-County working relationships in Nevada, which will ultimately benefit bull trout as well.

LITERATURE CITATIONS

Johnson, G.L. and D.E. Weller. 1994. The status of the bull trout in Nevada. Nevada Division of Wildlife, Reno. 13 pp.

Johnson, G.L. 1999. The status of the bull trout in Nevada. Nevada Division of Wildlife, Reno. 17 pp.

Montana Bull Trout Scientific Group. 1998. The relationship between land management activities and habitat requirements of bull trout. Report prepared for the Montana Bull Trout Restoration Team, Helena. 78 pp.

Listing and Recovery Planning for Bull Trout

Samuel Lohr[1], Timothy Cummings[2], Wade Fredenberg[3], Stephen Duke[1]

Abstract—As of November 1, 1999, all bull trout in the coterminous United States were listed as threatened under the Endangered Species Act by the U.S. Fish and Wildlife Service. The Service had earlier identified five distinct population segments of bull trout—Columbia River (Idaho, Montana, Oregon, and Washington), Klamath River (south central Oregon), Jarbidge River (southern Idaho and northern Nevada), Coastal-Puget Sound (western Washington), and St. Mary-Belly River (northwest Montana)—for which some population segments had been listed in 1998. All population segments have declined in overall distribution and abundance due primarily to habitat degradation and fragmentation, blockage of migratory corridors, poor water quality, and the introduction of nonnative species. In January 1999, the Service convened a recovery team to develop a recovery plan. The recovery team consists of Service personnel and representatives of State fish and wildlife agencies and Native American Tribes. The recovery team has identified 22 recovery units encompassing the Columbia River population segment, developed a draft recovery goal and objectives, and is developing recovery criteria. Recovery unit teams, consisting of personnel from natural resource agencies, industry and private groups, and Native American Tribes, have formed to assist in developing individual chapters specific to each recovery unit.

INTRODUCTION

On June 10, 1998, the U.S. Fish and Wildlife Service (Service) issued a rule listing the Columbia River and Klamath River populations of bull trout (*Salvelinus confluentus*) as threatened species (63 FR 31647) under the authority of the Endangered Species Act of 1973 (Act), as amended. This decision conferred full protection of the Act on bull trout occurring in four northwestern states. The listing contained a special rule allowing "take" of bull trout (i.e., through angling) if conducted in accordance with State and Native American Tribal fish and wildlife conservation laws and regulations existing on the date the rule was issued. A proposed rule to list the remaining three population segments of bull trout (Coastal-Puget Sound, Jarbidge River, and St. Mary-Belly River) as threatened was also published on the same date (63 FR 31693). An emergency rule listing the Jarbidge River population segment as endangered was published on August 11, 1998 (63 FR 42757) due to road construction activities, and the population was subsequently listed as threatened on April 8, 1999 (64 FR 17110), when the emergency rule expired. The Coastal-Puget Sound and St. Mary-Belly River population segments were listed as threatened on November 1, 1999 (64 FR 58910), which resulted in all bull trout in the coterminous United States being listed as threatened.

The purpose of this paper is to summarize activities and analyses conducted in evaluating bull trout for listing, present the approach the Service is taking in developing a recovery plan, and report on the current status of recovery planning for bull trout. This paper will focus on activities for the population segments first listed, particularly the Columbia River population segment.

LISTING BULL TROUT

Listing Activities

On September 18, 1985, the Service published a notice of review (50 FR 37958) designating bull trout a category 2 candidate for listing in the coterminous United States. This action was the first formal designation of bull trout as a species of concern. Category 2 taxa were those for which conclusive data on bio-

[1]*Fishery Biologist (SL) and Supervisory Fish and Wildlife Biologist (SD), U.S. Fish and Wildlife Service, Boise, Idaho*

[2]*Fishery Biologist, U.S. Fish and Wildlife Service, Vancouver, Washington*

[3]*Fishery Biologist, U.S. Fish and Wildlife Service, Kalispell, Montana*

logical vulnerability and threats were not currently available to support proposed rules. The Service elevated bull trout in the coterminous United States to category 1 for Federal listing on November 15, 1994 (59 FR 58982). Category 1 taxa were those for which the Service had on file substantial information on biological vulnerability and threats to support preparation of listing proposals. The Service ceased using category designations in February 1996 and included bull trout as a candidate species. Candidate species are those that the Service has on file sufficient information on biological vulnerability and threats to support proposals to list the species as threatened or endangered.

On October 30, 1992, the Service received a petition to list bull trout as an endangered species throughout its range from three conservation organizations (petitioners). A 90-day finding, published on May 17, 1993 (58 FR 28849), determined that the petitioners had provided substantial information indicating that listing of the species may be warranted. The Service initiated a rangewide status review of the species concurrent with publication of the 90-day finding.

On June 6, 1994, the Service concluded in the original finding that listing of bull trout throughout its range was not warranted due to unavailable or insufficient data regarding threats to, and status and population trends of, the species within Canada and Alaska. However, the Service determined that sufficient information on the biological vulnerability and threats to the species was available to support a warranted finding to list bull trout within the coterminous United States. Because the Service concluded that the threats were imminent and moderate to this population segment, the Service gave the bull trout within the coterminous United States a listing priority number of 9 on a scale of 1 (highest) to 12 (lowest). As a result, the Service found that listing a distinct vertebrate population segment of bull trout residing in the coterminous United States was warranted but precluded due to higher priority listing actions.

On November 1, 1994, two of the original petitioners filed suit in the U.S. District Court of Oregon arguing that the warranted but precluded finding was arbitrary and capricious. After further legal review, the Court issued an order and opinion remanding the original finding to the Service for further consideration on November 13, 1996. The reconsidered 12-month finding based on the 1994 Administrative Record was delivered to the Court on March 13, 1997.

Based upon the Court agreement and stipulation, and information contained solely in the 1994 record, the Service proposed the Klamath River population of bull trout as endangered and Columbia River population of bull trout as threatened on June 13, 1997 (62 FR 32268). On December 4, 1997, the Court ordered the Service to reconsider several aspects of the 1997 reconsidered finding. On February 2, 1998, the Court allowed the Service until June 12, 1998 to respond. The final listing determination for the Klamath River and Columbia River population segments of bull trout and the proposed listing rule for the Coastal-Puget Sound, Jarbidge River, and St. Mary-Belly River distinct population segments (63 FR 31693), concurrently published on June 10, 1998, constituted the Service's response. An emergency rule listing the Jarbidge River population segment as endangered was published on August 11, 1998 (63 FR 42757) due to habitat destruction caused by unauthorized road construction activities, and the population was subsequently listed as threatened on April 8, 1999 (64 FR 17110), when the emergency rule expired. The Coastal-Puget Sound and St. Mary-Belly River population segments were listed as threatened on November 1, 1999 (64 FR 58910), which resulted in all bull trout in the coterminous United States being listed as threatened. In summary, after seven years of review and litigation, all bull trout in the coterminous United States are now listed as threatened under the Act.

Analyses of Bull Trout Data

In the proposed rule, the Service identified distinct population segments within the coterminous United States because bull trout occur in widespread but fragmented habitats. Also, the threats to bull trout are diverse, and the amount and quality of information pertaining to fish abundance and trends varies greatly throughout the range.

The joint National Marine Fisheries Service (NMFS) and Service policy regarding the recognition of distinct vertebrate populations, published February 7, 1996 (61 FR 4722), guided the Service in evaluating and identifying bull trout populations. The policy provides three elements to consider—discreteness, significance, and conservation status. Discreteness refers to the isolation of a population from other populations of the species and is based on two criteria--1) marked separation from other populations of the same taxon resulting from physical, physiological, ecological, or behavioral factors, including ge-

netic discontinuity; and 2) populations delimited by international boundaries. Significance is determined either by the importance or contribution, or both, of a discrete population to the species throughout its range. Four criteria were used to determine significance--1) persistence of the discrete population segment in an ecological setting unusual or unique for the taxon; 2) evidence that loss of the discrete population segment would result in a significant gap in the range of the taxon; 3) evidence that the discrete population segment represents the only surviving natural occurrence of the taxon that may be more abundant elsewhere as an introduced population outside its historic range; and 4) evidence that the discrete population segment differs markedly from other populations of the taxon in its genetic characteristics. If a population segment is discrete and significant, its evaluation for endangered or threatened status is based on the Act's standards.

The Service found that numerous bull trout groups are isolated from each other by either unsuitable habitat or impassible dams and diversions, or both. Although many groups could be considered discrete, few meet the "significance" criteria. For example, although some genetic differences were identified among bull trout in specific watersheds of the Columbia River basin, they did not differ markedly and they inhabit similar habitats. The Service concluded that existing information supported designating five distinct population segments in the coterminous United States--1) Klamath River in south central Oregon, 2) Columbia River in Idaho, Montana, Oregon, and Washington, 3) Coastal-Puget Sound in western Washington, 4) Jarbidge River in southern Idaho and northern Nevada, and 5) St. Mary-Belly River in northwest Montana.

Although the range of bull trout extends into Canada and Alaska, bull trout outside the coterminous United States were not considered in this rulemaking. In accordance with the distinct vertebrate population policy, the Service may determine a population to be discrete at an international border where there are significant differences in the control of exploitation, management of habitat, conservation status, or regulatory mechanisms. Bull trout management and conservation strategy in Canada differs from the United States and such activities are beyond the regulatory scope of the Act. The best available information also disclosed uncertainty regarding the status of bull trout in Canada. The status of bull trout in Alaska is unknown.

To facilitate evaluation of current bull trout distribution and abundance in each population segment, the Service analyzed data on bull trout relative to subpopulations because fragmentation and barriers have isolated bull trout throughout their current range. A subpopulation was considered a reproductively isolated group of bull trout that spawns within a particular area of a river system. In areas where two groups of bull trout are separated by a barrier (e.g., an impassable dam or waterfall, or reaches of unsuitable habitat) that allows only individuals upstream access to those downstream (i.e., one-way passage), both groups were considered subpopulations.

The Service evaluated status of bull trout subpopulations based on modified criteria of Rieman et al. (1997), which included abundance, trends in abundance, and the presence of life-history forms of bull trout. The Service considered a subpopulation "strong" if 5,000 individuals or 500 spawners likely occur in the subpopulation, abundance appears stable or increasing, and life-history forms were likely to persist; and "depressed" if less than 5,000 individuals or 500 spawners likely occur in the subpopulation, abundance appears to be declining, or a life-history form historically present has been lost. If there was insufficient abundance, trend, and life-history information to classify the status of a subpopulation as either "strong" or "depressed," the status was considered "unknown."

In addition to status, the Service estimated whether subpopulations were susceptible to extirpation from naturally occuring events. Subpopulations were considered at risk of extirpation from naturally occurring events if they were--1) unlikely to be reestablished by individuals from another subpopulation (i.e., functionally or geographically isolated from other subpopulations); 2) limited to a single spawning area (i.e., spatially restricted); and either 3) characterized by low individual or spawner numbers; or 4) primarily of a single life-history form. For example, a subpopulation of resident fish isolated upstream of an impassable waterfall would be considered at risk of extirpation from naturally occurring events if the subpopulation had low numbers of fish that spawn in a restricted area. In such cases, a natural event such as a fire or flood affecting the spawning area could eliminate the subpopulation, and reestablishment from fish downstream would be prevented by the impassable waterfall. However, a subpopulation residing downstream of the waterfall would not be considered at risk of extirpation from

naturally occurring events because it could be reestablished by fish from the subpopulation upstream. Because resident bull trout may exhibit limited downstream movement (Nelson 1999), the Service's determination of subpopulations at risk of extirpation from naturally occurring events may have overestimated the number of subpopulations that are likely to be reestablished.

In the Columbia River population segment for example, the Service identified 141 subpopulations and considered the status of 5 (4%) to be "strong," 98 (70%) to be "depressed," and 38 (27%) to be "unknown" (Service 1998). Seventy-one (50%) of the subpopulations were considered at risk of extirpation from naturally occurring events, 64 (45%) were not considered at risk, and susceptibility to extirpation could were not determined for 6 (4%).

The Act stipulates that the Service evaluate species for listing relative to five factors: A) the present or threatened destruction, modification, or curtailment of habitat or range; B) overutilization for commercial, recreational, scientific, or educational purposes; C) disease or predation; D) the inadequacy of existing regulatory mechanisms; and E) other natural or manmade factors affecting continued existence. Because there are numerous activities affecting habitat of each bull trout subpopulation, the Service evaluated the first factor relative to several activities, which were dams, forest management practices, livestock grazing, agricultural practices, road construction and maintenance, mining, and residential development (Service 1998).

In regards to the first factor (i.e., habitat relations) for the Columbia River population segment, past or ongoing activities that affect most subpopulations were forest management practices (74%), livestock grazing (52%), and agricultural practices (48%).

The second factor (i.e., overutilization) is a concern for the Columbia River population segment, but States and Native American Tribes have instituted restrictive angling regulations. However, illegal and incidental harvest may be a factor in some areas.

The third factor (i.e., disease or predation) also affects the Columbia River population segment. Whirling disease has been documented in some areas of the Columbia River population segment, but it is not presently considered a limiting factor. However, 87 (62%) of the subpopulations co-exist with various introduced fish species for which predation may be occurring on bull trout.

The fourth factor (i.e., regulatory mechanisms) includes numerous Federal and State laws designed to conserve fishery resources, maintain water quality, and protect aquatic habitats. The Service found that, although many regulations have become more protective of bull trout and their habitats, the implementation and enforcement of existing regulations have not prevented past and ongoing habitat degradation from affecting bull trout.

The fifth factor (i.e., other natural and manmade factors) includes introduced nonnative species, and isolation and habitat fragmentation. The majority of subpopulations in the Columbia River population segment co-exist with introduced nonnative species that may hybridize or compete with bull trout, or prey on bull trout. The Service also concluded that the occurrence of bull trout in numerous subpopulations was an indication of increasing habitat fragmentation resulting primarily from activities discussed in the first factor affecting the species. By increasing the degree of isolation among groups of bull trout, habitat fragmentation increases the vulnerability of bull trout to extirpation from numerous causes.

RECOVERY PLANNING FOR BULL TROUT

Recovery is the process by which the decline of an endangered or threatened species is arrested or reversed, and threats to its survival are removed, so that long-term survival in nature can be ensured. The goal of the recovery process is to restore listed species to a point where they are secure, self-sustaining components of their ecosystem so as to allow delisting.

Recovery plans are not decision or regulatory documents. They are intended to provide information and guidance that the Service believes will lead to recovery of a listed species and their habitats. The Act specifically directs that all recovery plans include three component: 1) description of site-specific management actions necessary to achieve recovery; 2) objective, measurable criteria for delisting of the species; and 3) estimates of the time and cost to carry out recovery actions and achieve intermediate steps toward recovery, and ultimately to attain recovery. The Service also recommends that recovery plans are revised or updated every five years.

Approach to Recovery Planning for Bull Trout

Because the five bull trout population segments occur over a large area and population segments were subject to listing at different points in time, the Service sought to develop a systematic recovery planning approach that would accommodate planning over a large area and could also incorporate additional areas. The Service adopted a two-tiered approach, one tier addressing broad aspects of bull trout recovery (i.e., at the level of population segments) and another tier addressing recovery of specific areas within a population segment (i.e., recovery units).

The recovery plan will consist of an introductory chapter followed by chapters devoted to individual recovery units. The introductory chapter will contain an overview of bull trout biology; description of the recovery strategy; guidance on recovery issues; programmatic-level recovery actions; and overall recovery goal, objectives, and criteria applicable to bull trout population segments. Each recovery unit chapter will address an individual recovery unit with objectives, recovery criteria, and recovery actions specific to each recovery unit. Each of the recovery unit chapters can be thought of as a "mini-recovery plan" that contributes to and is consistent with the overall recovery plan.

The Service is relying on two types of teams, an overall recovery team and recovery unit teams, to assist in developing the recovery plan. The recovery team is responsible for "big-picture" issues, such as producing the introductory chapter, identifying recovery units, and providing guidance in development of recovery unit chapters for coordination and consistency. The recovery team is composed of Service biologists, a representative from fish and wildlife resource agencies in each of four northwestern states (Idaho, Montana, Oregon, and Washington), and representatives of the Nez Perce Tribe and Upper Columbia River United Tribes (Confederated Tribes of the Colville Reservation, Coeur d'Alene Tribe, Kalispel Tribe, Kootenai Tribe of Idaho, and Spokane Tribe).

Recovery unit teams are responsible for assisting in the development of recovery unit chapters. Membership on recovery unit teams consists of persons with technical expertise in various aspects of bull trout biology within each recovery unit. Major tasks of recovery unit teams include: defining recovery for recovery units (i.e., recovery unit-specific objectives and recovery criteria, primarily in terms of distribution and population characteristics); reviewing factors affecting bull trout; describing ongoing conservation efforts; and developing specific recovery actions.

Status of Recovery Planning for Bull Trout

The Service convened the first meeting of the recovery team in January 1999. The team has since held nine meetings, and holds regularly scheduled conference calls to discuss issues pertinent to the recovery plan. The primary accomplishments of the recovery team to date have been identifying recovery units for the Klamath River and Columbia River population segments, developing an overall goal and objectives for the recovery plan, and providing guidance to recovery unit teams. The guidance consists of a standard outline for each recovery unit chapter, terms to describe bull trout habitats and population units, and a "matrix" used to characterize bull trout populations. The recovery team has also benefited from a group of scientific experts actively involved in research on bull trout or salmonid ecology. Several individuals have reviewed items produced by the recovery team.

Recovery Units

The recovery team considered several factors in identifying recovery units, with primary emphasis on known biological and genetic factors. Because States have established conservation plans and strategies for bull trout or initiated efforts that are in various stages of development, political boundaries were also considered so that recovery unit chapters could build upon and mesh with ongoing activities. In some instances recovery unit boundaries were modified to maximize efficiency of established watershed groups, encompass areas of common threats, or accommodate other logistic concerns. The Klamath River population segment consists of a single recovery unit and the Columbia River population segment contains 22 recovery units. Most recovery units in the Columbia River population segment consist of one or more major river basin. Work is continuing on identifying recovery units in the remaining three population segments.

Goal and Objectives

The recovery team has also drafted an overall goal and four objectives for bull trout recovery. The recovery goal is to "ensure the long-term persistence

of self-sustaining, complex interacting groups of bull trout distributed across the species native range." This goal recognizes the importance of population and habitat characteristics that allow bull trout to maintain viability and the opportunity for bull trout to migrate. The recovery team determined that four objectives are necessary to attain the goal, these are to: 1) maintain current distribution of bull trout and restore distribution in some previously occupied areas within the species' native range; 2) maintain stable or increasing trends in abundance of bull trout in all recovery units; 3) restore and maintain suitable habitat conditions for all bull trout life stages and life histories; and 4) conserve genetic diversity and provide opportunity for genetic exchange.

Recovery Unit Team Guidance–Chapter Outline

The recovery team has developed several items to guide recovery unit teams in developing individual chapters for the recovery plan. One item is a standard outline for recovery unit chapters. The outline is intended to ensure consistency in the organization and presentation of information in each chapter. Examples of topics included in the outline include: a description of the recovery unit, bull trout distribution and abundance, reasons for bull trout decline, ongoing conservation efforts, recovery-unit-specific objectives and criteria, and actions needed.

Recovery Unit Team Guidance–Terms

Various terms to describe bull trout habitat and population units have been used in the literature, agency reports, and documents for ongoing conservation efforts. In many instances, there is considerable overlap and ambiguity in the terminology. To ensure consistency among recovery unit chapters and define the scope of recovery, the recovery team developed standardized terminology for bull trout habitat and population units to be used throughout the recovery plan. The recovery team defined two categories of bull trout habitat:

Spawning and rearing habitat: Stream reaches and the associated watershed (drainage area upstream) that provide all habitat components necessary for spawning and juvenile rearing of a local bull trout population. Spawning and rearing habitat generally supports multiple year classes of juveniles of resident or migratory fish and may support subadults and adults from local populations of resident bull trout as well.

Foraging, migrating, and overwintering habitat: Relatively large streams and mainstem rivers, including lakes and reservoirs, in which subadult and adult migratory bull trout use to forage, migrate, mature, or overwinter. Foraging, migrating, and overwintering habitat is typically (but not always) downstream from spawning and rearing habitat and must contain all the physical elements to meet critical overwintering, spawning migration, and subadult rearing needs. Although use of foraging, migrating, and overwintering habitat by bull trout may be seasonal or very brief (as in some migratory corridors), it is nonetheless a critical element for migratory bull trout to persist.

To draw a link between habitat and characteristics of particular bull trout groups, the recovery team adopted an additional term, core habitat.

Core habitat encompasses spawning and rearing habitat (resident populations) with the addition of foraging, migrating, and overwintering habitat if the population includes migratory fish. Core habitat is defined as habitat that contains, or if restored would contain, all of the essential physical elements to provide for the security of and allow for the full expression of life history forms of one or more local populations of bull trout. Core habitat may include currently unoccupied habitat if that habitat contains essential elements for bull trout to persist, or is deemed critical to recovery.

Terms for population units are hierarchical, allowing recovery efforts to be focused at various spatial scales. From broad to fine scales the terms are:

Distinct population segment: The Service has formally determined there are five bull trout distinct population segments across the species range within the coterminous United States—Klamath River, Columbia River, Jarbidge River, Coastal-Puget Sound, and St. Mary-Belly River. Each meets the tests of discreteness and significance under joint policy of the Service and NMFS (61 FR 4722), and these are the units against which recovery progress for delisting decisions currently must be measured.

Recovery unit: These are the major units for managing the recovery effort, with each recovery unit forming a separate chapter in the recovery plan. A distinct population segment may contain one or several recovery units. Several factors were considered in identifying recovery units (e.g., biological and genetic factors, political boundaries, and ongoing conservation efforts). Biologically, recovery units are

considered groupings of bull trout for which gene flow was historically or is currently possible.

Recovery subunit: For some large and diverse recovery units, it may be necessary to subdivide recovery units into subunits to maintain a manageable entity. Subunits will be treated similar to recovery units for administrative purposes (e.g., may have separate goal and objectives or recovery criteria), but typically their identity is less biologically significant and more for organizational purposes.

Core population: A group of one or more local bull trout populations that exist within core habitat (see definition of local population below).

Core area: The combination of core habitat (i.e., habitat that could supply all elements for the long-term security of bull trout) and a core population (i.e., bull trout inhabiting core habitat) constitutes the basic unit on which to gauge recovery within a recovery unit. The recovery team termed this combination core area. Core areas require both habitat and bull trout to function, and the number (replication) and characteristics of local populations inhabiting a core area can provide a relative indication of the core area's likelihood to persist.

Local population: A group of bull trout that spawns within a particular stream or portion of a stream system. Until site-specific research indicates spatial, temporal, or genetic isolation, a local population will be considered as the smallest group of fish representing an interacting reproductive unit. For most waters where specific information is lacking, a local population may be represented by a single headwater tributary or complex of headwater tributaries. Gene flow among local populations may occur (e.g., those within a core population or broader population unit), but is assumed to be infrequent compared to that among individuals within a local population.

As being used in the recovery plan, the concept of core area is similar to that in a conservation strategy for bull trout proposed by Rieman and McIntyre (1993). In the strategy, core areas must be selected to provide all critical habitat elements, should be selected from the best available habitat or habitat with the best opportunity to be restored to high quality, must provide for replication of multiple local populations (minimum 5-10) within its boundaries, should be large enough to incorporate genetic and phenotypic diversity but small enough to ensure that component local populations effectively connect, and must be distributed throughout the historic range of the species. In the recovery plan, the context of core area has been expanded with a use more specifically toward restoration. For example, recovery may entail designating core areas that contain a single local population, which is inconsistent with how the core area concept is used in Rieman and McIntyre (1993). However, in the context of restoration, comparing qualities of core areas noted in the recovery plan to the characteristics of core areas in the strategy may assist in identifying conditions and activities that may be necessary for recovery.

Recovery Unit Team Guidance–Matrix

The recovery team recognized the need to characterize bull trout populations in a consistent manner using variables useful for developing recovery criteria. The population status matrix was developed for bull trout as a tool for recovery unit teams to assess population attributes of individual core areas within recovery units.

The matrix relied on concepts contained in both the conservation strategy proposed by Rieman and McIntyre (1993) and the approach described in the NMFS document "Viable salmonid populations and the recovery of evolutionarily significant units" (McElhany et al. 2000). Four variables were selected that indicate attributes of demographic, population structure, and life history characteristics. The variables were: adult abundance (number of adult-sized bull trout), productivity (trend in abundance and variability), number of local populations, and life history forms (an indicator of connectivity). Ranges of values or descriptions were associated with variables so that core areas could be assigned to one of three categories for each variable—increasing, intermediate, and diminishing degree of threat.

In applying the matrix, recovery unit teams were requested to characterize bull trout for each core area within a recovery unit using the matrix. This described the current condition of bull trout in the core areas. The recovery unit teams were then requested to estimate how core areas would be characterized if threats in each were addressed. This described the potential conditions that might be achieved for each core area in the future. The information is intended to assist in the development of recovery criteria for each recovery unit. Using this approach, potential future conditions can be estimated based on attributes of a specific core area, not necessarily based on predetermined standards. This approach acknowledges that the potential future condition of bull trout in some core area may be less than that ideally de-

scribed by conservation biology theory. Bull trout in such core areas may be limited by natural attributes or patch size, and may always remain at a higher level of risk of extirpation than bull trout in other core areas.

CLOSING

The recovery team is continuing work on developing criteria by which to gauge achievement of recovery objectives and on which delisting decisions can be based. Although preliminary, the team is currently focusing on two categories of criteria, bull trout distribution and characteristics of bull trout populations. Distribution criteria likely will address the present distribution of bull trout core areas and local populations within each recovery unit, and identify areas essential for recovery where bull trout have been locally extirpated. Criteria addressing population characteristics will likely be developed from information generated by applying the matrix, such as that concerning adult abundance, trends in abundance, number of local populations, and barriers inhibiting migratory fish and connectivity.

Developing a recovery plan for a species as widely distributed as bull trout is a challenging undertaking. The assistance and cooperation among various State and Federal agencies, Native American Tribes, and private groups will be essential for completion of the recovery plan. Because a recovery plan is a guidance document, continued assistance and cooperation among the same various groups involved in plan development, as well as others, will be essential for actions in the plan to be implemented and contribute to recovery of bull trout. In short, the recovery plan will guide recovery, but it is the groups that will make it happen. Because our knowledge of bull trout will increase as recovery actions are implemented and their effects are subsequently monitored, the Service views the recovery plan as a living document that must be responsive to improvements in our knowledge.

LITERATURE CITED

McElhany, P. M.H. Ruchleshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant unit. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-42, 156 p.

Nelson, M.L. 1999. Evaluation of the potential for "resident" bull trout to reestablish the migratory life-form. M.S. thesis, Montana State University, Bozeman.

Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. U.S. Forest Service General Technical Report INT-302.

Rieman, B.E., D.C. Lee and R.F. Thurow. 1997. Distribution, status and likely future trends of bull trout within the Columbia River and Klamath River basins. North American Journal of Fisheries Management 17:111-1125.

U.S. Fish and Wildlife Service (Service). 1998. Klamath River and Columbia River bull trout population segments: status summary. Prepared by the Service's bull trout listing team.

Improving on the Endangered Species Act – Oregon's Approach to Restoring Salmon and Watershed Health

Jay W. Nicholas[1]

Abstract—Differences between theory of federal Endangered Species Act (ESA) implementation versus what has occurred with listed salmonids in Oregon are noted. ESA, alone, is not capable of recovering most listed salmonid species throughout the Pacific Northwest. ESA, alone, does not have sufficient authority, funding, staff, coordinating mechanisms, incentives to motivate participation by private landowners, and local technical knowledge needed to inspire and manage species recovery programs for listed salmonid species across their range. *The Oregon Plan for Salmon and Watersheds* is an alternative approach to restoring native salmonid species. The Oregon Plan complements federal ESA by mobilizing governments, industry, and private citizens in a cooperative, inspired effort to improve watershed health across Oregon. Four tangible aspects of the Oregon Plan and progress to date are described. Intangible aspects of the Oregon Plan, including statements of principles and a one-sentence distillation (the *heart*) of the Plan are described. Both tangible and intangible aspects of the Oregon Plan help bridge gaps that ESA does not adequately address and are essential to restoring healthy watersheds and building a future where people and salmon can flourish together.

THE ENDANGERED SPECIES ACT – FIRST THE THEORY

Can we depend on the federal Endangered Species Act (ESA) to save salmon and steelhead from extinction? Probably. Can we depend on the federal ESA to recover salmonids to levels where they are part of our cultural, economic and recreational lives? I don't think so, especially if the question refers strictly to federal administration of ESA law. Why not? The short answer is that the real world is very complicated and the federal ESA simply does not have sufficient tools or horsepower to deal with the complexity.

We have all heard the theory of how the Federal Endangered Species Act works. First, a petition initiates a species status review. Then, if warranted, the species is listed. Then prohibitions against "take" are established. Then consultations occur with federal agencies to ensure that the species is not harmed. Then a federal recovery plan is developed. Then a floodgate of federal funds opens and new money flows into the area to assist recovery efforts. Finally, (in theory) the species is recovered.

ESA—OREGON'S REALITY

In contrast to theory, here is a sketch of how the Federal Endangered Species Act has worked for fish and people in Oregon. Twenty one fish species that spawn and rear in Oregon waters, distributed across virtually the entire state, have been identified as threatened or endangered and placed on the ESA list. Fourteen of these listed species are salmonids and 7 are non-game species. All of the salmonid listings have occurred during the last decade. The National Marine Fisheries Service (NMFS) administers 14 listed species and the United States Fish and Wildlife Service (USFWS) administers 10 of the listings. The first salmonid species was listed nearly a decade ago, but

[1] *Oregon Plan Project Leader, Oregon Department of Fish and Wildlife, Corvallis, Oregon, 97333.*

most listings have occurred since 1997. More listings are anticipated. Development of federal recovery plans has been a very slow process.

We do have a mountain of new paperwork straining state and federal agencies. Many field projects on federal lands have been stopped cold because of the need to process consultation papers. Many habitat restoration projects on state and private lands have been postponed (sometimes for years) awaiting consultations and associated permits. Oregon has received several million federal dollars to assist recovery efforts – only a fraction of what is needed. We doubt that federal recovery plans, when developed, will be achievable within the social-economic-political dynamics of a real world. State and local governments, ports, businesses, and individuals across Oregon are increasingly concerned (in some areas, nearly hysterical) about "citizen" lawsuits and enforcement action by federal agents. In fact, however, there have been few, very few, less than a handful of enforcement actions by federal agents related to listed salmonid species in Oregon. And we have the future prospect of even more ESA listings in Oregon.

The reality of the ESA in Oregon is a clouded picture.

WHY THE DISPARITY BETWEEN ESA THEORY AND REALITY?

Why has there been such a disparity between the theory and reality of the ESA? The Act was established with noble intent. The real world, however, is more complex – biologically socially, economically, and politically – than the federal law and federal administrators are capable of handling.

First, consider the "risk agents" thought to be responsible for the problems Oregon's listed salmonids are facing. These risk agents include fishing, urbanization, road location and design, thousands of culverts that provide inadequate fish passage, hatchery operations, withdrawing water from streams, un-screened or inadequately screened water diversions, dams, forestry, agriculture, loss of wetlands, straightening streams, predators, and cyclic variation in climate and ocean conditions. No federal or state agency, including NMFS, has the power, the budget, or the staff to administer ESA law in such a manner as to protect and restore salmonid species that spawn, rear, and migrate across thousands of miles and are affected by so many risk agents.

Now, consider the situation for listed spring chinook in the Upper Willamette ESU). These fish migrate upwards of a couple of hundred miles, first through the Columbia River, then into the Willamette, than into the Santiam or the McKenzie, to spawn and rear in tributaries situated on the west slope of the Cascade Mountains. Their freshwater life cycle spans a patchwork of land ownerships of which only 25% is federal and 75% is private land. The Willamette basin supports Oregon's densest human population, and the area is expected to attract a million new citizens over the next two decades. Oregon's largest urban areas are located on or straddle the Willamette River. The Willamette basin also hosts fisheries, hatchery programs, power production, forestry, agriculture, and a variety of industries.

If these fish lived their whole life on federal lands, the federal government ought to be able to protect them from further decline, and even restore them. But the reality is that Willamette ESU chinook, like the majority of listed salmonids in Oregon and the West, do not live out their lives on federal lands. They spawn, rear, and migrate across private lands, through human population centers, forests and farmland, industry, and dams. And if that wasn't enough to put a strain on the reproductive success of the species, they are hunted by humans, mammals, birds and other fish.

If these Willamette spring chinook are in trouble, who's responsible for saving them? If the plight of these salmon is caused by a dozen, or a hundred, or a thousand separate actions, taken by governments, cities, individuals, industries – who is going to cause these actions to be curtailed? The federal government? The National Marine Fisheries Service? I don't think so. Does the federal ESA have the horsepower to protect and restore these species across their range? Not alone! Neither NMFS nor the USFWS has sufficient power, funding, staff, or technical expertise to get the job done in the real world that includes people, economics, and politics as part of the playing field.

IF FEDERAL ESA IS LACKING, ARE THERE ALTERNATIVES?

If ESA is judged to be lacking, are there alternatives? What might be done in addition to the federal listing and recovery process? This is where *The Oregon Plan for Salmon and Watersheds* fits in. However, the Oregon Plan isn't simply about saving salmon. Salmon need healthy watersheds and clean water. So do people. The Oregon Plan is every bit

about ensuring the sustainability of watersheds that support people, our culture, and our economy, as it is about ensuring the sustainability of salmon under the ESA.

WHAT IS THE OREGON PLAN FOR SALMON AND WATERSHEDS AND WHAT HAS IT ACHIEVED?

The Oregon Plan[2] is an effort to connect Oregonians to the understanding that salmon, like people, need whole, healthy watersheds. The Oregon Plan is a comprehensive effort to coordinate government and private resources to conserve and improve the health of watersheds in a manner that will help both salmon and people.

On one hand, the Oregon Plan is a series of tangible documents numbering thousands of pages that are supported by related legislation, scientific reports, Executive Orders, a new state agency (the Oregon Watershed Enhancement Board), state, federal, and private funds, Soil and Water Conservation Districts, watershed councils, and uncounted actions by industry, citizens, associations, and groups statewide. The document contains both statements of intent and specific commitments of action by government and industry.

The Oregon Plan Consists of Four Essential Elements

The Oregon Plan consists of four essential elements:

- commitments by government agencies, industries and others to take action,
- implementation and coordination at the local watershed level,
- a foundation of science, assessment of progress, and learning,
- an understanding that Oregon Plan programs and actions will need to adapt and evolve over time as we learn more.

Element 1: Commitments to Take Action

State and federal agencies were established in the past to administer laws related to obtaining social and economic benefits from natural resources. Prior to the Oregon Plan, government agencies operated independently, responding to discrete legislative demands and policy direction. Salmon and watershed health has suffered because individual agencies pursued independent management objectives. While the missions of government agencies have not changed, the Oregon Plan is bringing these agencies together to consider the impact of their programs on whole watersheds and salmon populations.

The Oregon Plan documents contain hundreds of specific commitments to take action in support of watershed and fish population health. Here are a few examples.

Twelve Oregon state agencies made commitments to support watershed health and salmonid restoration in the Oregon Plan.

- The Department of Fish and Wildlife committed to a harvest management policy that would provide new safeguards to support recovery of native coho salmon.
- The Department of Forestry pledged to revise Forest Practices Rules to provide needed protection for native fish species and water quality.
- The Department of Transportation pledged to improve management of impacts of road design, construction, and maintenance on watershed health and listed fish.
- The Department of Agriculture pledged to develop water quality management plans for agricultural activities statewide.
- State Lands pledged to support watershed health and fish by developing a new set of "best management practices" to guide fill and removal.
- Water Resources pledged to develop new programs to conserve and restore streamflows in areas thought to be most important to listed fish. Environmental Quality pledged to accelerate development of load allocations for quarter-quality impaired waters statewide.

Beyond state agency commitments, the Oregon Forest Industry Council members pledged to accomplish a ten-year voluntary program of assessing roads and culverts on private lands, and to replace or repair roads and culverts to reduce sedimentation and improve fish passage. Finally, federal agencies pledged to support watershed health and fish recovery activities across Oregon and to modify their programs to integrate with state and local restoration efforts.

[2] *For more information on the Oregon Plan for Salmon and Watersheds – www.oregon-plan.org; www.oweb.state.or.us; www.4sos.org; www.netcnct.net/community/oacd/*

Element 2: Implementation and Coordination at the Local Level

Government programs and regulations, alone, cannot restore salmon and healthy watersheds across the landscape. Citizen participation in watershed restoration has increased greatly since the Oregon Plan got rolling in 1997. An existing network of 45 Soil and Water Conservation Districts has been enhanced by 90 Watershed Councils, and private landowners all around Oregon are communicating and working with a focus on watershed restoration. The availability of new state dollars dedicated to watershed restoration has helped increase local coordination and action.

On-the-ground work has improved salmonid migration routes in Oregon rivers, provided more shade, reduced sediment inputs, and increased complexity and rearing habitat.

Element 3: Foundation on Science, Assessment, and Learning

Unlike previous salmon recovery plans that proclaimed to have *the* answer about what needed to be done to save the salmon, the Oregon Plan is founded on a premise that it is our best contemporary effort, plus an admission that we have a lot to learn. An independent panel of scientists (IMST) has been established and is beginning to evaluate the scientific basis of Oregon's restoration efforts. To date the IMST has issued reports on predation, hatchery practices, conservation hatcheries, defining recovery of coho salmon, and forestry practices.

The process of learning also requires collection and scientific analysis of new data. An Oregon Plan comprehensive Monitoring Program is establishing or improving connections among agencies, industry, and individuals collecting data about the fish and the environment so that we can learn more about how the world really works. This coordination of monitoring, analysis, and reporting is a key element of evaluating the effectiveness of the Oregon Plan over time.

Element 4: Adaptation and Evolution

Given that we expect to learn from our monitoring and experience, the Oregon Plan includes a commitment to making changes in future management programs based on what we have learned. Since we are only 3 years into implementation of the Oregon Plan, it is too early to say much about how well our programs and activities will respond to what we learn about our effectiveness, because we do not know much about how effective our efforts are yet. The business of improving watershed health and restoring salmon populations in Oregon, supported by both federal ESA and the Oreogn Plan, will take decades, under the best of circumstances.

HOW DOES THE OREGON PLAN VIEW LAW AND VOLUNTERISM?

Consider what the Oregon Plan is trying to accomplish. Rather than preventing extinction by telling people what they cannot do (i.e., harm salmon), the Oregon Plan strives to motivate people to restore watershed health and native salmonid populations statewide. Enforcing and evaluating the effectiveness of existing environmental protection laws that regulate activities including fill and removal, fishing, forestry, agriculture, water use, water quality, land use, and protection of endangered species is a critical element of the Oregon Plan. State and federal laws, including federal ESA, are an essential foundation to conserving natural resources.

But laws alone will never be able to restore watershed health and salmon populations statewide, because the laws deal poorly with non-point pollution and cumulative effects of human activities on private and urban lands. Laws are needed to define what people *must not* do. Volunteerism – personal ownership at the community and watershed level – defines what citizens *want* to do. Both regulation and volunteerism have limitations and power. Together, volunteerism and regulation have far more to offer than a sum of their individual parts.

What is volunteerism? Volunteerism is action by choice, ownership, commitment, willing participation in the effort to restore healthy watersheds that support people and salmon. It is practicing sensible conservation, innovation, partnering, and seeking solutions.

In a world where people often look for simple solutions to complex problems, it is tempting to imply that saving salmon is primarily the responsibility of focused interests or activities – loggers, farmers, fishers, tribes, agencies operating the dams, urban developers, laws protecting predators, and so-forth. On the contrary, saving salmon – restoring healthy watersheds – will require willing participation of a broad representation of agencies and citizens. Saving salmon is not really *someone else's* responsibility – it is *everyone's* responsibility.

One of the commitments of the Oregon Plan is first to do a better job protecting the environment with existing laws before establishing new laws. We are proceeding to examine the rates of compliance with environmental protection laws and explore ways that compliance rates can be improved through education and incentive programs. In addition, the Oregon Board of Forestry is considering revisions to Oregon's Forest Practices Rules and locally developed plans are emerging across Oregon to manage agricultural impacts on water quality.

HOW WAS THE OREGON PLAN CREATED?

Development of The Oregon Plan was an energy draining, gut-wrenching process, and implementing The Plan is only a little better.

Beginning in late 1995, Governor John Kitzhaber asked the independent state agency directors to support a workgroup tasked with developing a conservation plan for Oregon coastal coho salmon that had recently been proposed for federal ESA listing. In early 1997, the Oregon Plan was delivered to NMFS as Oregon's response to reversing the decline of watershed conditions and fish populations on the coast. The Oregon Legislature endorsed the Plan with enacting legislation and funding of about 15 million dollars for the biennium. In spring of 1998, a supplement to the Plan that addressed steelhead was delivered to NMFS and was again endorsed by the legislature. The expanded version of the Plan attempted to emphasize the relationship between watershed health and salmonid species health. An Executive Order issued by Governor Kitzhaber in early 1999 formally expanded the scope of the Oregon Plan to include native salmonid populations and water quality statewide. An initiative petition approved by Oregon voters in 1998 constitutionally dedicates 7 ½ % of the state lottery proceeds to support watershed restoration efforts for a 15 year period. A new state agency, the Oregon Watershed Enhancement Board, was established by the Legislature in 1999 to set priorities for and mange disbursement of funds to watershed restoration projects.

Most Likely, The Oregon Plan would not have been developed, endorsed by the Legislature, funded, and implemented without the perception that an Oregon-driven conservation plan would be preferable, perhaps less painful than the federal ESA. This plan could never have been generated by the Oregon Department of Fish and Wildlife, or any other individual state or federal agency. The personal commitment of Governor Kitzhaber to develop the conservation plan was absolutely essential.

The factors stacked against developing the plan were significant, and have only diminished a little. Many people do not want to cooperate. State and federal agencies are very territorial, and have seen grand plans (perhaps like the Oregon Plan) come and go over the years. Any new pot of money generates intense political competition for who's going to share the riches. Some environmentalists criticize the Oregon Plan's meager accomplishments. Some private landowners hate the government and view any (new or old) restrictions on land and water use as unacceptable. And since we do not have clear, measurable objectives for "desirable" levels of listed fish species, we continue to rely on general mission statements and our best-intentioned assessment of how and where to spend money.

And yet, with all the difficulties, the Oregon Plan for Salmon and Watersheds was developed, funded, and is being implemented.

WHAT'S *NEW* ABOUT THE OREGON PLAN?

The Oregon Plan did not create all the elements (laws, agencies, and programs) that are currently being applied in the name of restoring watershed health and salmon recovery. All are needed. The Oregon Plan has added some new items to the stew. It has added, at the core, a spirit of citizen ownership at the community and watershed level. It has added specific commitments by state and federal agencies to conduct their separate missions in a manner that respects their impacts on watershed health and salmon populations. It has spurred improved coordination and developed new incentives to support restoring watershed health. It has added new state money and a 15-year initial commitment to fund watershed restoration. It has provided a statewide scope of concern for watershed health. It has provided an explicit connection between the health of Oregon watersheds, culture and economy. It has supported establishment of roughly 90 watershed councils all over the state, supporting ongoing conservation efforts of an existing network of 45 Soil and Water Conservation Districts – local landowners and community members concerned with watershed health. State and federal agencies are communicating, coordinating, and sharing better than ever before. The message is being spread that salmon need whole, healthy

watersheds, from the mountains to the ocean – not just a little piece of river here and there.

HOW DO OREGONIANS *FEEL* ABOUT THE OREGON PLAN?

How do Oregonians feel about the Oregon Plan? Well, that depends on whom you ask. Representatives of environmental protection advocates say that the Oregon Plan isn't doing enough, fast enough. Some private landowners and industry representatives lament that the Oregon Plan is forcing too much change, too fast. Unfortunately, too many Oregonians have not heard about the Oregon Plan and have little interest in the effort to restore watershed health and save salmon. This is the stark reality of a growing urban population that has little connection to the natural world outside the city. Those most affected by the ESA, government employees and rural landowners, are generally aware of the Oregon Plan but have mixed reactions to it.

Officially, state and federal agencies warmly embrace the Plan, and have committed considerable resources to supporting watershed and salmon restoration programs at every administrative level from overarching policies to on-the-ground implementation. Privately, the response varies when one asks individuals what they think about the Oregon Plan. Individuals express opinions that range from enthusiastic support to grave skepticism, irritation about increasing workloads and shifting priorities, and new restrictions on landowner management options. How do employees of the Oregon Department of Fish and Wildlife view the Oregon Plan? The official and private answers from ODFW are exactly the same as from every other agency – smiling endorsement at the policy level and a mixture of "*love* it or *hate* it" at the field level.

ONE MORE LOOK AT ESA AND THE OREGON PLAN

Nothing in my remarks should be construed to be disrespectful of the intent of the ESA, federal employees, or species recovery programs. I simply believe that anyone who thinks that federal ESA, alone, is capable of recovering listed salmonids in the Pacific Northwest does not understand the statutory authority of the federal government, the funding actually available to federal agencies, the complexity of the scientific debates over what must be done to save salmon, and the power of national, state, and local politics to protect the status quo.

It is a gross overstatement to suggest that ESA is inadequate but the Oregon Plan *is* adequate. The ESA does offer listed salmonid species important protection, for example, requiring federal agencies to ensure that their actions do not jeopardize listed species. This is significant because federal agencies manage huge tracts of the western landscape and their ESA responsibilities extend to activities both on and off federal lands, including managing federal timber harvest, and issuing permits authorizing private actions like dredging and road building.

The Oregon Plan is attempting to do something that federal ESA has not achieved – inspiring broad-based citizen participation in watershed restoration across the landscape in Oregon, building from the federal ESA. The Oregon Plan is not the single or the final answer to species conservation. It has not proven effective yet. The Oregon Plan is a *start* – I think a *very good* start – at fostering community-based nurturing of watershed health and salmon populations – bridging some gaps in an imperfect federal law.

It is fair to ask if watersheds and salmon are really any better off with the Oregon Plan than with only the guardianship of the ESA. My answer is simple. *Yes*! There is more genuine hope for watershed health, salmon, and people – because of the Oregon Plan for Salmon and Watersheds. People, corporations, and government agencies are dedicating real dollars and effort to improving watershed health, clean water, and salmon.

The Oregon Plan has made huge strides in a positive direction – organizing cooperation and action by governments, industry, and citizens in support of restoring healthy watersheds and salmonid populations. At the same time, these huge strides are dwarfed by the magnitude of work that remains to be accomplished. We need more cooperation, more communication, more positive incentives, more public awareness, more sensible balance, and a lot of patience. The challenge of fostering healthy watersheds and salmon populations is huge when one looks only at today's issues. The challenge is staggering when one considers that the human population is growing and increasing pressure to change watersheds in ways that often conflict with sustaining watershed health and abundant natural salmonid populations.

INTANGIBLE ASPECTS OF THE OREGON PLAN

Although tangible aspects of the Oregon Plan are important, intangible aspects associated with the Plan are at least as important, perhaps more so. I refer to intangible aspects of the Oregon Plan as a way of thinking, a philosophy of relating to people and nature. My attempt to describe the philosophy of the Oregon Plan is represented by a series of statements I refer to as Oregon Plan *Principles*. I have also written a one-sentence version of the multi-thousand page Oregon Plan, and refer to this distilled version of the Plan as it's *heart*.

Oregon Plan Principles

- ***Seek truth, learn, and adapt*** – Our knowledge of the world is imperfect. Understanding and behavior must evolve over time.
- ***Be humble*** – Remember, Mother Nature does not answer to salmon or man. Both survive at her discretion.
- ***Obey the law and live up to commitments*** – Honorable behavior earns trust. Get busy and earn it.
- ***Respect people, respect nature*** – The two are inseparable.
- ***Act voluntarily*** – Do one's best each day. Miracles don't spring from just trying to get by.
- ***Exercise patience*** – Salmon have survived here for thousands of years. Our work won't be complete in a month, a year, or a decade. Our challenge is to build a world where both salmon and people can flourish on a greater time scale than most humans comprehend.
- ***Build partnerships, make friends, and strengthen community*** – No one man or organization has the power or understanding needed to keep the world safe for us all. We need each other.
- ***Strive to let rivers be rivers, and un-tame, a little, our watersheds*** – People have changed the land, changed the waters of the West in ways that do not respect salmon or people. We must un-do some of these changes to maintain a world in which we can thrive.
- ***Share*** – **Share information.** Share the power to make decisions. Share the responsibility to act.
- ***Consider our children's needs*** – Remember that they will inherit the world from us.
- **Never give up hope**

The Heart of the Oregon Plan

As the principle writer-editor of the Oregon Plan, I have often been asked to explain, "what the Plan is all about". This has been a challenge, to explain the meaning of thousands of pages of information that have been built-on by executive order, legislation, and engaged Oregonians. My effort to provide a simple explanation of the Oregon Plan resulted in a illustrated story, a fictional conversation with a little salmon that boils the Plan down to a single sentence. I often refer to this one-sentence version of the Oregon Plan as the *heart* of the Plan. It is a pledge:

We, the people of Oregon, Promise to do our best, to understand and respect the needs of salmon, and to make some change in the way we lead our daily lives, in the hope that both salmon and people will survive and flourish, together, in the future.[3]

The one-sentence version of the Oregon Plan – the pledge – is not designed to satisfy contract lawyers. It is a simple promise to do one's best. Three years is certainly too little time elapsed to know if the Oregon Plan will be able to provide effective support to restoring healthy watersheds and salmon populations. Over time – in two or three or more decades – people should be able to look back and judge the overall effectiveness of federal ESA and the Oregon Plan. Today, people tend to see individual aspects of ESA and the Oregon Plan as separate and distinguishable – to be liked or disliked. Both approaches have significant strengths and shortcomings. Both approaches offer tools that may be used appropriately and inappropriately, to accomplish much or little. Oregon's best hope is to build from both federal ESA and the Oregon Plan and get on with the work that is needed to improve watershed health and salmon populations.

Oregon will not be Oregon – culturally or economically – without healthy watersheds and salmon. People who live here have a determination to find ways to simultaneously maintain a vibrant economy and our natural resources – easy to *say* but tough to *achieve*. The Oregon Plan is an experiment in democracy. We are inviting governments *and* citizens to organize in watershed communities, focus their energy on common interests, and make sure that the best of Oregon's environmental heritage is passed on to our children.

Let us all hope, in the years to come, to learn, improve our effectiveness, and succeed in our efforts to restore the watersheds that support people and salmon.

[3] *From Down To the Sea – The Story of a Little Salmon and His Neighborhood. Jay Nicholas. 2000. Available from the Oregon Youth Conservation Corps. 1201 Court ST. NE, Salem, OR 97301*

Gila Trout Recovery in SouthwesternNew Mexico: Overcoming Obstacles Through Synergism

J. E. Brooks[1], John Kramer[2], J. A. Monzingo[3], D. L. Propst[4], and Russell Ward[5]

Abstract—Conservation of Gila trout in southwestern New Mexico has been subjected to a number of challenges and obstacles, some of which pertain to the federally protected status of the species. Listed as endangered by the Endangered Species Act of 1973, recovery actions have been delayed or prevented due to conflicts with the removal of angling opportunities for nonnative salmonids. These challenges and obstacles to recovery of Gila trout have been and are being overcome by collaborative efforts of field and low-level administrative personnel of the New Mexico Department of Game and Fish, U.S. Forest Service, and U.S. Fish and Wildlife Service. While downlisting to threatened would alleviate some concerns and allow State management of some populations for angling, conservation of the species will require continued cooperation of involved agencies and protection of the species to ensure that biological recovery is attained.

INTRODUCTION

Gila trout (*Oncorhynchus gilae*) is one of three species of native trout to the Southwestern United States (Behnke 1992). The species has been known in the Gila River Basin since the late 1800s, but was not described until 1950 (Miller 1950). Formerly abundant and widespread, Gila trout were found in only a handful of streams after 1900 and by the early 1960s was reduced to five small headwater streams in New Mexico (Propst et al. 1992). As a result, Gila trout was originally classified as endangered under the Federal Endangered Species Preservation Act of 1966 (Federal Register 32:4001) and as endangered under the Endangered Species Act of 1973 (Federal Register 40:44415-44429). Gila trout are listed as threatened in New Mexico under the Wildlife Conservation Act and are considered a species of concern by the Arizona Game and Fish Department.

The decline of Gila trout is attributed to numerous anthropogenic actions. The introduction of nonnative salmonids, primarily rainbow (*Oncorhynchus mykiss*) and brown (*Salmo trutta*) trouts, impacted populations through hybridization and competitive interactions. Intensive angling pressures resulted in the reduction of native trout numbers and accelerated nonnative trout stocking in an effort to satisfy anglers. Habitat degradation related to land use, including fire suppression and livestock grazing, caused elimination of populations in lower elevation streams. Thus by mid twentieth century, Gila trout were relegated to short reaches of headwater streams above natural barriers where human-caused habitat modifications were limited and nonnative trout could not invade.

In this paper, we describe the process for conserving Gila trout that is, in part, a result of federal protection of the species. Listing as endangered under the Endangered Species Act of 1973 has resulted in considerable public opposition to recovery actions in southwest New Mexico. However, progress has been and continues to be made and is possible

[1] *U. S. Forest Service, Gila National Forest, Mimbres/Wilderness Ranger districts, Mimbres, NM*

[2] *U. S. Forest Service, Gila National Forest, Mimbres/Wilderness Ranger districts, Mimbres, NM*

[3] *U. S. Forest Service, Gila National Forest, Mimbres/Wilderness Ranger districts, Mimbres, NM*

[4] *New Mexico Department of Game and Fish, Conservation Services Division, Santa Fe, NM*

[5] *U. S. Forest Service, Gila National Forest, Supervisor's Office, Silver City, NM*

because of the positive interactions among agency biologists and low-level administrators. Overcoming obstacles to Gila trout recovery is attributed to synergism of participating biologists. Here, we define synergism as the cooperation and collaboration of discreet agencies that creates a total effect greater than the sum of the individual effects working alone.

CONSERVATION ACTIVITIES

Most important in recovery of this species is the Gila Trout Recovery Team and associated Team consultants as the primary instrument for implementation and conduct of actions. The Team is represented by biologists from New Mexico Department of Game and Fish, U.S. Forest Service, New Mexico State University, and U.S. Fish and Wildlife Service. Team members, while responsible for the production of recovery plan development and revision (original plan 1979; revisions in 1984, 1993, and currently under revision), are also lead for field activities. Recovery goals are based upon the replication of separate lineages and incorporation of large drainages into strategies to minimize the potential for catastrophic losses of any single lineage. Interagency cooperation is essential to removing various obstacles to implementation of successful recovery actions.

OBSTACLES

Wildfire

Suppression of wildfire during this century has resulted in forest conditions prone to long-term impacts caused by high-intensity fires. For Gila trout, the loss of populations in Main and South Diamond creeks in 1989 contributed to the withdrawal of a 1987 proposal to downlist the species.

Hybridization With Nonnative Salmonids

Recovery strategies for Gila trout center around the elimination of nonnative salmonids above natural stream barriers to protect reintroduced populations. The discovery of hybridization in two relict populations, McKenna and Iron creeks, and their replicated populations seriously jeopardized recovery efforts for the species as a whole. For both streams, recent data suggested that hybridization occurred prior to any genetic analyses for the species (Leary and Allendorf 1998).

Public Opposition

Opposition by the public to Gila trout recovery efforts is focused on the loss of angling opportunities for nonnative trout through renovation of streams. Through implementation of the National Environmental Policy Act by the U.S. Forest Service, public efforts have succeeded in delay of stream renovation projects by as much as three years. Opposition to use of the fish toxicant, antimycin, has been the recent focus and has included the implementation of County government ordinances prohibiting the use of antimycin based upon unsubstantiated claims of human, wildlife, and livestock health impacts. Also, unauthorized stocking of nonnative salmonids into streams either currently occupied by Gila trout or proposed for introductions has been recently documented in two streams.

Limited Agency Commitment

Gila trout recovery has historically suffered from limited funding allocations and minimal support by agency hierarchy. For both of the federal agencies and the State of New Mexico, controversy surrounding elimination of angling opportunities and provision of native trout recreational fisheries has resulted in conservative decision making processes by agency administrations. In order to appease public concerns, agency decisions have often emphasized the creation of native sportfish populations over conservation of the species, as required by law. This is true for all agencies involved where funding sources primarily originate in programs geared toward establishment and maintenance of recreational fisheries.

Endangered Species Act Compliance

Compliance with Endangered Species Act provisions has not prevented the implementation of recovery activities. However, additional documentation is required through the consultation process in Section 7 to address potential impacts to other listed species occurring near recovery streams.

SOLUTIONS

The obstacles presented above are not insurmountable. Key to recovery of Gila trout is the continuation of the collaborative process implemented by agency biologists and the Recovery Team. Turf battles have not been an issue between the different agencies

involved when developing and implementing recovery actions. Bureaucratic processes within federal and state agencies are notoriously ineffective in accomplishing conservation needs in a timely manner. Productive relationships between biologists, lower level administrators, and the public are integral to timely completion of projects. For Gila trout, minimization of the steps in the chain of command has resulted in a more direct route to decision making.

Lead agency personnel involved in Gila trout recovery efforts number fewer than ten and, for the most part, have individually participated in on-the-ground actions for a minimum of ten years. This small group has longstanding working relationships that have been built over time based upon communication and trust. Local publics in southwestern New Mexico are familiar with personnel and near constant communication takes place. Thus, there is more public involvement than would be expected by more traditionally led recovery efforts from central agency offices. Response to public concerns is key to defusing opposition that delays or prevents recovery actions from taking place. While opposition has continued, information exchange has increased and public information and education has succeeded in gaining support from anglers and other members of the public.

Implementation of protective measures under the Endangered Species Act has caused public concern and opposition, but recovery actions have continued. Agency commitments that are based upon the synergism provided by on-the-ground personnel facilitate the conservation of native trout, whether federally protected or not. Concern over the protection of native trout through the Endangered Species Act and interruption of State jurisdiction over native trout management programs contributed to the reclassification of Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*), Paiute cutthroat trout (*Oncorhynchus clarki seleniris*), and Arizona trout (*Oncorhynchus apache*) from endangered to threatened in 1975 (Federal Register 40:29863-29864). Reclassification from endangered to threatened for Gila trout has been proposed by numerous agency personnel and members of the public for the same purpose. Undoubtedly, public opposition would be diminished and proposed recovery actions would proceed. Concerns by more conservative environmental protection interests, however, would likely oppose such a downlisting process and further delay recovery actions.

Federal listing occurs, in some instances but not all, when agencies (states and federal) have not fulfilled their responsibilities to conservation of species and habitats. This is often the case with salmonids where sufficient regulations, policies, and sportfish management programs were in place to prevent imperilment, but not effective in halting declines in distribution and abundance. For Gila trout, the issue is not whether protection under the Endangered Species Act has interfered with conservation programs. The issue is whether or not agencies have the tenacity and resoluteness to conserve a native species in the face of constant pressures to harvest natural resources.

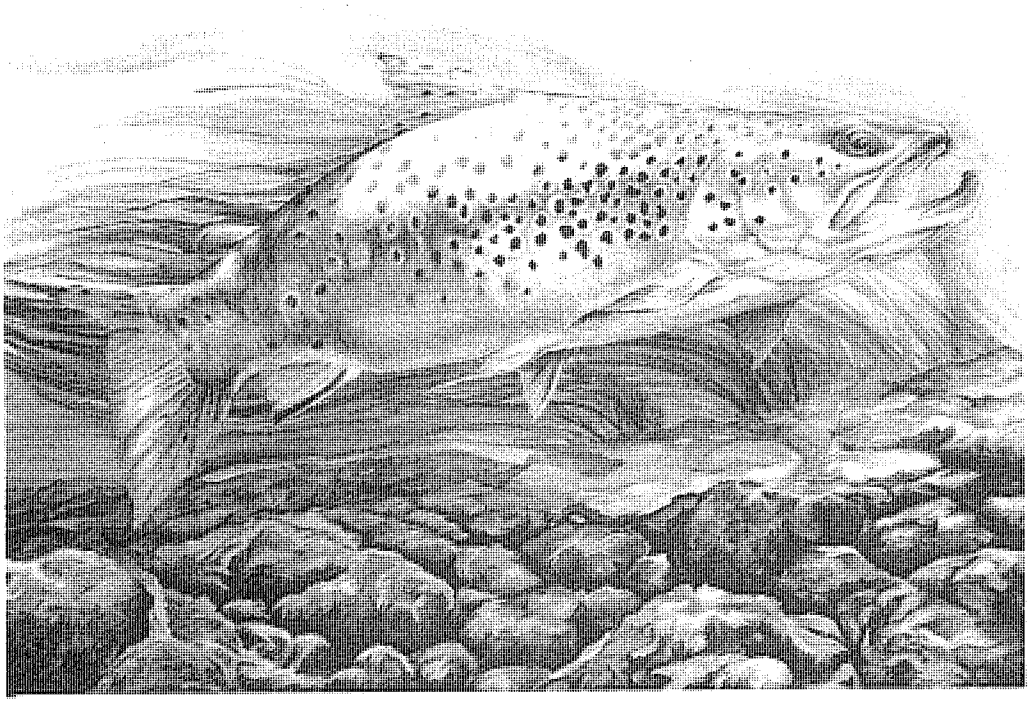
LITERATURE CITED

Behnke, R.J. 1992. Native trouts of western North America. American Fisheries Society Special Publication No. 6, Bethesda, MD.

Leary, R.F. and F.W. Allendorf. 1998. Genetic issues in the conservation and restoration of the endangered Gila trout. Wild Trout and Salmon Genetics Laboratory Report 98/1. Division of Biological Sciences, University of Montana, Missoula, Montana.

Miller, R.R. 1950. Notes on the cutthroat and rainbow trouts with the description of a new species from the Gila River, New Mexico. Occasional Papers of the Museum of Zoology, University of Michigan, University of Michigan Press, Ann Arbor, Michigan, 529:1-43.

Propst, D.L., J.A. Stefferud, and P.R. Turner. 1992. Conservation and status of Gila trout, *Oncorhynchus gilae*. The Southwestern Naturalist 37:117-125.



Artwork by Mimi Matsuda

The Role of Large Rivers in the Evolution and Conservation of Redband Trout

Kenneth P. Currens[1], Carl B. Schreck[2], and Hiram W. Li[2]

Abstract—Redband trout are subspecies of rainbow trout adapted to the arid environments of the isolated, interior desert basins of Washington, Oregon, northern California, and Idaho east of the Cascade Mountains. They were thought to have evolved during long periods of isolation from the common coastal rainbow trout, which occurs west of the Cascades. After examining rainbow trout from 243 locations, we found that the major geographical genetic differences were associated with large river systems rather than east-west differences. Because this suggested that even in isolated desert basins free-flowing rivers provided long-term sources of stable habitat and opportunities for unique groups, we also examined potential genetic effects of damming free-flowing rivers. In two of three major basins, we found that populations recently isolated by dams had less genetic diversity than unisolated populations and that were similar to populations isolated for thousands of years above ancient barriers. This apparent rapid loss of genetic diversity suggested that conservation efforts to reconnect recently isolated populations may help stabilize these losses and reduce risk of extinction.

INTRODUCTION

Redband trout are subspecies of rainbow trout that are found in the arid lands of eastern Oregon, Idaho, northern California, and Washington. Visitors to redband trout country are often overwhelmed by the isolation and an excitement that the harsh desert environment hides treasures from a time long forgotten. Rows of volcanic rimrock stand like sentinels on the high ridges between different basins where ancient lake beds and river channels tell of a time when water was more abundant. In the 1880s, the great paleontologist Edward Cope (1889) visited the fossil beds in the heart of redband trout country and described redband trout and the environment in which they still persisted:

"As far as the eye could reach was the same sage-brush desert, the same waterless region of death. Many a man has entered this region never to escape from its fatal drought...Many experienced hunters have been lost in this desert, and two years after my visit, one of the oldest rangers of Oregon entered it, and was never heard of afterwards. And it is indeed easy to miss the few small springs that are found at remote intervals in this desolation."

Later explorers would find redband trout in a variety of habitats, including large rivers, where redband trout had access to the sea, streams above barrier waterfalls, and ancient, isolated lake basins. Redband trout in different regions or isolated basin often exhibited a confusing mix of traits not found in more familiar rainbow trout. These differences confused ichthyologists and fishermen for nearly 150 years. Redband trout were sometimes considered undescribed species, cutthroat trout, or even hybrids of rainbow and cutthroat trout (Behnke 1992).

The advent of genetic techniques to examine evolutionary diversity resolved the question of whether redband trout were rainbow trout. Geneticists also began to identify geographical genetic differences among rainbow trout that indicated that there might be a number of unique groups that were important for conservation. One of the most striking differences was the difference between rainbow trout east and west of the Cascades (now considered different subspecies). This difference was attributed to long periods of isolation in different refuges from the Pleistocene glaciation (Allendorf 1975, Okazaki 1984, Behnke 1992). Redband trout also still existed in

[1] *Northwest Indian Fisheries Commission, Olympia, WA.*

[2] *Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR.*

isolated, desiccating lake basins left over from Pleistocene times, which suggested that these groups might also be genetically distinct (Wilmot 1974, Currens et al. 1990).

Understanding the importance of isolation in the evolution and persistence of redband trout has important implications for conservation. Genetic and evolutionary theory predicts that isolated populations restricted to small areas of habitat have much greater losses of genetic variation and higher rates of exinction than unisolated ones (Diamond 1984, Frankham 1998). Over the last 150 years, humans have increased the isolation of redband trout through dams and habitat fragmentation. Redband trout that once migrated between streams and lakes or from rivers to the sea are now restricted to islands of habitat. Although the history of climatic changes and geological events during the last 20,000 years suggests that periods of restricted habitat are not new to redband trout, these recent changes need to be viewed from a long-term perspective. What kinds of habitat allowed redband trout to survive long periods of isolation? How do the effects of recent habitat changes compare to past changes? Efforts to protect redband trout by protecting habitat need to be based on the long-term importance of those habitats to persistence.

In this paper, we examine the importance of two different kinds of habitat to persistence of redband trout over evolutionary and recent times. The two habitats are lake systems (where many redband trout presumably evolved) and large river systems. Over evolutionary time, if isolation in different lake basins has been most important in the evolution of redband trout, then the strongest patterns of genetic divergence should be between groups in different lake basins. In contrast, if river systems have been more important, then the largest geographical genetic differences might be between groups in different rivers. In recent times, construction of dams has created lakes out of rivers and isolated once-migratory populations above barriers. If rivers were important to the persistence of these fish, then genetic and ecological theory predicts that these recently isolated populations should lose genetic variation and be at increased risk of extinction. To examine potential losses of genetic variation caused by human actions that have restricted redband trout habitats, we compared genetic variation in three groups: populations of redband trout in free-flowing streams, populations in nearby streams recently isolated by dams, and populations that have been isolated for thousands of years by ancient geological barriers.

METHODS

We looked at broad geographical patterns of genetic variation among different habitats by examining differences among 11,400 rainbow trout from 243 locations in major basins throughout the Columbia River, northern Great Basin, and adjacent regions (Figure 1) at 28 enzyme encoding loci. These included fish from large river systems as well as fish from lake systems with no access to large rivers or the ocean. To examine effects of recent isolation, we examined fish from streams below impassable dams constructed during this century, streams above the dams that once held anadromous fish, and streams that were isolated by ancient geological barriers in the Deschutes, Snake, and Klamath Basins. Areas of ancient isolation included the White River (Deschutes River Basin), Harney Basin (Snake River Basin) and Upper Klamath Lake (Minckley et al. 1986). Samples with evidence of introgression from introduced hatchery fish were excluded.

RESULTS

We found that redband trout from different basins were as different from each other as they were from coastal rainbow trout, a separate subspecies (Figure 2). The major geographical genetic difference, however, was associated with large river systems, rather than the east-west axis of the Cascade Mountains or isolation in individual lake basins. Populations fell into four major groups: 1) Columbia River populations; 2) populations from southeastern Oregon and northern California lake basins, which are biogeographically related to the Sacramento River; 3) populations associated with the Klamath River and the coastal Klamath Mountains; and 4) populations from pluvial lake basins in Oregon that have no current access to large river systems but that are geographically and genetically intermediate between Columbia and Klamath Basins.

In two of the three major basins we examined, we found that recently isolated populations had levels of genetic variation lower than levels of adjacent unisolated populations from which they were derived and similar to populations isolated for thousands of years (Figure 3). In the Snake River, populations recently isolated above dams had lower heterozygosities, fewer polymorphic loci, fewer rare alleles, and fewer alleles per locus than unisolated populations. In the Deschutes River, populations above dams had fewer rare alleles than those below

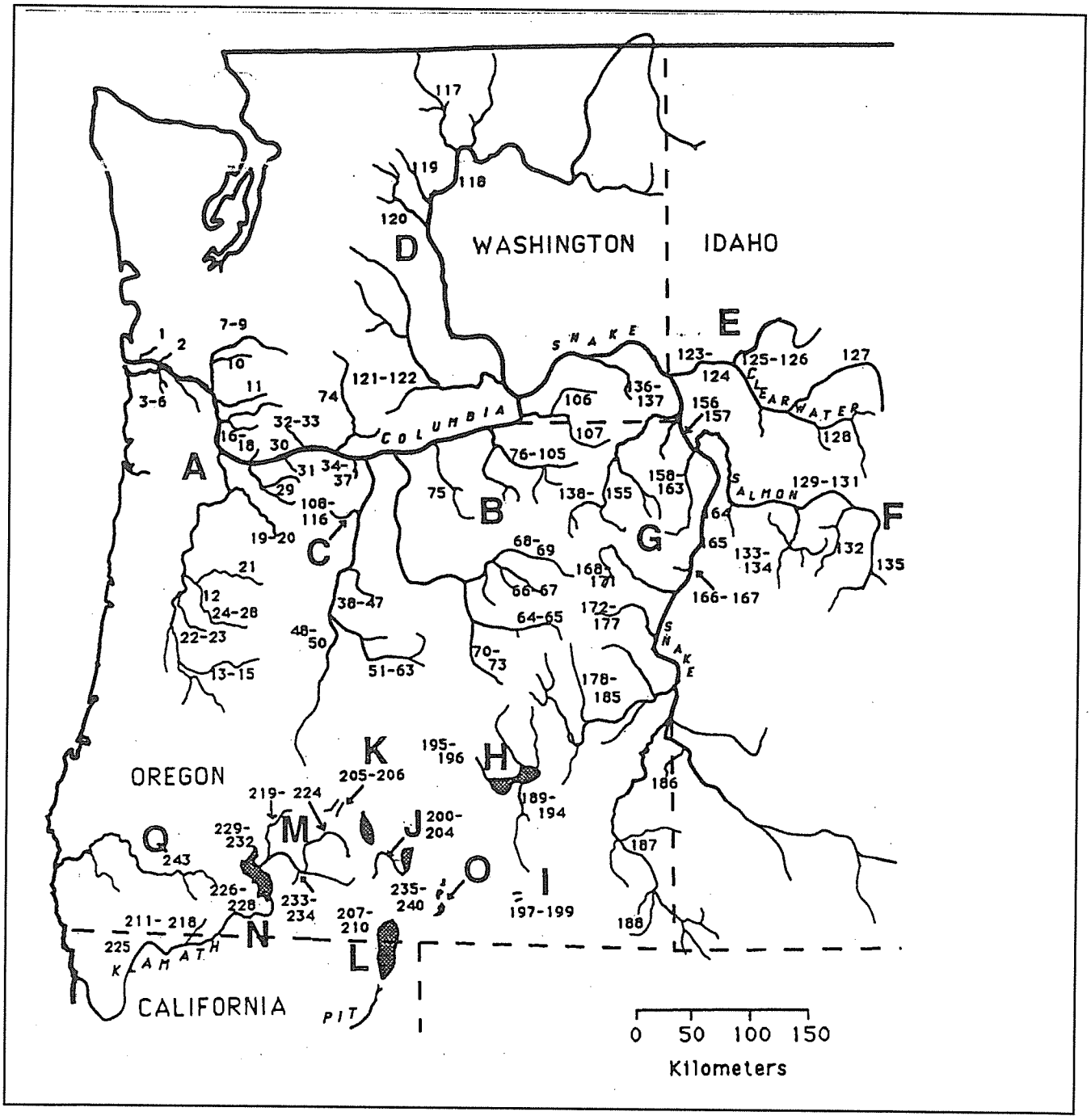


Figure 1.—Locations of where rainbow trout were collected. Numbers identify individual populations. Upper case letters indicate major basins: A, Lower Columbia River; B, mid-Columbia River; C, White River; D, Upper Columbia River, E, Clearwater River; F, Salmon River; G, Snake River; H, Harney Basin; I, Catlow Valley; J, Chewaucan Basin; K, Fort Rock Basin; L, Goose Lake Basin; M-N, Upper Klamath Lake Basin; O, Warner Valley; Q, Coast Klamath Mountains.

dams, but we lacked the statistical power to detect lower levels in other measures. Populations above barriers had lower levels of variation for two of the four measures. In the Klamath Basin, the patterns were more complex. Populations recently isolated above dams were not different from those below. Populations in areas of ancient isolation, however, had fewer rare alleles and fewer polymorphic loci than unisolated populations and higher levels of heterozygosity.

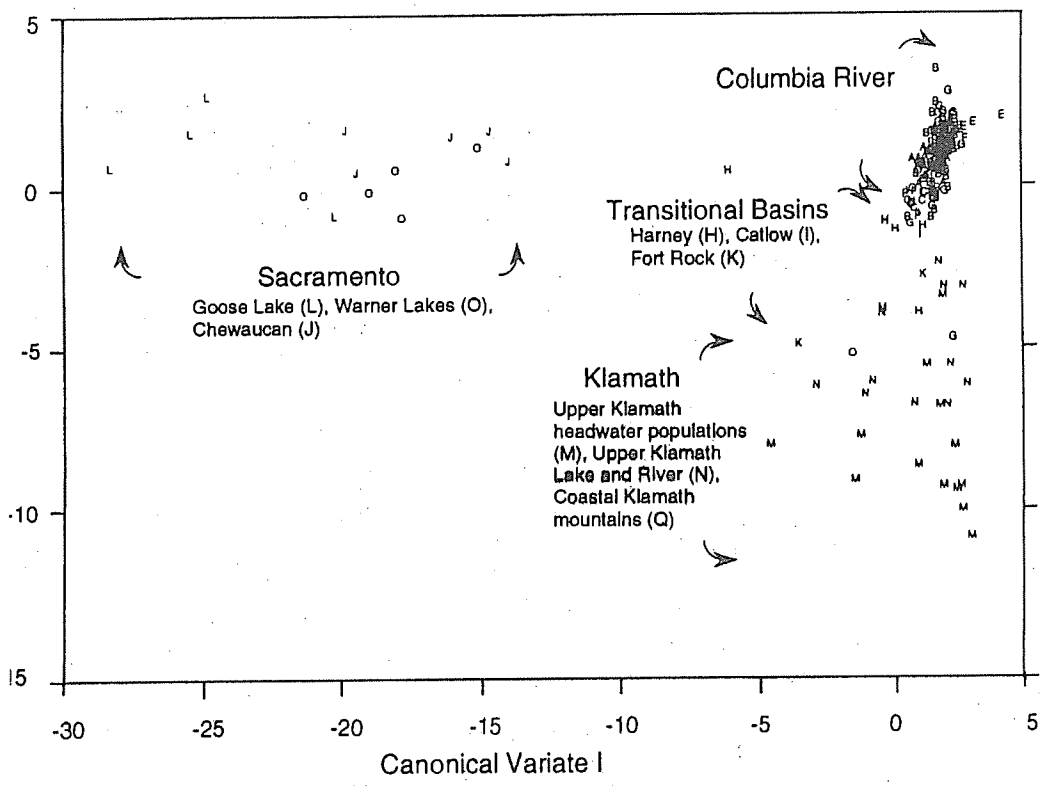


Figure 2.—Genetic differences among 243 rainbow trout populations based on ordination by canonical variates. Letters refer to basins identified in Figure 1.

DISCUSSION

Large Rivers Provide Stability

Our results indicated that the relationship between large rivers systems and isolated desert lake basins has been dynamic. Over evolutionary time, large river systems provided stable habitat that allowed redband trout to persist in the harsh, arid, variable environment of the northern Great Basin. Despite obvious isolation of many redband trout in different basins, for example, the major source of geographical genetic variation in rainbow trout was not among different lake basins but among three major river systems—the Columbia, Klamath, and Sacramento. These were the three rivers that provided persistent habitat and opportunities for dispersal of fishes during volcanic eruptions and lava flows, advancing and retreating glaciers, and periods of wet and dry that came during the Pleistocene (Minckley et al. 1986). In contrast, ancient pluvial lakes filled, dried, and reformed many times (Antevs 1925, Mehringer 1977) with occasions when high water or changes in small headwater streams provided intermittent connections to other basins or rivers. These lakes provided unique habitats and long period of isolation that allowed the redband trout that survived to diversify but the lack of persistent habitat also led to local extinctions

More Than One Subspecies

Despite the importance of large rivers, our results show that redband trout consist of multiple subspecies of rainbow trout. In general, each of the closed basins contains a different subspecies. Exceptions are the basins recently isolated from the Columbia River, such as the Harney Basin. Different subspecies show a common affinity associated with a large river system.

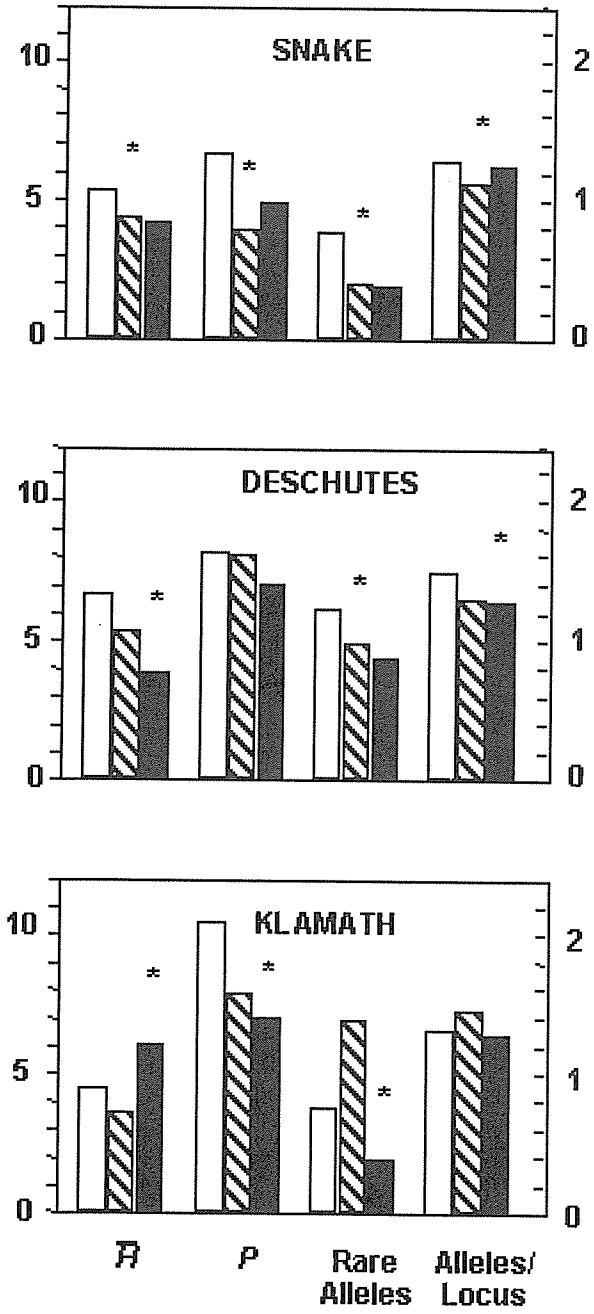


Figure 3.—Levels of genetic variation in unisolated populations (open bars), populations isolated by dams (shaded bars), and populations above ancient barriers (solid bars). Percent average heterozygosity (*H*), number of polymorphic loci (*P*), and number of rare alleles are shown on the left abscissa; number of alleles per locus is on the right abscissa.

Figure 2 shows the evidence for different subspecies. In the Columbia River system, inland rainbow trout (or redband trout), *Oncorhynchus mykiss gairdneri*, are considered a different subspecies than the coastal rainbow trout, *O. m. irideus* (Behnke 1992). The genetic differences between these two subspecies are contained in the cluster found in the upper right hand corner of the figure. The differences among redband trout from isolated basins associated with the Sacramento River system (Goose Lake, Warner Lakes, and the Chewaucan Basin) is clearly greater than the differences between inland and coastal rainbow trout. Based on redband trout in Sheepheaven Creek (a tributary of McCloud River in the upper Sacramento system), Behnke (1992) suggested a single subspecies, *O. m. stonei*, for Sacramento redband trout. Our results suggest that there may be at least two other related subspecies. Likewise, Klamath Lake rainbow trout have been identified as a subspecies, *O. m. newberryi* (Bond 1973, Behnke 1992). Our results suggested that redband trout found in the headwaters of the Williamson and Sprague Rivers and above waterfalls in Jenny Creek are also a different subspecies.

Effects of Dams

If large river systems are important to the persistence of redband trout, it is not surprising perhaps that our results show that when rivers are dammed, redband trout are affected. We found that during a century of isolation, loss of habitat, and population control, rainbow trout in tributaries above dams have lost as much genetic variation as related populations isolated for thousands of years. This was most obvious in the Snake River system (Figure 3). Effects were less obvious in the Deschutes River, where main stem dams were closed only 30 years ago.

In the Klamath Basin, the results were more complex. Upper Klamath Lake was once isolated from lower Klamath River, but overflows breached the barrier during the Pleistocene and formed the present upper river (Moyle 1976). This has provided a long-period of potential colonization and gene flow. In addition, compared to most isolated basins, a large number of unique fish species evolved and persisted in Upper Klamath Lake (Minckley et al. 1986). This suggests that fish in this basin may have had long periods of stable habitat with fewer extinctions. Finally, it is possible that populations below the dams on the Klamath River, which have suffered recent substantial declines in abundance, may also have lost genetic variation.

Our results indicate that human activities are taking a toll on the long-term ability of redband trout to persist. Genetic variation is one of the vital signs to the long-term health of these populations. These signs, however, have more immediate demographic and ecological implications: populations and habitats that were once held together by rivers are shrinking. Studies of populations of many different species isolated on islands indicate that loss of genetic diversity is one of the causes of extinctions (Frankham 1997, 1998). Actions that increase population size by reconnecting islands of habitat for redband trout will help stabilize the loss of genetic variation and reduce the risk of extinction to these subspecies.

LITERATURE CITED

Allendorf, F. W. 1975. Genetic variability in a species possessing extensive gene duplication: genetic interpretaion of duplicate loci and examination of genetic variation in populations of rainbow trout. Ph.D. Dissertation. Univ. Washington, Seatttle, Washington.

Antevs, E. 1925. On the Pleistocene history of the Great Basin, pp. 51-114. *In*: Quaternary Climates. Carnegie Inst. Wash. Publ. 352.

Behnke, R. J. 1992. Native Trout of Wetern North America. American Fisheries Society Monograph 6. American Fisheries Society, Bethesda, Maryland.

Bond, C. E. 1973. Key to Oregon Freshwater Fishes. Agricultural Experiment Station Technical Bulletin 58. Oregon State University, Corvallis, Oregon.

Cope, E. D. 1889. The Silver Lake of Oregon and its region. American Naturalist 23: 970-982.

Currens, K. P., C.B. Schreck and H.W. Li. 1990. Allozyme and morphological divergence of rainbow trout (*Oncorhynchus mykiss*) above and below waterfalls in the Deschutes River, Oregon. Copeia 1990(3):730-746.

Diamond, J. M. 1984. "Normal" extinctions of isolated populations, p. 191-246. *In*: Extinctions. M. H. Nitecki (ed.). University of Chicago Press, Chicago, Illinois.

Frankham, R. 1997. Do island populations have less genetic variation than mainland populations? Heredity 78:311-327.

Frankham, R. 1998. Inbreeding and extinction: island populations. Conservation Biology 12:665-675.

Mehringer, P. J., Jr. 1977. Great Basin Late Quaternary environments and chronology, pp. 113-117. *In*: Models and Great Basin Prehistory: A Symposium. D. D. Fowler (ed.). Desert Res. Inst. Soc. Sci. Publ. 12, Univ. Nevada, Reno, Nevada.

Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American freshwater fishes: description and relationships to intracontinental tectonism, pp. 519-614. *In:* The Zoogeography of North American Freshwater Fishes. C. H. Hocutt and E. O. Wiley (eds.). Wiley and Sons, New York, New York.

Moyle, P. B. 1976. Inland Fishes of California. University of California Press, Berkeley, California.

Okazaki, T. 1984. Genetic divergence and its zoogeographical implications in closely related species *Salmo gairdneri* and *Salmo mykiss*. Jap. J. Ichthyol. 31:297-310.

Wilmot, R. L. 1974. A genetic study of the redband trout (*Salmo* sp.). Unpubl. Ph.D. Dissertation. Oregon State University, Corvallis, Oregon.

Triploid Hatchery Trout Programs in Idaho – Meeting Public Demand for Consumptive Angling while Protecting Genetic Integrity of Native Trout

Jeff Dillon[1], Dan Schill[2], David Teuscher[3], and Douglas Megargle[3]

Abstract—Introductions of fertile nonnative hatchery trout have led to interspecific and intraspecific hybridization of native trout throughout North America. In theory, judicious use of sterile triploid hatchery trout could help meet public demand for consumptive trout fishing while reducing or eliminating further genetic risks to wild stocks. However, information on performance of triploid trout in recreational fisheries is lacking. In Idaho, we evaluated relative survival and performance of triploid and control diploid hatchery rainbow trout in 18 stream and 3 lake fisheries. Results to date suggest that triploid hatchery trout can provide fishing opportunity comparable to that provided by fertile fish. Triploid trout eggs are readily available from commercial egg suppliers. With minimal investment in time and effort, state agencies can also use well-established techniques to produce triploids from their own in-state broodstocks. Beginning in 2001, Idaho plans to produce or purchase about 17,000,000 triploid rainbow trout eggs annually, enough to meet stocking requests for all streams and most lakes statewide. Other programs include development of sterile cutthroat for mountain lake stocking, and sterile rainbow x cutthroat hybrids for Henrys Lake. Although additional field evaluations are needed, we suggest that triploid hatchery trout are a valuable tool with which fishery managers can meet the demand for harvest opportunity and still conserve native stocks.

INTRODUCTION

The widespread hybridization of native salmonid stocks due to introduction of nonnative species or strains is well documented (Allendorf et al. 1980; Campton and Johnston 1985; Hindar et al. 1993). Despite concerns for genetic impacts and other interactions with wild trout, hatchery trout stocking continues to play a significant role in the management of many trout fisheries (Wiley 1993; Van Vooren 1995). Trout stocking continues in many cases because the demand for consumptive fishing opportunity exceeds production by native fish.

The Idaho Department of Fish and Game (IDFG) maintains eleven resident fish hatcheries in the state. These facilities produce over one million pounds of rainbow trout *Oncorhynchus mykiss* annually, including about 7,000,000 fingerlings and 2,000,000 catchables. Of the catchable rainbow trout production, about 600,000 are stocked into streams. Approximately 1,450 km of Idaho streams receive hatchery trout, only 3.3% of the state's 44,000 fishable stream kilometers. Despite an increased emphasis on wild trout management in the last two decades, 40% of stream stocking is in waters with wild trout present. Hatchery trout planted into lakes and reservoirs also frequently have access to wild or native trout populations above or below impoundments. Minimizing the potential for genetic interaction between hatchery and wild trout is an important management priority.

[1] *Regional Fishery Biologist, Idaho Department of Fish and Game, Idaho Falls, Idaho*

[2] *Principal Fishery Research Biologist, Idaho Department of Fish and Game, Nampa, Idaho*

[3] *Senior Fishery Research Biologist, Idaho Department of Fish and Game, Jerome, Idaho*

Over the last decade, the production and use of sterile fish as a fishery management tool has received increasing attention. One method to produce sterile trout is through induced triploidy. Triploid salmonids are viable but are functionally sterile. Triploidy is typically induced by heat or pressure shock of fertilized eggs, and triploid trout eggs are readily available from many commercial egg suppliers. Although triploid trout are easily produced or purchased, information on their performance in sport fisheries is lacking.

We evaluated the return to creel of commercially-provided triploid and control diploid rainbow trout in 18 stream fisheries. We also monitored growth and relative survival of triploids and diploids for an extended period in two reservoir fisheries. Additionally, we worked with hatchery broodstock managers to develop methods to mass-produce triploids with our own in-state broodstocks. We evaluated the costs of development and discuss implementation of the sterile hatchery trout program in Idaho.

METHODS

Field Evaluations

Stream Catchables

We purchased mixed-sex triploid and control diploid rainbow trout eggs from a commercial egg supplier. Fish in each group were reared to catchable size (256-272mm), and a sample (n = 60) from the triploid group was evaluated for ploidy using flow cytometry. Triploids and controls were jaw-tagged and stocked into 18 Idaho streams, 300 triploids and 300 controls in each. Relative tag returns for triploids and controls were monitored through the fishing season. Statistical comparisons were made using a paired-t analysis.

Lake and Reservoir Fingerlings

In spring, 1996 we purchased all-female triploid and control diploid rainbow trout eggs from a commercial supplier. Resulting fish were reared to 155mm and tested for ploidy. In fall of 1996 triploids and controls were differentially grit marked with fluorescent dye, and stocked in equal proportions into seven lakes and reservoirs statewide. Relative survival and growth were monitored by electrofishing for over three years, with adequate long-term data collected from two of the seven reservoirs.

Triploid Production

Beginning in 1996, we conducted experimental heat shock treatments on eggs collected from our primary in-state rainbow trout broodstock, the Hayspur strain. We chose a range of heat shock treatments suggested from the literature, with variations in temperature, time after fertilization, and duration. Experimental lots were reared and triploidy induction rates were evaluated with flow cytometry. In 1997, we duplicated the most successful treatments, and again reared and tested resulting fish. In 1998, we developed equipment and methods to mass-produce triploids, and confirmed triploidy rates in resulting fish. By 1999, responsibilities for producing triploid rainbow trout were handed over to the broodstock manager and staff.

Similar experiments were conducted to produce triploid rainbow x cutthroat trout hybrids for the Henrys Lake program. Ongoing research is focused on developing mass-production methods for our domestic Kamloops broodstock and for westslope cutthroat used in mountain lake stocking programs. Throughout this development phase, manpower and capital expenditures have been monitored to describe costs of the program.

RESULTS

Field Evaluations

Stream Catchables

All (n = 60) of the fish from the triploid group were confirmed to be triploid. A total of 5,400 triploid and 5,400 control diploids were tagged and stocked into the 18 streams. Through the fishing season, a total of 1,849 tags were returned, 931 from triploids and 918 from diploids (Figure 1). There was no significant difference in overall return rate for triploids and diploids ($p = 0.80$).

Lake and Reservoir Fingerlings

Only two reservoirs, Treasureton and Daniels, provided adequate sampling data for long-term evaluations. Growth of triploids and diploids in both waters was comparable throughout the over 40 month duration of sampling (Figure 2). Relative survival, expressed as a ratio of triploids to diploids in the catch, varied by season and water, but overall survival of triploids appeared to exceed that of diploids (Figure 3).

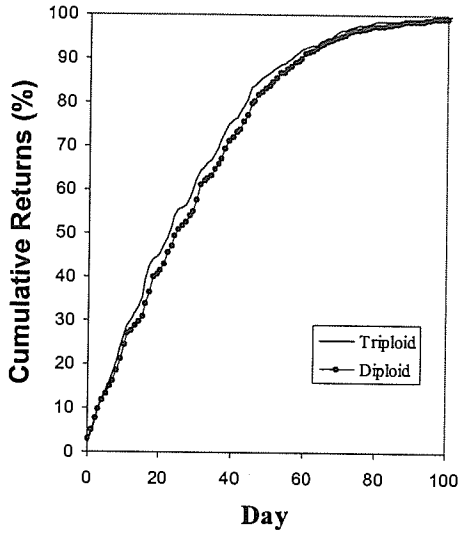


Figure 1.—Cumulative first-year return to creel over time (100 days post-stocking) for triploid and diploid hatchery rainbow trout in 18 Idaho streams combined.

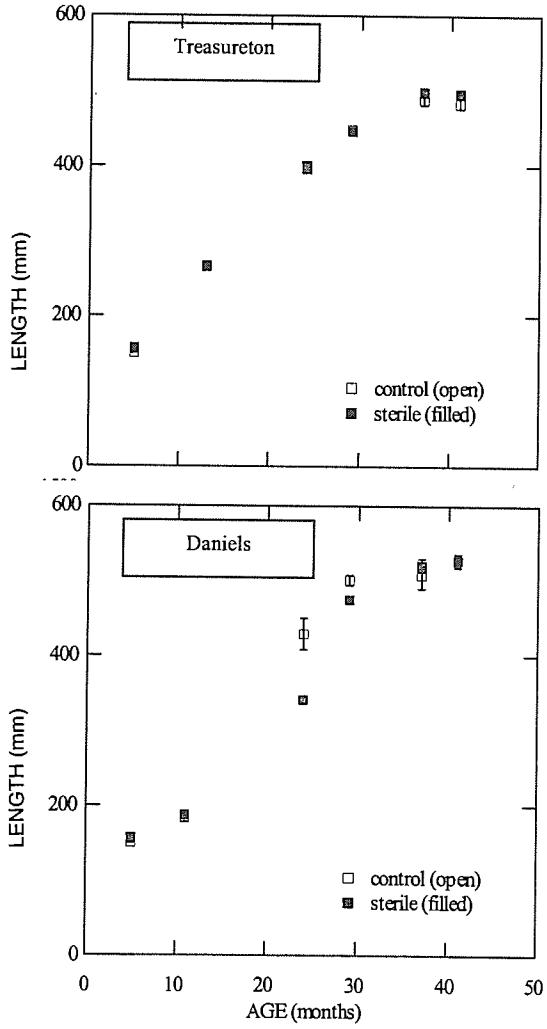


Figure 2.—Relative growth of sterile and control rainbow trout in Treasureton and Daniels reservoirs. Error bars represent one standard error.

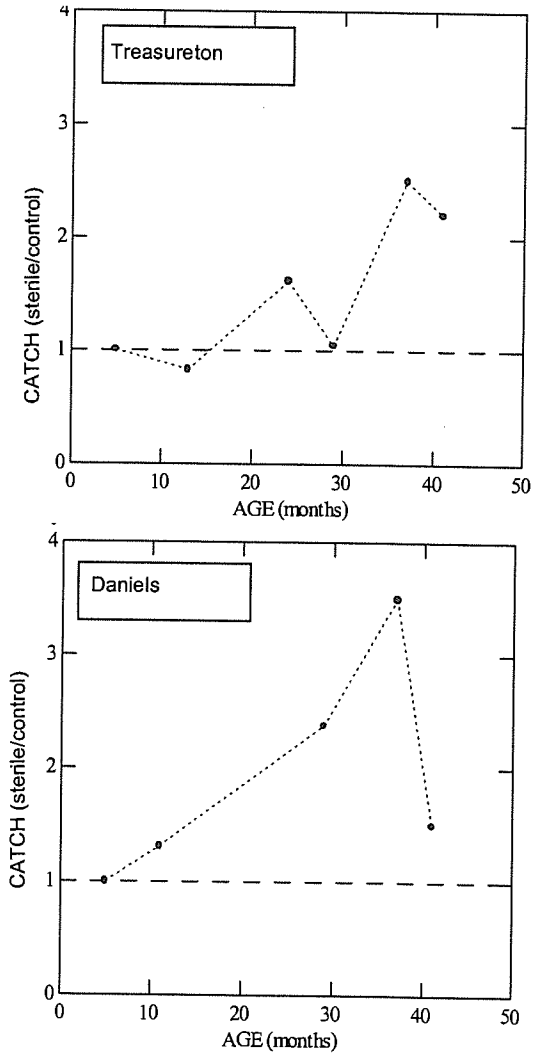


Figure 3.—Relative survival (catch) of sterile and control rainbow trout in Treasureton and Daniels reservoirs. Error bars represent one standard error.

Triploid Production

In our experimental heat shocks of Hayspur rainbow trout eggs, treatments of 26°C applied 20 min after fertilization for a duration of 20 min consistently provided triploidy induction rates approaching 100%. In 1998, while developing methods for mass-production, research personnel heat shocked 1.2 million eggs with an overall triploidy induction rate of 98%. In 1999, Hayspur Hatchery personnel heat shocked over 2 million eggs.

Experimental heat shocks on rainbow x cutthroat trout eggs have been less consistent. Small treatment lots shocked at 27°C 10 min after fertilization with a 20 min duration yielded triploidy induction rates of 90-95%. However, when this treatment was applied to production eggs lots, induction rates have been

only 65-75%. Results from preliminary work on domestic Kamloops rainbow and westslope cutthroat trout are not yet available for inclusion in this manuscript.

The total manpower and equipment required for the heat shock experiments was minimal. A circulating water bath with a temperature regulator was used, most often in a standard egg picking table. Eggs were fertilized and placed in Heath trays for treatments. Total capital costs for circulating heat pumps, plus two custom designed heat shocking troughs, was less than $5,000. Less than 30 man-days total was required to develop and refine the treatment protocol for the Hayspur rainbow broodstock.

DISCUSSION

Our field evaluations provide strong evidence that sterile triploid rainbow trout can provide stream and reservoir fisheries comparable to those provided by fertile hatchery fish. Given the ongoing concern for genetic impacts from hatchery introductions, and the likelihood that public demand for hatchery stocking will continue, using only triploid trout in stocking programs appears a viable strategy to minimize conflicts between hatchery and wild trout management.

Triploid trout are available from many commercial suppliers. Egg costs are typically about twice the cost of normal eggs, although costs seem to be decreasing in recent years. It is important to note that egg costs are only a small percentage of total costs for hatchery production, particularly for catchable-size fish. We estimated in our stream catchable experiments that the average cost per triploid fish was about 15% higher than for normal catchables.

Verifying the triploidy induction rates in commercial triploids is also important. Suppliers typically do not guarantee 100% sterility, and in our experience triploidy rates can vary among commercial egg lots. Although our experimental triploid lots were confirmed to be 100% triploids, we have ordered other commercial triploid rainbow trout eggs with triploidy rates of 70-75%.

We also demonstrated that, with relatively little effort and cost, agencies can develop methods to produce triploid hatchery trout with their own broodstocks. One or two seasons of experimental heat shocks should be adequate to refine treatments and develop large-scale production techniques. Because of the constraints of treatment timing, broodstock managers would also need to adjust egg-taking schedules to accommodate the heat shocking process. We did not account for the cost of additional spawning logistics in our assessment.

Based on the above field evaluations and development of in-state triploid production, the Idaho Department of Fish and Game has developed new policies to minimize impacts of hatchery trout stocking on wild or native trout. Unless fishery managers specifically request fertile fish, all hatchery rainbow trout stocked by IDFG hatcheries will be sterile triploids. Fully implementing this policy will take several years, but in the last year we purchased 2 million commercial triploids and produced over 2 million triploids from our own broodstocks. Beginning in 2001, IDFG plans to produce or purchase about 17 million triploid rainbow trout eggs annually, enough to meet stocking demands for all streams and most lakes statewide.

Persistence of Native Brook Trout in Great Smoky Mountains National Park after 35 Years of Stocking with Northern Derived Hatchery Strains

Stan Guffey[1]

Abstract - During this century, stream mileage inhabited by brook trout decreased about 70% in the area of Great Smoky Mountains National Park. Attempts to stem population decline included stocking with hatchery strains. From 1940 through 1974 over 800,000 fertilized eggs and mixed age hatchery strain fish were stocked into all but 12 Park streams. Stocking was terminated in 1975 consistent with NPS policy to manage for native taxa. Subsequent molecular genetic evidence indicated that southern Appalachian brook trout might be genetically distinct from hatchery strains used for stocking. We sampled 47 wild populations and three hatchery strains for electrophoretic variation in muscle proteins from 24 gene loci. Hatchery strains and samples from streams with no record of stocking were fixed for different alleles at one locus and showed significant allele frequency heterogeneity at 9 of 10 polymorphic loci. Mean genetic identity (Nei's I) between unstocked and hatchery samples was 0.788, and was 0.988 among unstocked samples and 0.978 among hatchery samples. The diagnostic hatchery allele was detected in only 11 of 40 samples from streams known to have received stocking. Although small sample sizes limited our power to detect low frequency alleles, our data indicate surprising persistence of native genotypes.

INTRODUCTION

Between 1900 and the establishment of Great Smoky Mountains National Park in 1934, brook trout range in the Park area declined an estimated 60 - 70% (Lennon, 1967). Attempts to curb this decline and expand the range to its historical limits included establishment of fishing regulations and stocking with hatchery reared brook trout (King, 1942). Stocking of brook trout in the Park began in 1937. From 1937 through 1939 about 200,000 hatchery reared native Southern Appalachian brook trout were stocked annually into Park streams (King, 1942). Heavy stocking continued from 1940 through 1947 using hatchery strains derived from northeastern populations. Evidence from this experience indicated that northern derived hatchery strains used in stocking were less hardy than native populations and less likely to become established (Holloway, 1945). Extensive stocking effort was reduced after 1947 but continued, employing northern derived hatchery strains, until 1975. Over the period 1940 - 1975 more than 800,000 fertilized eggs, fry, fingerlings, and adults from northern derived hatchery strains were stocked into at least 76 Park streams. Only 12 streams in the Park have no record of stocking (McCracken et al, 1993). The effects of these introductions of northern derived domesticated strains into native Southern Appalachian brook trout gene pools are of obvious conservation concern, particularly if the source populations are genetically differentiated from indigenous populations.

In an unpublished report to the Park, Brussard and Nielsen (1976) concluded on the basis of allozyme variation that Southern Appalachian brook trout populations might differ from northeastern populations at the level of species or subspecies. Stoneking

[1]*Division of Biology, The University of Tennessee, Knoxville 37996-0001*

et al. (1981) reached the same conclusion from their observation of significant allele frequency differences between three southern and four northern populations at four of 39 allozyme loci, and estimated a mean genetic similarity of $I = 0.890$ between the two regions. Stoneking et al. (1981) also suggested that stocking of northern hatchery strains in the Southern Appalachians might be a confounding factor in their study.

McCracken et al. (1993) considered stocking history to examine genetic differences between native brook trout populations and the northern derived hatchery strains used for stocking in the Park. Five presumed native Southern Appalachian populations with no record of stocking with hatchery fish were sampled as well as three other Park streams that had documented stocking onto existing populations. Northern derived hatchery strains were represented by two strains used in stocking in the region (Pisgah and Owhi strains) and by a wild reproducing population from a Park stream, Meigs Creek, which was devoid of brook trout prior to stocking. McCracken et al. (1993) observed that unstocked populations and hatchery strains were fixed for different alleles at one locus (CK-A2*) and had significant allele frequency differences at an additional 9 of 16 polymorphic loci that contained alternative alleles of presumed northern ancestry. They estimated a mean genetic similarity (Nei, 1972) of $I = 0.906$ between unstocked and northern hatchery strains, comparable in magnitude to the estimate of Stoneking et al. (1981). The effects of hybridization were evident in the three populations where hatchery strains had been stocked onto extant populations. Homozygotes and heterozygotes were observed for both CK-A2* alleles and presumptive "northern" alleles were present at several other loci in the three stocked populations.

Here I report protein electrophoretic studies on the genetic structure of 47 brook trout populations from the Park. Four of the populations studied were also sampled by McCracken et al. (1993), and one, Bunches Creek, was studied by McCracken et al. (1993) and by Stoneking et al. (1981). The total of 52 distinct populations sampled in this study and by McCracken et al. (1993) are thought to represent the majority of brook trout populations in the Park (Steve Moore, Great Smoky Mountains National Park, personal communication). I also examined two additional hatchery strains derived from northeastern populations, the EdRay strain and the Rome strain. These strains are known to have been stocked in the region, if not specifically in the Park. Examination of the diagnostic loci documented by Stoneking et al. (1981) and McCracken et al. (1993), and other diagnostic loci that are first reported here, allow me to evaluate the extent of hatchery strain introgression into native gene pools throughout the Park.

METHODS

Collections

Between 1992 and 1994, 47 wild brook trout populations in the Park were sampled by electrofishing. Two hatchery strains were sampled by dip netting from hatchery raceways. Only age 1 and older fish were collected. In the field, fish were euthanized with MS-222 (100mg/liter) after capture. Eyes, liver, and a skeletal muscle tissue sample were removed and immediately frozen in liquid nitrogen. Upon return to the laboratory tissues were stored at -80° C prior to and after processing.

Sample size varied according to population densities observed in the field and according to long term data on population density. Because most streams lack long term census data, most samples were limited to 10 specimens to minimize possible negative effects on population viability. Three populations are represented by fewer specimens because of extremely low population densities observed at the time of sampling. Sample sizes from eight streams are larger than 10 specimens, and three of these streams with large brook trout populations were sampled on three separate occasions. Multiple samples were obtained from the same general stream locality in each of the three years of sampling. The hatchery samples consist of 25 specimens.

McCracken et al. (1993) examined five of the 12 streams in the Park with no record of stocking. Here I examine populations from six of the other seven unstocked streams. The remaining unstocked stream was not sampled. The Meigs Creek population in the Park is a naturalized population derived from the Pisgah hatchery strain. Meigs Creek was devoid of brook trout prior to stocking (McCracken et al., 1993; John Boaz, Fish and Wildlife Associates, Inc., personal communication). The EdRay strain was collected at the state fish hatchery in Pisgah, North Carolina, and the Rome strain at the state hatchery in Marion, Virginia.

Protein Electrophoresis

Horizontal starch gel electrophoresis was used to examine all samples for variation in 15 muscle proteins encoded by 24 gene loci. Electrophoresis of tissue extracts followed the procedures of Selander et al. (1971) and McCracken and Wilkinson (1988). Buffer systems for resolving brook trout allozymes are after May et al. (1979) and Stoneking et al (1981). Loci and alleles were designated as recommended by Shaklee et al. (1990). By convention, the most common mobility product was designated as the 100 allele. Lower frequency allelic products at a locus were identified by their mobility relative to the common allele. The practice of designating the common allele as the 100 mobility variant can lead to some confusion in comparing studies of the same taxon where the common allele at a locus differs between studies. For example, the CK-A2* 100* allele that is fixed or at high frequency in Southern Appalachian populations (McCracken et al., 1993) is synonymous with the 122* allele observed by Stoneking et al. (1981).

Data Analysis

Genetic variation within populations is assessed as percent polymorphic loci and heterozygosity. Observed and expected heterozygosities were calculated for each polymorphic locus in each population sample. The duplicated sAAT-1,2* locus and the duplicated sMDH-B1,2* locus were each treated as single loci in these analyses. Observed genotype frequencies were evaluated for conformance to Hardy-Weinberg expected frequencies with the fixation index F_{IS} and the G-test (Levene, 1949; Nei, 1977; Sokal and Rohlf, 1981). The average fixation index F_{IS} for all populations and subsets of populations was tested for significant difference from zero by the t-test a $p < 0.01$. The duplicated locus sAAT-1,2* was not included in these analyses because both loci are polymorphic in some populations and alleles could not be assigned to a specific locus.

Sample sizes and heterozygosities of most samples were not sufficient to reliably assess linkage disequilibrium. All pairs of polymorphic loci in samples with more than ten specimens were evaluated for conformity to expected two locus genotypes by Chi-square contingency analysis. Possible linkage disequilibrium was evaluated in these samples using the procedure of Hill (1974). Samples from populations sampled three times were evaluated independently and as a pooled sample. Association between CK-A2* 78* allele frequency and the frequency of alternative alleles at other loci was evaluated for samples polymorphic at CK-A2* and for all samples using the Pearson correlation coefficient.

Genetic heterogeneity among populations was evaluated with G-tests of allele frequencies (Sokal and Rohlf, 1981), standardized genetic variances (F_{ST}; Wright, 1978; Nei, 1977), and genetic identity coefficients (Nei, 1972; 1978). Variation at the duplicated sAAT-1,2* locus was partitioned equally between the two loci for purposes of these analyses (Krueger et al., 1989). Test statistics and coefficients were calculated for each pairwise comparison between and among all populations, groups of populations within watersheds, and populations classified as Park or hatchery. Multiple samples from the same population were pooled for these analyses. Rare alleles were pooled where appropriate in the contingency table analyses (Sokal and Rohlf, 1981). G-test critical values were adjusted to account for the increase in type I error associated with multiple independent tests of the null hypothesis (Cooper, 1968). The adjusted 0.01 alpha value for these tests was 0.001 using Sidak's multiplicative inequality (Sokal and Rohlf, 1981). G-values with more than 100 degrees of freedom were evaluated using Fisher's normal approximation (Fisher, 1953). Standardized genetic variances were estimated for loci polymorphic among all populations and among subsets of populations. Sampling variances of F_{ST} estimates were calculated following Workman and Niswander (1970).

Genetic data analysis was performed with the "Genes in Populations" microcomputer program by B. May, C. C. Krueger, and W. Eng of Cornell University. Other statistical analyses were performed using the SAS system (SAS Institute, 1985).

RESULTS

Genetic Variation Within Samples

Ten of the 22 loci (45%) were polymorphic with alternative alleles at a frequency greater than 0.05.Three additional loci carried rare alleles in one sample each. Thirty seven samples were polymorphic at one or more loci. Seventeen samples from the Park were identically monomorphic across all loci. Average polymorphism across all polymorphic loci (frequency of the common allele less than 1.0) was 11.7% (Table 1). Average polymorphism of Park samples across all polymorphic loci was 9.9% (range: 0.0% - 36.4%). The Meigs Creek samples were polymorphic at an average of 30.3% of the loci examined

Table 1.—Genetic variability within samples: Summary statistics.

	All Samples	All Park Samples	Samples fixed CK-A2* 100*	Samples Polymorphic at CK-A2*	Hatchery Samples
Number of samples	55	50	35	15	5
Average H_S [1]	0.053	0.032	0.014	0.074	0.096
Standard Error H_S	0.015	0.010	0.005	0.005	0.030
Range H_S	0.0 – 0.143	0.0 – 0.143	0.0 – 0.044	0.008 – 0.143	0.070 – 0.130
H_T [2]	0.111	0.050	0.025	0.096	0.109
Standard Error H_T	0.031	0.015	0.009	0.030	0.035
Average P [3]	0.117	0.099	0.031	0.242	0.291
Range P	0.0 – 0.364	0.0 – 0.364	0.0 – 0.227	0.045 – 0.364	0.174 – 0.364

[1] H_S is expected heterozygosity of a sample.
[2] H_T is expected heterozygosity of pooled samples.
[3] P is the proportion of loci polymorphic in the sample (frequency of the common allele less than 1.0).

(range: 22.7% - 36.4%). The EdRay and Rome hatchery strain samples were polymorphic at 31.8% and 18.2% of the loci respectively.

Mean expected heterozygosity ($_S$) was 0.053 for all samples (range: 0.0 – 0.143), 0.032 (range: 0.0 - 0.143) for the samples from the Park, and 0.096 (range: 0.070 - 0.130) for the hatchery and Meigs Creek samples (Table 1). Four of 89 observed genotype frequencies exhibited deviations from Hardy-Weinberg expectation by the G-test. This is the number that would be expected by chance alone at the 5% level. Average fixation indices (F_{IS}) were not significantly different from zero in any of the subsets examined.

Samples from 35 Park populations, including samples from the seven unstocked streams, were fixed for the CK-A2* 100* allele, and fifteen samples from eleven populations carried the 100* allele at high frequency (average frequency of the 100* allele: 0.79 (range: 0.50 - 0.95; Table 2). The Meigs Creek samples and the hatchery strain samples were fixed for the CK-A2* 78* allele. The Dunn Creek population from the Park carried an 83* allele at the CK-A2* locus at a frequency of 0.16, in addition to the 100* and 78* alleles. The 83* allele has not been reported in previous studies of brook trout allozyme variation. Following McCracken et al. (1993), Park populations fixed for the CK-A2* 100* allele are designated "native" populations, and those polymorphic at the CK-A2* locus are designated "hybrid." The EdRay and Rome hatchery strains and the hatchery derived Meigs Creek population are referred to collectively as hatchery strains.

Variation at PEPB*, which has not been previously reported, exhibited a pattern similar to and largely concordant with variation at CK-A2* (Table 2). Six of the seven unstocked populations were fixed for the PEPB* 100* allele (Table 3). The putatively unstocked McGinty Branch population (MGB) was polymor-

Table 2.—Average Allele Frequencies of Loci Diagnostic Between Native Smoky Mountain Brook Trout and Northern Derived Hatchery Strains.

	N	CK-A2*		PEPB*		AAT-1,2*			GPI-B2*		
		100*	8	100*	8	100*	0	118*	100*	40*	70*
Unstocked	7	1.0	-	0.99	0.01	0.05	-	0.95	0.05	-	0.95
Fixed CK-A2* 100*	35	1.0	-	0.99	0.01	0.06	-	0.94	0.04	-	0.96
Polymorphic CK-A2*	15	0.79	0.21	0.81	0.19	0.26	-	0.74	0.17	-	0.83
Hatchery Strains	5	-	1.0	0.06	0.94	0.78	0.10	0.12	0.89	0.11	-

Table 3.—Frequencies of Diagnostic Alleles in Samples from Unstocked Park Streams and Hatchery Strain Samples.

	N	CK-A2*		PEPB*		AAT-1,2*			GPI-B2*		
		100*	8	100*	8	100*	0	118*	100*	40*	70*
Unstockd									-	-	
BUN	38	1.0	-	1.0	-	0.22	-	0.78	-	-	1.0
ENL	10	1.0	-	1.0	-	-	-	1.0	-	-	1.0
RAV	10	1.0	-	1.0	-	-	-	1.0	-	-	1.0
SAM	8	1.0	-	1.0	-	-	-	1.0	-	-	1.0
SIL	10	1.0	-	1.0	-	-	-	1.0	-	-	1.0
LBC	10	1.0	-	1.0	-	-	-	1.0	-	-	1.0
MGB	10	1.0	-	0.95	0.05	0.10	-	0.90	0.35	-	0.65
Hatchery											
MEG	40		1.0	0.17	0.83	0.91	-	0.09	0.99	0.01	-
EDY	25		1.0	-	1.0	0.70	0.10	0.20	0.68	0.32	-
ROM	26		1.0	-	1.0	0.73	0.19	0.08	1.0	-	-

phic for PEPB* with the 68* allele at a frequency of 0.05. The two hatchery strain samples were fixed for the 68* allele. The samples from the naturalized Meigs Creek population were polymorphic with the 68* allele at a high frequency (average frequency of the 68* allele: 0.83; range: 0.77 - 0.86; Table 3). Overall, 37 populations from the Park were fixed for the PEPB* 100* allele and 13 samples from 11 populations carried the 100* allele at high frequency (average frequency of the 100* allele: 0.78; range: 0.30 - 0.97). Ten of the Park samples polymorphic at PEPB* were also polymorphic at the CK-A2*.

Unstocked Park populations and hatchery samples also had different common alleles at AAT-1,2* and GPI-B2* (Tables 2 and 3). The AAT-1,2* 118* allele was fixed in 29 Park samples and was the common allele in 15 samples (average frequency of the AAT-1,2* 118* allele: 0.78). The AAT-1,2* 100* allele was the high frequency allele in the hatchery derived Meigs Creek samples and in the hatchery samples (average frequency of the AAT-1,2* 100* allele: 0.83). The highest frequency of the AAT-1,2* 100* allele among Park populations was observed in the Taywa Creek samples (average frequency: 0.64). The Taywa Creek samples also had the highest CK-A2* 78* allele frequency among Park populations (average frequency, 0.47).

Thirty five Park samples were fixed for the GPI-B2* 70* allele and the other 11 carried the 70* allele at high frequency (average frequency of the GPI-B2* 70* allele: 0.75; range: 0.50 - 0.99). The GPI-B2* 70* allele was not observed in the hatchery or Meigs Creek samples. Two of the Meigs Creek samples and the Rome hatchery strain were fixed for the GPI-B1* 100* allele and one Meigs Creek sample and the EdRay hatchery strain sample carried the 100* allele at high frequency and the 40* allele at low frequency (Table 3).

Alleles at four other loci that were polymorphic in two or more samples showed patterns of variation that appear to reflect strain or stocking history but which are not diagnostic between hatchery strains and Park populations. Unstocked streams were fixed for the 100* alleles at G3PDH-1*, LDH-B1*, MDH-B1,2* and sMEP-1*. These loci were polymorphic in the hatchery samples and in few Park populations that had been stocked, but the 100* allele was the common allele in all samples. Low frequency polymorphisms at DDH* and PROT-1* also exhibited variation among samples indicating allelic differences between native populations and hatchery strains.

Table 4.—Correlations (Pearson's r) of CK-A2* 78* allele frequencies with frequencies of alleles at other loci. (*p[r =0] < 0.05; **p[r = 0] < 0.01)

Locus – allele	Samples Polymorphic at the CK-A2* Locus	All Samples
PEPB* 68*	0.884**	0.962**
LDH-B1* 67*	0.733**	0.815**
AAT-1,2* 100*	0.595**	0.856**
sMEP-1* 63*	0.376*	0.750**
GPI-B2* 100*	0.339	0.878**
G3PDH-1* 78*	0.058	0.797**
PROT-1 –130*	0.318	0.554**
MDH-B1,2* 120*	-0.036	0.166

Association Between Alleles

The observed two-locus genotype frequencies for all pairs of loci were not significantly different from those expected with random assortment of alleles. Statistically significant linkage disequilibrium was not detected between any pair of loci. However, in samples that were polymorphic for CK-A2*, the frequency of the CK-A2* 78* allele was significantly correlated with the frequencies of PEPB* 68*, LDH-B1* 67*, AAT-1/2* 100*, and sMEP-1* 63* alleles (Table 4). The frequency of the CK-A2* 78* allele was not significantly correlated with low frequency alleles at the MDH-B1,2*, GPI-B2*, G3PD-1*, and PROT-1* loci in samples polymorphic at CK-A2*. However, across all samples the CK-A2* 78* allele frequency was significantly correlated with low frequency alleles at all loci examined except MDH-B1,2* (Table 4)

Genetic Variation Among Samples

Significant allele frequency heterogeneity was observed among all samples and all subsets of samples. The number of loci showing significant heterogeneity ranged from nine of the ten polymorphic loci among all samples, and among the subset of Park samples fixed for the CK-A2* 100* plus hatchery, to five of 10 loci for the subset of Park samples fixed for the CK-A2* 100* allele (Table 5).

The average standardized genetic variance (F_{ST}) for all populations was F_{ST} = 0.542 (Table 5). The highest F_{ST}, 0.659, was for the subset Park native plus hatchery. The lowest F_{ST}, 0.113, was observed for the hatchery subset. Because of the large total sample sizes, sampling variances of F_{ST} estimates were small, 0.001 for all populations and all subsets of populations except the subsets hatchery and Park hybrid. Sampling variances for these subsets were 0.005 and 0.002 respectively. Average F_{ST} values for polymorphic loci were significantly different from zero for all sample subsets examined.

Table 5.—Genetic heterogeneity among sample subsets: G-test statistics, number of loci exhibiting significant allele frequency heterogeneity, genetic variance (F_{ST}), and sampling variance of F_{ST} estimate.

Sample Subset (n)	Total G	Total df	Number of Loci Showing Significant Heterogeneity	F_{ST}	F_{ST} Sampling Variance
All Samples (49)	7010.6	1222	9	0.542	0.001
Park Samples (46)	3173.3	968	8	0.363	0.001
Fixed CK-A2* 100* (35)	1259.2	510	5	0.453	0.001
Polymorphic CK-A2* (11)	1097.5	220	7	0.223	0.002
Hatchery Samples (3)	218.2	40	7	0.113	0.005
Fixed Ck-A2* 100* + Hatchery (38)	5817.8	814	9	0.659	0.001

Table 6.—Average normalized genetic identities (Nei's *I*) across all samples and selected subsets of samples.

Sample Subset	Number of Comparisons	Average *I*	Range of *I*
All Samples	1485	0.950	0.718 – 1.0
Park Samples	1225	0.985	0.859 – 1.0
Fixed CK-A2* 100*	595	0.988	0.925 – 1.0
Polymorphic CK-A2*	55	0.981	0.922 – 1.0
Hatchery Samples	3	0.978	0.973 –0.986
Fixed CK-A2* 100* + Polymorphic CK-A2*	385	0.973	0.859 – 1.0
Fixed CK-A2* 100* + Hatchery	105	0.778	0.718 – 0.832

The average normalized genetic identity (Nei's *I*) among all samples was 0.950 (range: 0.718 - 1.0; Table 6). Among all Park populations the average genetic identity was 0.985 (range: 0.859 - 1.0). The highest genetic identity was observed among the subset Park samples fixed for the CK-A2* 100* allele (natives), $\bar{I}$ = 0.988 (range: 0.925 - 1.0). Genetic identities among the population subsets Park samples polymorphic at CK-A2* (hybrids, $\bar{I}$ = 0.981; range: 0.922 - 1.0), hatchery ($\bar{I}$ = 0.978; range: 0.973 - 0.986), and Park natives plus Park hybrids ($\bar{I}$ = 0.973; range: 0.859 - 1.0) were similar. The lowest genetic identity was observed among the subset Park natives plus hatchery ($\bar{I}$ = 0.778; range: 0.718 - 0.832; Table 6). The normalized genetic identities among multiple samples from the same population were, 0.997 (HYC), 0.991 (TAY), and 0.993 (MEG).

DISCUSSION

Identification of Marker Alleles

This study corroborates and extends our earlier findings (McCracken et al., 1993; Hayes et al. 1996) that native (unstocked) Park brook trout populations and northern derived hatchery strains differ at a number of loci. As in earlier studies (Stoneking et al., 1981; McCracken et al., 1993), the samples from all unstocked streams were fixed for the CK-A2* 100* allele. Also concordant with earlier studies, the naturalized Meigs Creek samples and the hatchery strain samples were fixed for the CK-A2* 78* allele. Stoneking et al. (1981) also observed that the 78* allele (designated the 100* allele) was fixed in their samples from New York and Pennsylvania. All unstocked, naturalized, and hatchery samples that were examined by Perkins et al. (1993) from New York and Pennsylvania were also fixed for the same slower

allele. I conclude that presence of the CK-A2* 78* allele in Park populations is evidence of introgression with northern derived hatchery strains and that the frequencies of the northern allele can provide an index of the relative intensities of hatchery introgression.

The frequencies of the common alleles at PEPB*, AAT-1,2* and GPI-B2* also differed between native brook trout populations in the Park and northern derived hatchery strains, but the differences did not involve fixation of alternative alleles in the two groups. The presence of the PEPB* 68* allele and the GPI-B2* 100* allele in some Park populations appears to suggest introgression with hatchery strains, but the presence of these alleles at a low frequency in some unstocked populations cannot be excluded. The hatchery derived Meigs Creek population and the reportedly unstocked McGinty Branch population are polymorphic for PEPB*, and I cannot determine if these polymorphisms are consequences of recent hybridization or reflect low frequency polymorphism in source populations. The relatively high frequency of the GPI-B2* 100* allele segregating in the McGinty Branch population suggests that this reportedly unstocked population may have in fact received undocumented stocking.

It seems likely that the high frequency of the AAT-1,2* 100* allele in some Park populations is indicative of introgression from hatchery strains, but it also appears that some unstocked native populations carry the AAT-1,2* 100* allele at low frequency. Correlation between CK-A2* 78* allele frequencies and the frequencies of alternative alleles at G3PDH-1*, LDH-B1*, sMEP-1*, and PROT-1* suggests a hatchery origin of these alleles as well, but low frequency polymorphism in native Park populations cannot be excluded.

Genetic Differentiation

My estimates of genetic similarity (Nei's *I*) indicate substantial genetic divergence between brook trout populations from Great Smoky Mountains National Park and hatchery strains used in stocking. The average genetic identity between hatchery strains and samples fixed for the CK-A2* 100 allele ($\bar{I}$ = 0.778) was the lowest observed among all subsets and across all samples (Table 6). This estimate is in contrast to the high average identity observed between all Park samples ($\bar{I}$ =0.988) and between all hatchery samples ($\bar{I}$ = 0.978). These estimates of genetic identity may be usefully compared to estimates obtained from other studies of allozyme variation in brook trout. Examining a larger number of loci, Perkins et al. (1993) obtained estimates of *I* ranging from 0.910 to 0.999 in comparisons between 28 samples of wild and hatchery brook trout in New York and Pennsylvania. In an earlier study Stoneking et al. (1981) obtained a mean *I* of 0.973 between populations from New York and Pennsylvania, a mean *I* of 0.955 between populations from Tennessee and North Carolina, and a mean *I* of 0.890 between the northern and southern populations. These are similar in magnitude to our earlier estimate of a mean similarity of 0.995 between unstocked populations from the Park and of a mean similarity of 0.906 between these unstocked populations and three hatchery strains (McCracken et al., 1993). My current estimate of a mean genetic similarity of 0.778 is clearly at the low end of observed genetic similarity between brook trout populations. This extremely low value results in part from the calculation of *I* from a subset of loci that were selected in this study because they are informative.

Our assessment of differentiation among brook trout populations at allozyme loci does not directly address taxonomy within *Salvelinus fontinalis*, and we recognize the limitations of making taxonomic assessments on the basis of biochemical data (Frost and Hillis, 1990; Dowling et al., 1992). However it is clear from our data that populations from Great Smoky Mountains National Park and northern derived hatchery strains are significantly differentiated. This points to the existence of two evolutionarily significant units within the taxon, an observation that is of considerable biogeographical interest and importance to the conservation of biodiversity.

Hybridization

Eleven of 47 Park populations sampled in this study gave evidence at the CK-A2* locus of hybridization with hatchery strains. Samples from seven populations were monomorphic for the CK-A2* 100* allele but carried suspected hatchery alleles at one or more other loci (G3PDH-1*, GPI-B2*, LDH-B1*, sMEP-1*, PEPB*). Unfortunately the hatchery origin of these alleles cannot be established with certainty, nor can the absence of CK-A2* 78* alleles definitively preclude hatchery introgression. However, the relatively small number of samples (23.4%) containing the diagnostic CK-A2* 78* allele is surprising given the intensity of documented stocking and the small number of streams with no record of stocking. This obser-

vation of intense stocking, and the low sample size from most populations, encourages the suspicion that 23.4% (or 38.3% if I include populations with other suspected hatchery alleles) is an underestimate of the number of brook trout populations in the Park that carry hatchery genes. This is likely to be the case, but the only clear conclusion that can be drawn from the allozyme data is that a relatively low percentage of Park populations carry high frequencies of hatchery genes.

The low frequencies of diagnostic hatchery alleles in Park populations suggest low levels of introgression. Only two Park populations, Taywa Creek and Indian Flats Branch, carried the CK-A2* 78* allele at a frequency of 0.35 or greater. The average frequency of the CK-A2* 78* allele in the other hybrid populations was 0.10. The Taywa Creek and Indian Flats Branch populations also had the putative hatchery PEPB* 68* allele at the highest frequency among Park populations. The absence of gametic phase disequilibrium between CK-A2* and PEPB* alleles in hybrid populations suggests that these populations are randomly mating hybrid swarms. Random association of alleles at loci diagnostic between native populations and hatchery strains also suggests that selection against these alleles or against alleles at linked loci is weak or is not occurring. However, the low levels of detectable introgression may reflect past selection against hatchery or hybrid genotypes in stocked populations. Support for this hypothesis comes from an observed correlation between the recency but not the intensity of stocking, and levels of mtDNA and allozyme introgression in populations from Tennessee outside the Park (Kriegler et al., 1995; Hayes et al., 1996). Long term genetic monitoring of hybrid populations are required to determine if hatchery alleles decline in hybrid populations over time, and determination of the relative roles of selection and drift in the dynamics of hybrid gene pools will require comparative habitat studies and studies of the relative fitness of different genotypes in wild populations. Holloway's (1945) contention that stocking with hatchery strains was ineffective in stemming the decline of brook trout in the Park because hatchery fish were not sufficiently hardy to become established or were rapidly fished out, remains the most parsimonious explanation for the low levels of hatchery introgression in Park brook trout gene pools.

Management Implications

Brook trout populations in the Park and elsewhere in the Southern Appalachians have declined substantial since 1900. The molecular genetic data indicate that stocking with hatchery brook trout contributed little to the persistence of brook trout in the Park, and did not promote downstream expansion. An important and positive consequence of the limited effectiveness of hatchery stockings is the persistence of native populations in streams that had received hatchery fish. About 75% of Park populations have no evidence of hatchery genes in my samples, and most of the hybrid samples have hatchery genes at low frequency. As discussed above, the small sample sizes from most populations are likely to make this an underestimate of the number of populations carrying hatchery genes. However, the conclusion that levels of hatchery introgression are low is unaffected. For purposes of management emphasizing native gene pool conservation, populations with no evidence of hatchery introgression should be treated as native Southern Appalachian populations.

Evidence of relatively low levels of hatchery introgression in Park populations in no way argues for a role of hatchery strains in fisheries management in the Park. Consistent with National Park Service policy (National Park Service, 1988) to manage for native taxa and strains, stocking with hatchery strains should not be considered an option. Management efforts should instead focus on maintenance of habitat quality, removal of rainbow trout from selected streams to permit establishment of lower elevation brook trout populations, and establishment of native brook trout populations in streams from which brook trout have been extirpated. Because there is significant heterogeneity among native populations in the Park, establishment of new populations in the Park should be through stock transfer or hatchery propagation of native populations from adjacent watersheds within river drainages. The allozyme data presented in this paper should be employed in making such decisions.

The goal of re-establishing a brook trout sport fishery in the Park should also be informed by the allozyme data. Fishery regulations such as size and take limits are primarily instituted in response to and for control of target population demographics. Predicated on the assumption that some populations have greater native biodiversity value than others, the genetic data may be of use in suggesting populations

to open to sport fishing. For example, opening the hatchery derived Meigs Creek population to fishing would help meet public desire for a brook trout fishery and might be employed as a means of eradicating the population. With the hatchery population eradicated or reduced, Meigs Creek would become a candidate for introductions of native brook trout from other populations in the Little River watershed. Similarly, the hybrid population in Taywa Creek could probably support an active regulated fishery, but even in the event of a decline induced by overfishing, the loss would be of little consequence in terms of loss of native biodiversity and would open a location for stocking with local native populations.

ACKNOWLEDGEMENTS

This research was supported by contracts with Great Smoky Mountains National Park and through a grant from the Great Smoky Mountains Conservation Association. I want to thank Dr. Gary McCracken and Dr. Richard Strange (The University of Tennessee), Dr. Chuck Parker (U. S. Geological Survey), Mr. Jim Habera and Mr. Bart Carter (Tennessee Wildlife Resources Agency), Mr. Matt Kulp (Great Smoky Mountains National Park), and a host of Student Conservation Association volunteers and seasonal Park Service employees who help and inspired.

I wish to offer special thanks to Mr. Steven Moore of Great Smoky Mountains National Park. While Steve and I don't always see eye to eye, he has been a constant source of ideas and inspiration. Steve is a model for the type of person that I want managing our natural resources.

Any foolishness or errors are of course entirely my own.

LITERATURE CITED

Bivens, R. D. 1985. History and distribution of brook trout in the Appalachian region of Tennessee. Tennessee Wildlife Resources Agency Technical Report No. 85-1. The University of Tennessee, Knoxville.

Bivens, R. D., R. J. Strange, and D. C. Peterson. 1985. Current distribution of the native brook trout in the Appalachian region of Tennessee. Journal of the Tennessee Academy of. Science 60: 101-105.

Brussard, P. F., and D. F. Nielsen. 1976. Allozyme variation in the brook trout, *Salvelinus fontinalis*: A preliminary report. Unpublished report to Great Smoky Mountains National Park, Gatlinburg, Tennessee.

Clayton, J. W., and D. N. Tretiak. 1972. Amine-citrate buffers and pH control in starch gel electrophoresis. Journal of the Fisheries Research Board of Canada 29: 1169-1172.

Cooper, D. W. 1968. The significance level in multiple tests made simultaneously. Heredity 23: 614-617.

Dowling, T. E., B. D. Demarais, W. L. Minckley, M. E. Douglas, and P. C. Marsh.1992. Use of genetic characters in conservation biology. Conservation Biology 6: 7-8.

Fisher, R. A. 1954. Statistical methods for research workers. 12th ed. Oliver and Boyd, Edinburgh.

Frost, D. R., and D. M. Hillis. 1990. Species in concept and practice: herpetological applications. Herpetologica 46: 97-104.

Habera, J. W., and R. J. Strange. 1993. Wild trout resources and management in the Southern Appalachian Mountains. Fisheries 18: 6-13.

Hayes, J. P., S. Z. Guffey, F. J. Kriegler, G. F. McCracken, and C. R. Parker. 1996. The genetic diversity of native, stocked, and hybrid populations of brook trout in the southern Appalachians. Conservation Biology 10: 1403-1412.

Hill, W. G. 1974. Estimation of linkage disequilibrium in randomly mating populations. Heredity 33: 229-239.

Holloway, A. D. 1945. Report on the fisheries of the Great Smoky Mountains National Park. Unpublished internal report to Great Smoky Mountains National Park, Gatlinburg, Tennessee.

Jones, R. D. 1978. Regional distribution trends of the trout resource. Pp. 1-10 *In* Harshbarger, T. J. (ed.), Southeastern Trout Resource: Ecology and Management Symposium Proceedings. U. S. Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

Kelly, G. A., J. S. Griffith, and R. D. Jones. 1980. Changes in distributions of trout in Great Smoky Mountains National Park, 1900-1977. U. S. Fish and Wildlife Service Technical Paper 102.

Kincaid, H. L. 1981. Trout strain registry. U.S. Fish and Wildlife Service, National Fisheries Center - Leetown / 81-1, Kearneysville, West Virginia.

King, W. 1937. Notes on the distribution of native speckled trout and rainbow trout in the streams of Great Smoky Mountains National Park. Journal of the Tennessee Academy of Science 12: 351-361.

King, W. 1942. Trout management studies at Great Smoky Mountains National Park. Journal of Wildlife Management 6: 147-61.

Kriegler, F. J., G. F. McCracken, J. W. Habera, and R. J. Strange. 1995. Genetic characterization of Tennessee brook trout populations and associated management implications. North American Journal of Fisheries Management 15: 804-813.

Krueger, C. C., J. E. Marsden, H. L. Kincaid, and B. May. 1989. Genetic differentiation among lake trout strains stocked into Lake Ontario. Transactions of the American Fisheries Society 118: 317-330.

Lennon, R. E. 1967. Brook trout of Great Smoky Mountains National Park. U. S. Fish and Wildlife Service Technical Paper 15. Department of the Interior, Washington.

Levene, H. 1949. On a matching problem arising in statistics. Annals Mathematical Statistics 20: 91-94.

McCracken, G. F., C. R. Parker, and S. Z. Guffey. 1993. Genetic differentiation and hybridization between stocked hatchery and native brook trout in Great Smoky Mountains National Park. Transactions of the American Fisheries Society 122: 533-542.

McCracken, G. F., and G. S. Wilkinson. 1988. Allozyme techniques and kinship assessment in bats. Pp. 141-156 *In* T. H. Kunz (ed.), Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington.

May, B., J. E. Wright, and M. Stoneking. 1979. Joint segregation of biochemical loci in Salmonidae: results from experiments with *Salvelinus* and review of the literature on other species. Journal of the Fisheries Research Board of Canada 36: 1114-1128.

National Park Service. 1988. Management policies. National Park Service, Washington.

Nei, M. 1972. Genetic distance between populations. American Naturalist 106: 283-292.

———. 1977. F-statistics and analysis of gene diversity in subdivided populations. Annals of Human Genetics 41: 225-233.

———. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 41: 225-233.

Perkins, D. L., C. C. Kruger, and B. May. 1993. Heritage brook trout in northeastern USA: Genetic variability within and among populations. Transactions of the American Fisheries Society 122: 515-532.

Ridgeway, G. J., S. W. Sherburne, and R. D. Lewis. 1970. Polymorphism in the esterases of Atlantic herring. Transactions of the American Fisheries Society 99: 147-151.

Selander, R. K., M. H. Smith, S. Y. Yang, W. E. Johnson, and J. B. Gentry. 1971. Biochemical polymorphism and systematics in the genus *Peromyscus* I. Variation in the old field mouse (*Peromyscus polionotus*). University of Texas Studies in Genetics 6: 49-90.

Shaklee, J. B., F. W. Allendorf, D. C. Moritz, and G. S. Whitt. 1990. Gene nomenclature for protein-coding loci in fish Transactions of the American Fisheries Society 119: 2-15.

Sokal, P. R., and F. J. Rohlf. 1981. Biometry, 2nd edition. Freeman, San Francisco.

Stoneking, M., D. J. Wagner, and A. C. Hildebrand. 1981. Genetic evidence suggesting subspecific differences between northern and southern populations of brook trout (*Salvelinus fontinalis*). Copeia 1981: 810-819.

Workman, P. L., and J. D. Niswander. 1970. Population studies on southwestern Indian tribes. II. Local genetic differentiation in the Papago. American Journal of Human Genetics 22: 24-49.

Wright, S. 1978. Evolution and the genetics of populations: 4 variability within and among natural populations. University of Chicago Press.

Recovery and Conservation of the Henrys Lake Yellowstone Cutthroat Trout Population

Mark Gamblin[1], Jeff Dillon[2], and Matt Powell[3]

Abstract—The Henrys Lake watershed supports one of the five most important Yellowstone cutthroat trout *Oncorhynchus clarki bouvieri* populations in the Snake River Basin. The state of Idaho puts a high priority on Henrys Lake in state plans to conserve and restore genetically viable Yellowstone cutthroat throughout their historic Idaho range. As early as 1891, rainbow trout *Oncorhynchus mykiss* were introduced into the Henrys Lake native trout population that consisted solely of Yellowstone cutthroat trout and mountain whitefish *Prosopium williamsoni*. Genetic analyses conducted in 1998, 1999 and 2000 documented relatively low level of rainbow trout introgression in the cutthroat population and near 100% accuracy rates in field identification of genetically pure cutthroat. Emphasizing the development of a sterile rainbow-cutthroat trout hatchery hybrid program and incorporating a genetically pure stock of cutthroat into the hatchery cutthroat program, we predict that within 5 generations (20 years) the level of rainbow trout introgression could be reduced from the current level of 14% to near 2% and within 10 generations (40 years) to less than 1%.

INTRODUCTION

Henrys Lake, at the head of the Henrys Fork Snake River (Figure 1), is one of five critically important Yellowstone cutthroat trout watersheds in Idaho. Henrys Lake is a shallow, productive 6,500 acre impoundment with a mean depth of 12 feet supporting a mixed-stock fishery that includes wild and hatchery cutthroat and hybrid cutthroat-rainbow trout and feral brook trout. In 1999 cutthroat trout comprised 48% (47,000), hybrid trout accounted for 42% (42,000) and brook trout contributed 9% (8,800) to the total catch. Henrys Lake is remarkably productive and lightly exploited. In 1994 a conservative mark-recapture population estimate included 425,000 cutthroat trout and 117,000 hybrid trout, over 14 inches in length. Natural mortality and total exploitation estimates for cutthroat trout were 70% and 7.2% and for hybrid trout were 60% and 12.8% respectively.

Despite being regulated for irrigation water storage since 1922, Henrys Lake has sustained a wild native Yellowstone cutthroat trout population. The reduced distribution of Yellowstone cutthroat trout in Idaho, particularly within the Henrys Fork Snake River drainage, and the pending petition to the U.S. Fish and Wildlife Service to list the sub-species under the Endangered Species Act highlights the importance of the Henrys Lake population. The presence of rainbow trout and hybrid rainbow-cutthroat trout in Henrys Lake and the threat posed to the viability of the cutthroat population has caused concern and controversy for the Department of Fish and Game and its fishery management program. With the advent of improvements in fish genetics technology, the Idaho Department of Fish and Game is adapting the Henrys Lake fishery management program to halt and reverse the process of rainbow trout introgression and enhance the genetic integrity of the Yellowstone cutthroat trout population.

Henrys Lake History

Resource exploitation in Henrys Lake began in 1872 when the first settler, Gilman Sawtelle began a commercial fishery for native cutthroat trout. Up to 90,000 pounds of fish per year were harvested for the market in Salt Lake City and the Montana mines.

[1] *Regional Fisheries Manager, Idaho Department of Fish and Game, Idaho Falls, Idaho*

[2] *Regional Fisheries Biologist, Idaho Department of Fish and Game, Idaho Falls, Idaho*

[3] *Research Scientist, University of Idaho Center for Salmonid and Freshwater Species at Risk, Hagerman, Idaho*

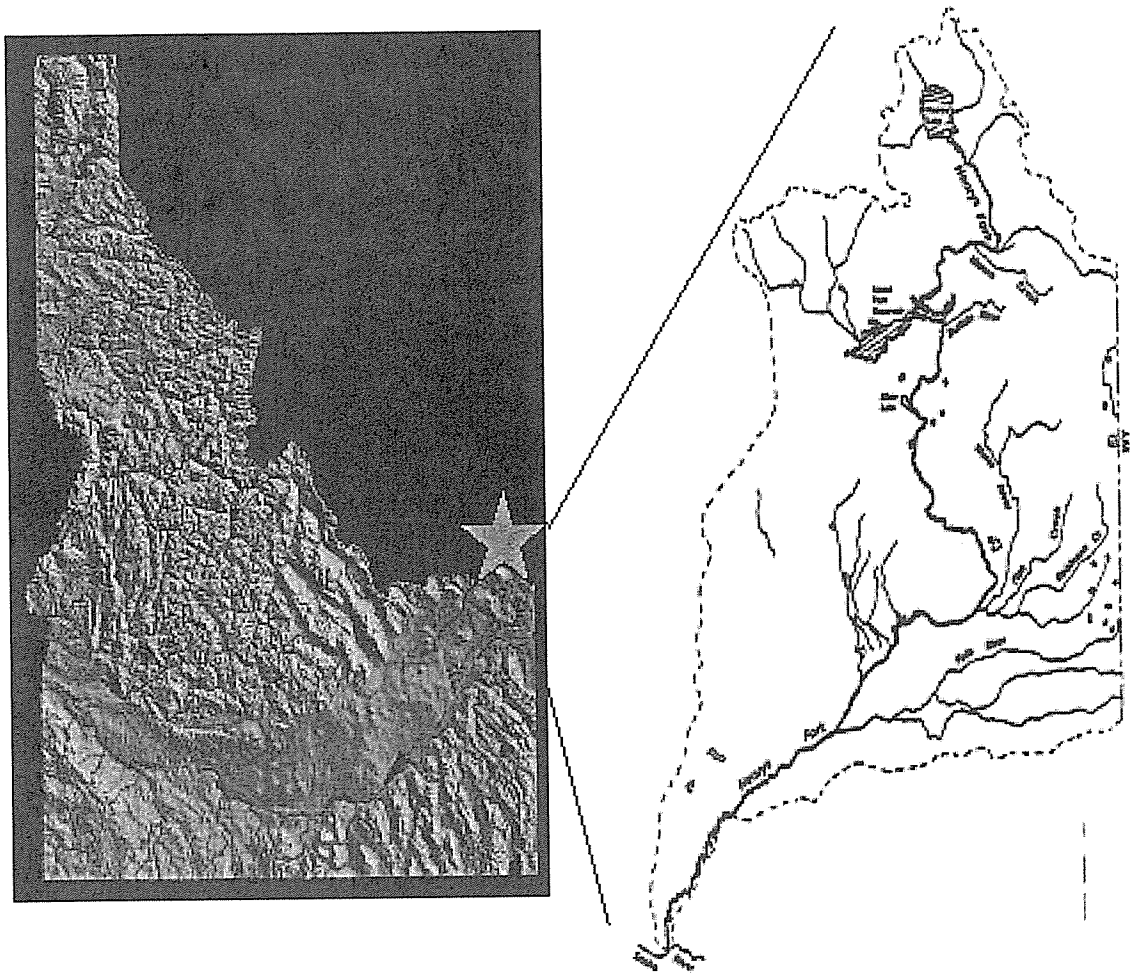


Figure 1.—Henrys Lake, Henrys Fork Snake River drainage, eastern Idaho.

Rainbow trout were first introduced in Henrys Lake in 1890 when Joe Sherwood developed a rainbow trout hatchery on the north shore of the lake. In 1922 the Henrys Lake dam was constructed by the North Fork Reservoir Company to store irrigation water. Two years later the Idaho Department of Fish and Game acquired the Sherwood hatchery facilities to mitigate for tributary spawning and production habitat flooded by the impoundment. Since the hatchery acquisition, the Henrys Lake hatchery has been an egg-taking facility, supplying eggs for hatchery cutthroat trout supplementation across southern Idaho, including the Henrys Lake management program. Henrys Lake hatchery supplementation is founded entirely on eggs taken from Henrys Lake cutthroat trout, rather than from a hatchery brood stock.

By 1950, hybrid cutthroat-rainbow trout, progeny of the early rainbow trout introductions, were a popular complement to the predominately Yellowstone cutthroat trout fishery. The Department of Fish and Game began producing and stocking hybrid trout in 1950, but later suspended hybrid supplementation. In 1976, public demand for a managed hybrid fishery persuaded the Department to resume hybrid trout production and supplementation. Staff recommendations to cease hybrid stocking, for cutthroat conservation purposes, was met with strong, organized public opposition in 1978. Hybrid fingerling supplementation (200,000 per year) has continued without interruption since then. During the same period, cutthroat supplementation varied between one million and two million fingerlings per year. Cutthroat stocking densities are now set at one million fingerlings per year.

In 1981 Department of Fish and Game fishery managers began efforts to produce sterile hybrid trout by heat-shocking fertilized eggs. Achieving marginal success, the efforts were suspended in 1985 then resumed in 1995, taking advantage of technical improvements in shocking techniques and equipment. Refinements in heat-shocking protocols achieved 97% triploidy induction rates and sterile

hybrids replaced reproductively viable hybrid releases in 1999.

Genetic Status of Henrys Lake Trout

Given the history of rainbow trout introductions and introgression in the Henrys Lake cutthroat trout population and the desire to conserve the cutthroat population, there is an obvious need to understand the genetic status of the population. Knowing the introgression rate and level allows us to develop management options to conserve and ultimately recover genetic purity in the cutthroat population.

Genetic surveys of Henrys Lake tributaries, the Henrys Lake hatchery spawning ladder and the lake-wide post-spawning population of Henrys Lake trout were begun in 1998 and continued through 2000. Genetic analyses were performed by the University of Idaho genetics laboratory in Hagerman, Idaho and by the Washington Department of Fish and Wildlife genetics laboratory in Olympia, Washington. In 1998 fish samples were collected from Targhee Creek, Howard Creek, Duck Creek and the hatchery ladder. Wild Rose Creek, Timber Creek, Hope Creek and the hatchery ladder were sampled in 1999. Henrys Lake proper and the hatchery ladder were sampled in 2000. Genetic analysis of the tributary fish samples utilized nuclear DNA markers, hatchery ladder fish samples were analyzed using both allozyme and nuclear DNA markers, and the fish sampled from the lake were analyzed with allozyme markers.

These analyses addressed two objectives. Fundamentally, we wanted to assess the genetic status of each population (tributary, hatchery ladder spawning run and the at-large lake population) in terms of introgression levels and rates of introgression. We also tested our ability to accurately identify genetically "pure" cutthroat in the hatchery ladder and the lake population.

Throughout this paper we use the term "pure" in discussions of the genetic status of Henrys Lake trout. It is important to emphasize that the Henrys Lake trout population is introgressed and will remain so. It will not be possible to manage the Henrys Lake trout population to remove all rainbow trout alleles in the genome. However, as we demonstrate in this paper, the frequency of rainbow trout alleles can be manipulated to reduce introgression to levels that reduce the ecological significance and relevance to fisheries management of introgression in this population. The use of the term "pure" refers to this concept.

Tributary Genetic Analysis Results

Fish samples from Targhee Creek, Duck Creek and Howard Creek indicate variable introgression levels among those streams (Table 1). The absence of F1 suggests that straying of hatchery hybrids (to those streams) is minimal or absent. Backcrossed hybrids were present is each stream. Conversely, Timber Creek, Hope Creek and Wild Rose Creek samples included only one backcrossed hybrid, but F1 hybrids were well represented in each of those tributaries.

Table 1.—Henrys Lake tributary genetic analysis results.

Tributary	n	F_1 Hybrids	Back-crossed Hybrids
Targhee Creek	60	—	15
Duck Creek	60	—	1
Howard Creek	54	—	7
Timber Creek	21	10	—
Hope Creek	10	4	—
Wild Rose Creek	34	11	1

While it is possible to naturally produce a gene combination that resembles an F1 hybrid, it is far more probable that those fish were hatchery products. The relatively small proportion (10%) of backcrossed hybrids in the tributary samples is especially important. Backcrossing indicates random reproduction among hybrids and between hybrids and non-introgressed cutthroat. Such a low incidence of backcrossing is strong evidence that the Henrys Lake trout population has not developed a hybrid swarm.

Hatchery Ladder Genetic Analysis Results

Our genetic identification accuracy rate for all three years was surprisingly high at 98% (Table 2). These samples also indicate that the hatchery Yellowstone cutthroat spawning run is introgressed at a very low level. For example, in the 2000 analysis of phenotypic cutthroat trout from the hatchery ladder, only two diagnostic rainbow trout alleles were detected out of the total sample of 2,240 alleles (80fish x 14 diagnostic loci x 2 alleles per loci). The "population" represented by the 2000 hatchery ladder sample is introgressed no more that 9 one-hundredths of one percent (2/2,240 x 100).

Table 2.—Henrys Lake hatchery ladder genetic analysis results.

Year	n	"Geneically pure YCT"	ID Accuracy
1998	20	18	90%
1999	60	60	100%
2000	80	78	97.5%

We emphasize two conclusions from these results. First, we have demonstrated a high degree of accuracy in identifying genetically pure cutthroat trout based on phenotype. Equally important, it is clear that the hatchery program has selected for a stock of cutthroat trout that is genetically "pure". Each of these findings has profound implications for the Henrys Lake management program. We have the capability to identify a genetically "pure" individual fish in the field, allowing us to manage discreetly for non-introgressed cutthroat. More importantly, we have a strong stock of essentially genetically pure cutthroat to serve as the foundation for a management program to conserve and restore genetic integrity of the Henrys Lake Yellowstone cutthroat trout population.

Lake-wide Genetic Analysis Results

The lake-wide population sample included 71 trout randomly collected. Each tissue sample was screened with eight diagnostic allozyme markers. With a genetic population sample size of 1,076 (71x2x8), 148 diagnostic rainbow trout alleles were detected in the analysis. This analysis found that the Henrys Lake trout population is currently introgressed at a level of 13.9% (148/1,076 x 100). Given over 100 years of interaction with introduced rainbow and rainbow-cutthroat hybrid trout, an introgression level of 14% is unexpectedly low.

Management Options

We now know the genetic status of the Henrys Lake trout population. We have identified a strong stock of genetically pure cutthroat trout in the trout population. We have demonstrated an ability to accurately identify genetically pure cutthroat on site. We have the capability to intensively manage the Henrys Lake trout population with the hatchery program. In total, these capabilities give us a powerful set of management tools to conserve and enhance the genetic viability of the Henrys Lake Yellowstone cutthroat trout population.

Refine the Hybrid Program

With continued refinements to the heat shocking protocols, we expect to exceed the experimental triploidy induction rates of 97%. Within 5 years, we are confident that we will succeed in blocking virtually all new introductions of rainbow trout genetic material into the Henrys Lake cutthroat trout population, without sacrificing the popular hybrid fishery program.

Expand the Genetically Pure Cutthroat Population

Starting with the year 2000 sample of cutthroat trout from the hatchery spawning run we have initiated a new phase of Yellowstone cutthroat trout management in Henrys Lake. Each of the 80 fish that were collected, 60 males and 20 females, was spawned prior to being sacrificed for tissue collection. Each resultant egg lot was labeled with cross-referenced parental identities and segregated in individual heath egg trays. After genetic analysis, those introgressed egg lots were identified and removed from the egg pool. We now have a pool of 10,000 genetically pure Henrys Lake Yellowstone cutthroat trout fingerlings. Each fingerling will be permanently marked with an adipose fin clip and implanted with discrete coded wire tag. The coded wire tag will allow us to distinguish between the pure cutthroat and fingerlings that have been previously fin-clipped for hatchery evaluation studies. Two years from their spring 2001 release into Henrys Lake, these fingerlings will begin to return to the hatchery ladder. Beginning 2003, each adipose fin-clipped cutthroat spawner returning to the hatchery ladder will be scanned for a coded wire tag. Those with coded wire tags will be segregated and spawned to produce cutthroat of known genetic heritage. The resultant year-class of fingerlings will again receive a unique identifying mark continuing the process. Genetic screening of cutthroat parental pairs will be continued to ensure that the breadth of the spawning run is represented and genetic heterogeneity is optimized in the refined stock. We expect to convert 100% of our hatchery production to "pure" Henrys Lake Yellowstone cutthroat trout within the next 15 years.

Modeling Genetic Enhancements

Refining the sterile hybrid program and developing genetic integrity in the hatchery cutthroat program are clear choices to responsibly manage the Henrys Lake Yellowstone cutthroat trout population. Regardless, it is instructive and useful to estimate the speed and scale of enhancements to the genetic status of the cutthroat population. Figure 2 provides a *hypothetical* example of the simple mathematical model we employed to predict the rate and level of introgression reductions we will achieve by reducing future rainbow trout genetic contributions and increasing future cutthroat genetic contributions to the Henrys Lake trout population. Figure 2A represents a hypothetical tributary trout population, before the sterile hybrid program was instituted,

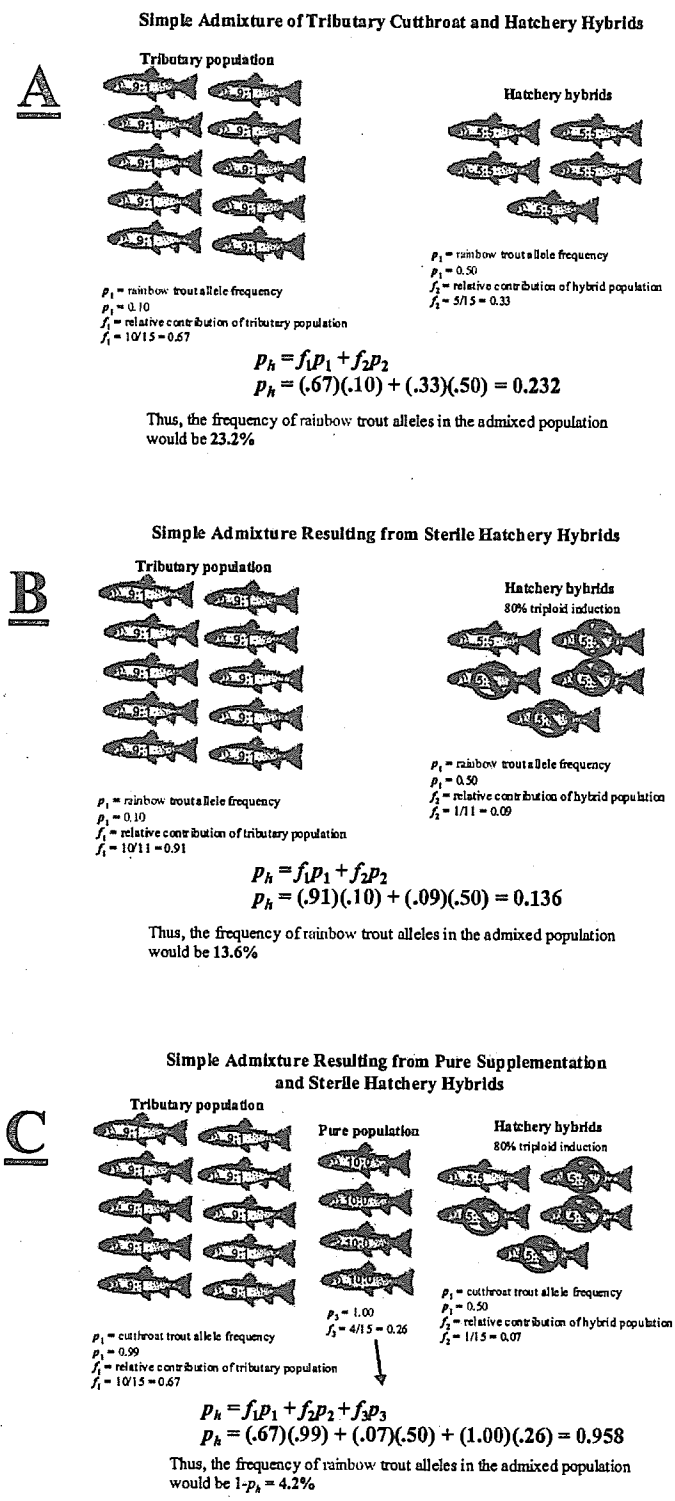


Figure 2.—Hypothetical examples of sterile hybrid and non-introgressed hatchery cutthroat trout supplementation on introgression levels and rates in Henrys Lake.

with an introgression level of 23.2%. Figure 2B describes the same hypothetical population managed with a sterile hybrid program achieving only 80% triploidy induction rates. In this example 20% of the hybrid supplementation will be reproductively viable and are assumed to contribute to the population genome. Given these variables, this population will be 13.6% introgressed after 5 generations, a difference of 9.6% introgression compared to the previous example. Figure 2C describes the same population managed with both 80% sterile hybrids and genetically pure cutthroat trout. With the given proportion of each group of fish in the population, the addition of genetically pure cutthroat supplementation reduces the introgression level another 9.4%, after 5 generations..

Employing the modeling approach illustrated in Figure 2, we estimate the following outcomes given the known genetic status of the Henrys Lake at-large trout population. A generation is assumed to be 4 years, the average life span of Henrys Lake cutthroat trout.

Henrys Lake Population *Without* Genetic Conservation Management

- Current lake-wide level of introgression: ***13.9%***
- Current mean rate of introgression: ***6.3%***
- Estimated level of introgression after 5 generations without intervention: ***23.9%***
- Estimated level of introgression after 10 generations without intervention: ***31.1%***

Henrys Lake Population *With* Genetic Conservation Management

- Estimated level of introgression after 5 generations with sterile hybrid (80% induction rate) intervention: ***16.1%***
- Estimated level of introgression after 10 generations with sterile hybrid (80% induction rate) intervention: ***18.3%***
- Estimated level of introgression after 5 generations with sterile hybrid (80% induction rate) intervention and 20% "pure" cutthroat supplementation: ***12.2%***
- Estimated level of introgression after 10 generations with sterile hybrid (80% induction rate) intervention and 20% "pure" cutthroat supplementation: ***9.3%***
- Estimated level of introgression after 5 generations with sterile hybrid (80% induction rate) intervention and 50% "pure" cutthroat supplementation: ***1.9%***

- Estimated level of introgression after 10 generations with sterile hybrid (80% induction rate) intervention and 50% "pure" cutthroat supplementation: ***0.0003%***

The levels of "pure" cutthroat supplementation (20% or 50%) in the last two model estimates are assumptions that hatchery cutthroat supplementation will account for 20% or 50% of the lake-wide trout population. We consider 20% to be an underestimate and 50% a reasonable estimate of hatchery contribution to current lake population densities. For the purposes of modeling potential benefits of conservation strategies, these assumptions give us conservative and "best approximation" estimates of improvements to the genetic integrity of the lake population as we fully implement these management changes.

These modeled outcomes emphasize several important aspects of the conservation measures we are now implementing. We will slow the rate of introgression by simply implementing the sterile hybrid program without further improvements in triploidy induction rates, but we will not likely reverse the flow of rainbow trout introgression in the lake-wide population. However, by including genetically "pure" cutthroat trout supplementation, we will begin to reduce introgression levels in the population. The rate of reduction will be strongly influenced by the relative contribution of genetically pure supplementation to the lake population. If hatchery cutthroat supplementation contributes close to 50% of the lake total population we should detect a large reduction in the lake-wide population introgression level, within 20 years (5 generations).

CONCLUSION

We are now implementing relative minor changes in the Henrys Lake hatchery program that will effect profound changes in the genetic composition of this important native Yellowstone cutthroat trout population. We also hope to demonstrate that with balanced management, giving appropriate consideration to genetic and ecological principles, hatchery management can be a powerful tool to conserve and restore fishery resources.

Whirling Disease: Putting the Pieces Together

David Nickum[1] and Jerri Bartholomew[2]

Since 1994, whirling disease has become the focus of intensive national research involving dozens of researchers and millions of dollars from federal, state, and private sector partners. These efforts have improved the understanding of whirling disease and possibilities for controlling its impacts on wild trout.

HISTORY

Whirling disease was first diagnosed in the United States in 1958 at the Benner Spring Fish Research Station in Pennsylvania; it has been speculated that *M. cerebralis* arrived at the facility in 1956 in frozen trout imported from Europe. Around the same time, the parasite was found in Nevada, then in Connecticut (1961), Virginia (1965), California (1966), and Massachusetts (1966). Since then, *M. cerebralis* has been found either in hatcheries or the wild in a total of 22 states: Alabama, California, Colorado, Connecticut, Idaho, Maryland, Massachusetts, Michigan, Montana, Nevada, New Hampshire, New Jersey, New Mexico, New York, Ohio, Oregon, Pennsylvania, Utah, Virginia, Washington, West Virginia, and Wyoming.

ARE SOLUTIONS IN SIGHT?

Much of the latest research was presented at the 6th Annual Whirling Disease Symposium, held in February 2000 in Coeur d'Alene, Idaho. The conference theme, "Solutions to Whirling Disease: Putting the Pieces Together," reflects a progression in research efforts. Earlier in the 1990s, research focused almost exclusively on developing a basic understanding of the disease because so little was known about the parasite and its relationship to its worm (*T. tubifex*) and fish hosts and the environment. With this information, scientists are now conducting studies on potential solutions such as habitat enhancement, improved stocking practices, and promotion of trout life histories that reduce disease risks. While studies have produced no "silver bullets" for trout management in the face of whirling disease, the growing extent of research on management solutions bodes well for the future.

In Montana, researchers are studying trout life histories that offer hope for managers to sustain trout fisheries despite the presence of whirling disease. Studies on the Madison River reveal temporal variation in infection, with infection rates correlating with water temperatures and peak infection occurring near 14°C. Similarly, there appears to be spatial variation in infection rates along the Madison River. Montana studies continue to explore options for promoting trout life histories that place vulnerable juvenile fish in situations where infection levels are reduced, either due to the timing of emergence or the location within the river.

Much research investigates the relative susceptibility of different species. Colorado scientists presented data suggesting that Snake River cutthroat trout are more resistant to whirling disease than rainbow trout. The state is expanding its use of the Snake River cutthroat in sportfish management programs to reduce the levels of whirling disease in trout habitat. At the same time, studies from New York with parallel exposures of Finger Lake (NY) and Eagle Lake (MT) strains of rainbow trout found that the Montana strain showed significantly more deformities and higher spore concentrations at 103 days post-hatch. These results may offer an explanation for the differences in the severity of whirling disease between eastern and western states.

Other Colorado research suggests that changes in stocking practices may reduce the risks of whirling disease. It appears that stocking infected fish into standing waters increases spore concentrations in trout downstream of the standing water, and conversely, that eliminating stocking of infected fish may lead to reduced levels of infection downstream. While it may not be possible to eliminate *M. cerebralis*

[1] *Trout Unlimited, 1966 13th Street, Suite LL 60, Boulder, CO 80302, 303-440-2937, 303-440-7933 (fax)*

[2] *Whirling Disease Foundation, P.O. Box 327, Bozeman, MT 59771-0327, (406) 585-0860*

from enzootic waters, managers may be able to reduce disease risks by eliminating the stocking of infected fish.

Researchers in Oregon postulate that importation of oligochaete worms may also help spread the pathogens. Worms purchased from a pet supply company were tested and found to be releasing actinospores. While the DNA for these spores did not correspond to *M. cerebralis*, this discovery suggests that the import of live worms (commonly used for ornamental fish food) is another risk factor that should be controlled.

Another intriguing option involves habitat improvement. *T. tubifex* is considered a pollution-tolerant species and is found most commonly in degraded areas where the natural benthic community has been disrupted. Research from Wyoming's Salt River reveals that trout populations remain stable in some portions of the river but have declined in others. The affected segments correspond with areas of increased habitat degradation, lower gradient, and higher amounts of silt and organic material – conditions favorable for *T. tubifex*. Previous studies indicate that infection levels may be increased near "hot spots" for disease such as Colorado's Windy Gap Reservoir, a small, shallow, sediment-rich environment on the Colorado River. Thus, it may be possible to reduce whirling disease impacts by improving degraded riverine habitats or other hot spots.

Researchers from Montana and Washington studied different strains of *T. tubifex* to determine whether they differ in their production of the infective form of the parasite (TAMs) and if the strains could be distinguished using DNA testing techniques. Some found differences in TAM production and in reproductive success among strains from two sites in Montana and one in California, as well as DNA markers that could be used to distinguish among the strains. This variability may be help managers assess the disease risks in different locations. Some suggest using resistant *Tubifex* strains as a biological control for whirling disease.

Much work remains for developing management solutions for whirling disease, but this research offers great future promise. Symposium Chair Dr. Bill Granath struck a note that was both cautionary and congratulatory. He noted that, despite billions of dollars and over a half-century of research on the human parasite malaria, there was still no vaccine and disease prevalence was on the rise. In this context, the progress that has resulted from whirling disease research has been remarkable, especially given limited funding and the short time frame. As for malaria, a cure for whirling disease may prove elusive and require many more years of study.

Managers may take another lesson from the human experience with malaria. The greatest success in fighting malaria stemmed from efforts to control habitat for its alternate host, the mosquito. Similarly, seeking solutions to whirling disease for trout may require a look not only at the parasite, but also at its interactions with hosts and environment. Future studies will improve our understanding of how wild trout fisheries can benefit from strategies involving favorable trout life histories, fish management changes, habitat improvements to contain disease "hot spots", and perhaps even biological control of the *Tubifex* worm.

REFERENCES

These can be provided upon request. Contact the Whirling Disease Foundation at (406) 585-0860; whirling@mcn.net.

Response of a Resident Bull Trout Population to Nine Years of Brook Trout Removal, Crater Lake National Park, Oregon

M.W. Buktenica, B.D. Mahoney, S.F. Girdner, and G.L. Larson[1]

Abstract—Native bull trout (*Salvelinus confluentus*) were threatened with a high risk of extinction from hybridization and competition with introduced brook trout (*S. fontinalis*) in Sun Creek, Oregon. A bull trout restoration plan was written, peer reviewed, and implemented. The goals of the plan were to restore the remnant population of bull trout to historic numbers and distribution in Sun Creek, remove brook trout, and prevent re-invasion of non-native fish. Barriers were constructed to prevent re-invasion of non-native fish in 1992. Before stream-wide brook trout eradication was attempted, bull trout abundance was increased and refugial populations were established to reduce the risk of local extinction during the restoration project. Brook trout were eradicated using a combination of techniques including electrofishing, snorkel diving, trap nets, and the fish toxin antimycin. Bull trout have increased in abundance from approximately 200 individuals in 1992 to nearly 800 in 2000, and have increased in stream distribution from approximately 2 kilometers to 14 kilometers.

INTRODUCTION

The decline of bull trout (*Salvelinus confluentus*) throughout the Western United States and Canada is well-documented (Roberts 1987; Goetz 1989; Bond 1992; Ratliff and Howell 1992; Buchanan et. al. 1997; Fitch 1997). The US Fish and Wildlife Service listed bull trout as Threatened throughout their range in the Western United States in 1998 and 1999. There have been many probable contributing factors toward this decline including, commercial and recreational harvest (Brown 1971; Ratliff 1992; Ratliff et. al. 1996), passage barriers (Nelson 1965; Moyle 1976), non-native fish (Nelson 1965; Markle 1992; Ratliff 1992), and habitat degradation from land management activities (Light et. al. 1996).

There are eleven historic bull trout populations in the Klamath Basin (Buchanan et. al. 1997). Four are probably extinct, 6 are at a high risk of extinction, and 1 population is at a moderate risk of extinction (Buchanan et. al. 1997). One of the populations at high risk of extinction is found in Sun Creek, Crater Lake National Park. The Sun Creek watershed has been under Federal protection since 1986. Except for the Crater Lake Rim Road which crosses the top of the Sun Creek Basin and the introduction of non-native brook trout (*S. fontinalis*), this portion of the watershed remains vir tually free from human impact. Downstream of the park boundary land management practices have included timber harvest, livestock grazing, and water withdrawal for irrigation.

Based on a fish survey conducted in 1947 (Wallis 1948), bull trout are thought to be the only native fish to inhabit Crater Lake National Park. Bull trout were once distributed throughout Sun Creek starting below Sun Falls, a natural waterfall 3.4 km below the headwaters, and continuing downstream beyond the park boundary (Wallis 1948). By 1989 the species was restricted to a 1.9-km reach of the creek, and the population had declined to 100 to 300 adult fish (Figure 1; Dambacher et al. 1992). Bull trout were replaced by brook trout, which were introduced between 1926 and 1971 (Dambacher et. al. 1992), it appeared that hybridization and competition with non-native brook trout were the primary threats to the survival of the Sun Creek bull trout population.

[1]*Buktenica M.W., Aquatic Ecologist, National Park Service, Crater Lake, OR; B.D. Mahoney, Fisheries Biologist, National Park Service, Crater Lake, OR; S.F. Girdner, Aquatic Biologist, National Park Service, Crater Lake, OR, and; G.L. Larson, Aquatic Ecologist, US Geological Survey, Corvallis, OR.*

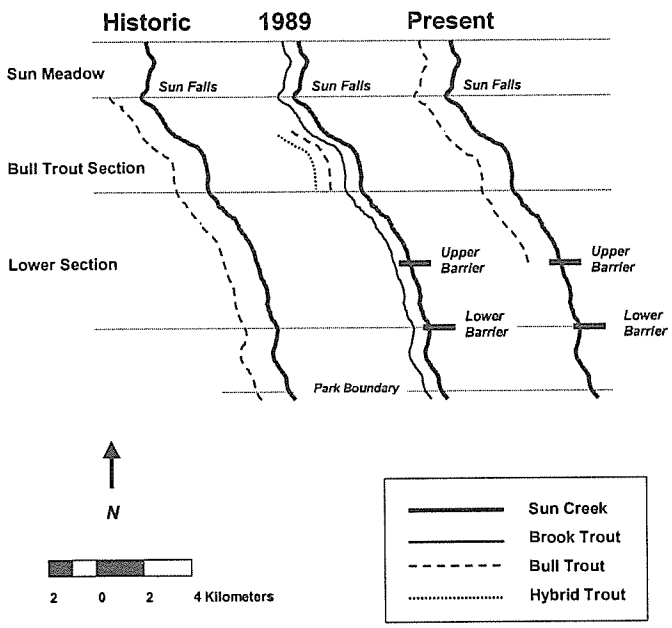


Figure 1.—Past and present fish distribution maps for the Sun Meadow, Bull Trout, and Lower Study Reaches of Sun Creek.

Based on the alarming reduction in distribution and abundance of bull trout in Sun Creek, a bull trout restoration plan was drafted in 1990. The long-term goals of the plan were to: 1) eradicate brook trout; 2) restore the remnant population of bull trout to historic numbers and distribution in Sun Creek within the park; and 3) prevent re-invasion of non-native fish. The initial focus of the project was to increase bull trout abundance and create additional refugial populations. When this goal was accomplished, stream-wide brook trout eradication would be attempted.

One of the cornerstones of our management approach was to utilize an advisory panel to review the restoration plan and make recommendations on implementation of the plan. The advisory panel met several times over the duration of the project, and membership changed as program priorities changed (Table 1). The panel members contributed expertise in the fields of restoration, conservation genetics, aquatic macroinvertebrate ecology, hydrology and fish barrier design, taxonomy, and the use of electrofishing and fish toxins for fish population restoration. The project was divided into 3 phases. Phase one included the construction of two fish immigration barriers near the park boundary (Figure 1). During this phase, brook trout were reduced in abundance throughout the creek so that bull trout would have an opportunity to increase in abundance. Phase II involved eradicating brook trout in Sun Meadow and nearby Lost Creek and introducing bull trout into these areas to reduce the risk of local extinction during the rehabilitation project. Phase III involved removing as many bull trout as was physically possible from Sun Creek and holding them in Sun Meadow, Lost Creek, a stream-side raceway, and an Oregon State fish hatchery, while brook trout were eradicated from the rest of the creek.

Table 1.—Crater Lake National Park, bull trout advisory panel.

Panel Chair:	Affiliation:
Phil Pister	Desert Fishes Council
Panel Members:	
Fred Allendorf	University of Montana
Norm Anderson	Oregon State University
Tom Felando	US Forest Service
Doug Markle	Oregon State University
Steve Moore	National Park Service
Bruce Rosenlund	US Fish and Wildlife Service

This preliminary report reviews twelve years of bull trout management in Crater Lake National Park (1989-2000), nine years of brook trout removal (1992-2000), using a variety of techniques that incorporated electrofishers, snorkel-divers, fish traps, and the fish toxin antimycin (trade name FINTROL), and the response of the resident bull trout population. The project focused on modifying and developing techniques to efficiently remove brook trout, while minimizing impact to bull trout. The project was not designed to be a systematic or statistical evaluation or comparison of methods. Methods evolved as the project progressed.

STUDY SITE

Sun Creek occupies a glacial valley that was inundated with hot ash and pumice, hundreds of feet deep, during Mount Mazama's climactic eruption roughly 7,000 years ago (Bacon 1983). The creek originates from headwater springs, several hundred meters from the rim of the Mt. Mazama Caldera at approximately 2,200-m in elevation. In the upper reaches, Sun Creek meanders through sub-alpine meadows (Sun Meadow) and forest, and varies in width from 0.1 m to 1.5 m. Stream discharge increases at the confluence of Vidae Creek, and Sun Creek cascades down a series of natural waterfalls, some of which preclude upstream fish passage. Downstream from the waterfalls, the creek is incised into deep pumice deposits and meanders across a narrow valley floor. Fourteen kilometers downstream from its headwaters where Sun Creek leaves the park (elev. 1,400-m), it is 3 m to 6 m in width and

seasonal flows vary between 20 and 63 cfs. Because of downstream water diversions for field irrigation, Sun Creek flows into Annie Creek and the Wood River, tributaries of the Upper Klamath Lake Watershed.

Old-growth mountain hemlock (*Tsuga mertensiana*) and Shasta red fir (*Abies magnifica*) communities are the dominant vegetation types in the basin and in much of the riparian zone. Canopy closure, stream elevation, and the spring-fed nature of the stream maintain low daily water temperatures in the bull trout reach during low flow periods in summer and fall. For example, in August the water temperatures typically range from 3.3 to 11.7°C, whereas outside of the park boundary the temperature typically ranges from 6.0 to 15.1°C. Conductivity typically ranges between 30 and 46 S/cm in the bull trout reach. Sun Creek is commonly covered by snow from December through May.

Sun Creek actively erodes the base of adjacent hill slopes, which stand near their angle of repose, thus supplying large amounts of pumice sediment to the stream. Sand-sized and smaller sediment are actively transported during seasonal periods of low flow. Most substrate crevices are filled with pumice fines. In stream structure is dominated by large wood, undercut banks, and pumice, with very little bedrock and boulder substrates (Dambacher et al. 1992). Outside Crater Lake National Park, Sun Creek crosses Oregon State Forestry land where lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) are harvested. The lowermost reaches of Sun Creek cross private land in the Wood River Valley and are impacted by channelization, water withdrawal, and cattle grazing.

Lost Creek is a small spring-fed system that originates at 1,900 m in elevation and flows for approximately 2.5 km before it disappears into the pumice soil. There are no tributaries. The creek meanders through sub-alpine meadow and forest where it varies in width between 0.5 m and 1.5 m. August water temperatures vary between 3.3 and 9.7 °C.

METHODS

Reach Descriptions

Sun Creek was divided into three reaches for purposes of data analysis and stream restoration treatment (Figure 1). The boundaries of the reaches were adjusted slightly from those in Dambacher et al. (1992), and Buktenica (1997), based on fish distribution, treatment strategy, and natural barriers. The stream was marked off in 50-m sections starting at the headwaters. The Sun Meadow Reach extended from the headwaters to a natural waterfall 3.4-km downstream (stream sections 1-68). The bull trout reach started at the waterfall and continued 5.1-km downstream to section 171. The lower reach extended roughly 3.1-km from the bull trout reach to the upper artificial barrier at stream section 232.

Electrofishing

Four different electrofishing units, and several levels of sampling effort were used to minimize sampling impacts on bull trout and to maximize brook trout removal between 1992 and 1994 (Buktenica 1997). Between 1995 and 2000, Smith Root Model 15-D Backpack Electrofishers were principally used. Electrofisher settings varied from 900 - 1000 V, 30 - 60 Hz, with a square-wave pulse width of 0.5 to 1 milliseconds, which produced duty cycles of 3-6%.

Diver-directed Electrofishing

Diver-directed electrofishing to remove brook trout began in 1994. A snorkel diver moved upstream counting bull trout. If a brook trout was encountered or if no bull trout were observed, a crew immediately electrofished the habitat to remove brook trout. Two diver-directed passes of the bull trout reach were completed each year.

Trap-net Electrofishing

Stream trap-nets were designed and built for fish collection in shallow water fluvial habitats. Each net consisted of two wings, a funnel, and a net bag (Figure 2). Two electrofishing units were used to herd fish into the net. During the summer of 2000, two complete surveys and one partial survey were conducted through the bull trout reach to remove fish. A survey consisted of up to five consecutive passes per 50-m section.

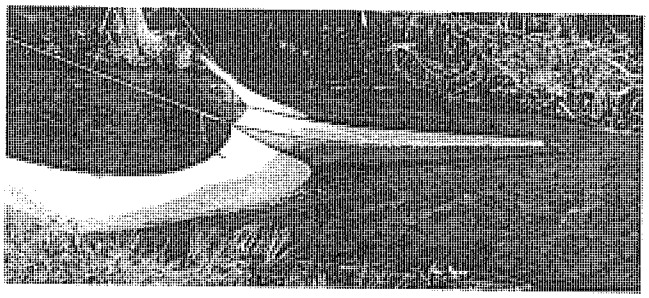


Figure 2.—Sun Creek trap-net.

Antimycin Treatment

Antimycin (trade name FINTROL) is an antibiotic that is toxic to fish and is licensed by the U.S. Environmental Protection Agency (EPA). Antimycin was neutralized with potassium permanganate directly below treatment reaches.

RESULTS

Phase I

Phase ITwo fish immigration barriers were built near the park boundary in 1992 (Buktenica 1997). Brook trout were successfully removed from Sun Meadow using electrofishing techniques from 1992 to 1997 (Figure 3). Brook trout were removed within the bull trout reach by diver-directed electrofishing. This technique was successful in reducing the number of brook trout. As a result, bull trout increased in abundance (Figure 3). Bull trout – brook trout hybrids were not removed from the creek from 1992 through 1996 because hybrids were believed to be sterile (Leary et. al. 1983). Hybrids were removed from the creek starting in 1997 after identification techniques were refined through genetic sampling. Brook trout were successfully removed downstream of the area occupied by bull trout with antimycin in 1992 (Figure 3)(Buktenica 1997). Subsequent increases in trout abundance in the Lower Reach were presumably due to the downstream movement of fish.

Population estimates were based on sampling efficiencies for antimycin, electrofishing, and snorkeling (Buktenica 1997). Based on this information the population estimates from 1995 on were based on the number of fish observed in a single snorkel pass multiplied times 3. The population estimates of fish in figure 3 underestimated actual population numbers because the number of fish removed often exceeded the estimate. Population estimates also indicated that the ratio of bull trout to brook trout, in all study reaches, increased from approximately 1:13 in 1992 to nearly 3:1 in 1999 (Figure 4).

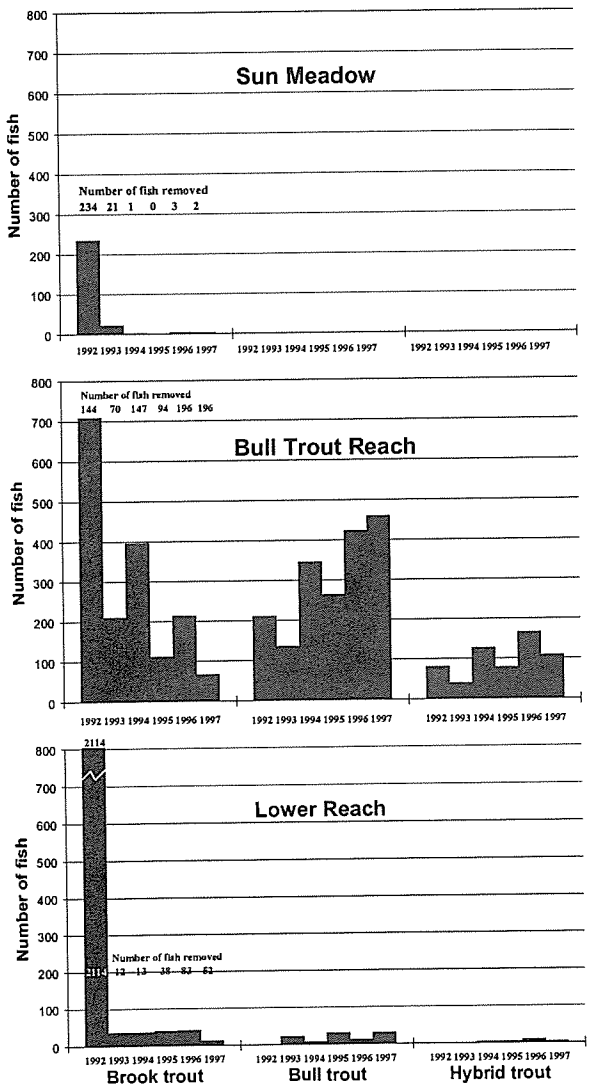


Figure 3.—Phase I, population estimates of brook trout, bull trout, and hybrid trout, and the number of brook trout removed, in the Sun Meadow, Bull Trout, and Lower Study Reaches of Sun

Phase II

Brook trout were eradicated from nearby Lost Creek with antimycin treatments in 1996 and 1997. One hundred and nineteen bull trout were introduced into Lost Creek in 1997 and 1998 to serve as a refugial population during subsequent antimycin treatments to Sun Creek.

In 1998, Sun Meadow was treated with antimycin to make certain that no brook trout remained. Although antimycin killed brook trout placed in small

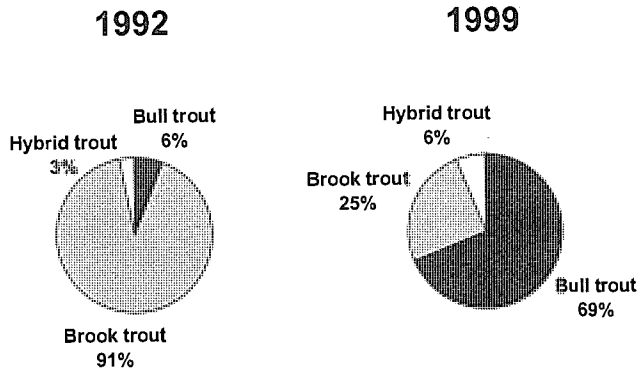


Figure 4.—Phase I, percent brook trout, bull trout, and hybrid trout in the Bull Trout Study Reach of Sun Creek.

net-pens, no brook trout were found in the creek. During this treatment, 197 bull trout were held in a stream side raceway in case the treatment impacted downstream bull trout. The antimycin was detoxified one kilometer upstream of the nearest bull trout and upstream of four waterfalls and several tributaries that doubled the in-stream flow. Brook trout held in net-pens within the bull trout reach showed no signs of stress and no mortality occurred one week after the treatment.

Bull trout were held in the stream side raceway between July 28 to September 3, 1998. The maximum length of time a bull trout was held was 37 days. No mortality occurred in the raceway. The raceway was equipped with phone alarms for high and low water level and for low flow. One week after the antimycin treatment, the bull trout were introduced into Sun Meadow.

Phase III

A stream trap-net was designed and built, and trap-net electrofishing protocols developed in 1999. Over one thousand fish were removed from Sun Creek by trap-net electrofishing in 2000 (Table 2), which included 618 bull trout. Four hundred and eighty six bull trout were held in the stream side raceway. Bull trout were held in the stream side raceway between July 6 and September 7, 2000. The maximum length of time a bull trout could have been held was 63 days. One hundred and thirty immature fish presumed to be immature bull trout were taken to the Klamath Fish Hatchery. An additional 116 immature fish not identified to species also were transported to the hatchery.

Once the bull trout were removed of Sun Creek, downstream from Sun Meadow, the creek was treated with antimycin in August 2000. Antimycin was neutralized downstream of the park boundary with potassium permanganate. Four hundred and eighty bull trout were returned to Sun Creek, below Sun Meadow, one week after the antimycin treatment.

The creek was searched repeatedly for mortalities during and after treatment, and after bull trout were returned to the stream. A total of 37 known bull trout mortalities occurred during 2000 (Table 3). Eight bull trout died that had visible spinal injuries from electrofishing, 2 during transportation, and 6 in the raceway. At least 27 bull trout died from the antimycin treatment, and at least two died after being returned to the stream, the latter were small fish that drifted downstream into a trap-net that was set above the upper barrier to monitor for out-migration and post return mortality.

Population estimates consistently underestimated the number of fish in the creek (Figure 3, Table 2). The 1999 population estimate for bull trout represented 66% percent of the bull trout known to have occurred in the stream in 2000 (Table 2), or approximately 4.6 times the number of bull trout observed by a single-pass snorkel count in 1999. The total number of bull trout known to occur in Sun Creek, below Sun Meadow (478), Sun Meadow (49), Lost Creek (119), and the Klamath Hatchery (130), excluding un-documented mortality and reproduction, and the unidentified fish in the hatchery (116), equals 776. Bull trout distribution in the park has increased from nearly 2 kilometers of Sun Creek in 1989, to approximately 14 kilometers, in Sun Creek (Figure 1) and Lost Creek, in 2000.

A long-term monitoring program will be designed. Monitoring goals will include: 1) evaluate re-colonization and dispersal of bull trout in Sun Creek, below Sun Meadow, 2) monitor for re-colonization of non-native fish, 3) evaluate the stability and sustainability of Sun Meadow and Lost Creek populations, and 4) monitor barrier integrity.

Table 2.—The number of trout removed by trap-net electrofishing and antimycin treatments in 2000, and population estimates of trout in the corresponding section of the creek in 1999.

Species	Number of Fish Electrofishing	Removed Antimycin	Total	Population Estimate
Bull Trout	618	27	645	424
Brook Trout	298	38	336	219
Hybrid Trout	94	8	102	58
Total	1010	73	1083	701

Table 3.—Bull trout mortality in Sun Creek, 2000.

Electrofishing Injury Transportation	Raceway	Antimycin	Post Return	Total
2	6	27	2	37

REFERENCES

Bacon, C.R. 1983. Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U.S.A. Journal of Volcanology and Geothermal Resources. 18:57-115.

Bond, C.E. 1992. Notes on the nomenclature and distribution of the bull trout and the effects of human activity on the species. Pages 1-4 *in* Howell, P.J. and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Brown, C.J.D. 1971. Fishes of Montana. Big Sky Books, University of Montana, Missoula.

Buchanan, D. V., M. L. Hanson and R. M. Hooton. 1997. Status of Oregon's Bull Trout. Oregon Department of Fish and Wildlife, Portland, Or.

Buktenica, M. W., 1997. Bull trout restoration and brook trout eradication at Crater Lake National Park, OR. Pages 127-135 *in* Mackay, W. C., M. K. Brewin, and M. Monita, editors Friends of the bull trout conference proceeding. Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Dambacher, J. M., M. W. Buktenica, and G. L. Larson. 1992. Distribution, abundance, and habitat utilization of bull trout and brook trout in Sun Creek, Crater Lake National Park, Oregon. Pages 30-36. *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Fitch, L.A. 1997. Bull trout in southwestern Alberta: notes on historical and current distribution. Pages 147-160 *in* Mackay, W. C., M. K. Brewin, and M. Monita, editors Friends of the bull trout conference proceeding . Bull Trout Task Force (Alberta), c/o Trout Unlimited Canada, Calgary.

Goetz, F. 1989. Biology of the bull trout *Salvelinus confluentus*, a literature review. U.S. Forest Service report, Eugene, Oregon. 53 p.

Leary, R.F., F.W. Allendorf, and K.L. Knudsen. 1983. Consistently high meristic counts in natural hybrids between brook trout and bull trout. Systematic Zoology 32:369-376.

Light, J., L. Herger, and M. Robinson. 1996. Upper Klamath Basin Bull Trout Conservation Strategy. Part 1. A conceptual Framework for Recover. Final. Klamath Basin Bull Trout Working Group.

Markle, D.F. 1992. Evidence of bull x brook trout hybrids in Oregon. Pages 58-67 *in* Howell, P.J. and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Moyle, P.B. 1976. Inland fishes of California. University of California Press, Berkeley.

Nelson, J.S. 1965. Effects of fish introductions and hydroelectric development on fishes in the Kananaskis River System, Alberta. Journal of the Fisheries Research Board of Canada 22:721-753.

Ratliff, D. E. 1992. Bull trout investigations in the Metolius River-Lake Billy Chinook system. Pages 37-44 *in* Howell, P. J. and D. V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Ratliff, D.E., and P.J. Howell. 1992. The status of bull trout populations in Oregon. Pages 10-17 *in* Howell, P.J. and D.V. Buchanan, editors. Proceedings of the Gearhart Mountain bull trout workshop. Oregon Chapter, American Fisheries Society, Corvallis, Oregon.

Ratliff, D.E. S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.K. Riehle and D.V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat, and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon, 1983-1994. Information Report, Oregon Department of Fish and Wildlife, Portland.

Roberts, W. 1987. The bull trout—endangered in Alberta. Pages 129-131 *in* G.L. Holroyd, W.B. McGillivray, P.H.R. Stepnie, D.M. Ealey, G.C. Trottier, and K.E. Eberhart, editors. Proceedings of the workshop on endangered species in the prairie provinces. Natural History Section Provincial Museum of Alberta, Edmonton, Alberta.

Wallis, O. L., 1948. Trout studies and a stream survey of Crater Lake National Park. M.S. Thesis. Oregon State University, Corvallis, Oregon.

Restoration of Two Adirondack Brook Trout Populations Lost to Acidification[1]

William H. Gordon[2]

Abstract—Acid precipitation continues to exert negative impacts on New York State's Adirondack Mountain Region. Brook trout *(Salvelinus fontinalis)*, the principal Adirondack sportfish and an important component of the region's aquatic fauna, have declined substantially. Stocking has helped maintain their distribution and the region's sport fishery, while the occurrence of naturally spawning populations has become very limited.

Two Adirondack waters, Evergreen and Hidden Lakes, were treated with agricultural lime to restore their long-standing acid-degraded ecosystems. These treatments have paved the way for the reestablishment of brook trout populations. Prior to treatment these fish-less lakes looked to be very suitable brook trout habitats, except for evidence of severe acidification, such as low pH and low acid neutralizing capacity. Post treatment water chemistry improvements have been considerable. Excellent survival of stocked brook trout has been confirmed in both lakes. A popular sportfishery has developed. Stocked brook trout populations are expected to be augmented by naturally spawned fish within the next few years. To achieve the natural spawning goal, management strategies may need to be enhanced with habitat improvement, and a combination of restrictive angling regulations and fall outlet blocking tactics to increase the number of mature adults in the populations.

Fish species distribution and abundance within New York State's Adirondack Region has been drastically altered in the past century. This has been attributed to a number of impacts related to both anthropogenic and biological causes, such as acid deposition, logging, expanding beaver populations, and the introduction and spread of non-endemic fish species (Webster 1962, Perkins 1992, Baker et al. 1990). Acid deposition, in particular, has been cited in numerous publications as a major problem (Charles 1990, Simonin 1990, Kretser et al. 1989).

Researchers have found that approximately 25% of the Adirondack's 3000+ lakes and ponds, as well as many of the region' s high elevation headwater streams, are acidified (Kretser et al. 1989, Baker et al. 1990). A recent federal General Accounting Office report, based on long term monitoring data, concluded that despite reductions in some acid deposition causing emissions, many Adirondack waters continue to be impacted by acidic inputs (Acid Rain 2000).

Negative impacts have been especially noted for the Adirondack's indigenous brook trout. Historically, populations of this popular sportfish were believed to be widespread across the region, but have been greatly reduced by the combined effects of the causes noted above (Greeley and Bishop 1931, Webster 1962, George 1980, Schofield 1976). In response, the stocking of hatchery-reared brook trout was initiated in the mid-1800s (Pfeifer 1979, Perkins 1993).

Stocking continues to be an important component of the New York State Department of Environmental Conservation's (DEC) Adirondack brook trout management strategy and has very successfully maintained their widespread distribution. The DEC annually stocks approximately 400,000 hatchery produced hybrid strain fingerling brook trout in Adirondack lakes and ponds, supporting a sport fishery valued at more than five million dollars (Connelly et al. 1996). On the negative side, stocking has substantially al-

[1] *This project made possible through a grant from Federal Aid in Sportfish Restoration, and the cooperation of the U.S. Army 10th Mountain Division, Fort Drum, New York.*

[2] *Sr. Aquatic Biologist, Division of Fish, Wildlife and Marine Resources, NYS Dept. of Environmental Conservation, Watertown, New York.*

tered wild populations of unique genetic or 'heritage' strains of brook trout in Adirondack waters by compromising their gene pools (Keller 1979, Perkins 1993). Keller (1979) suggested that as few as seven heritage strains (not influenced by stocking) are known to remain in Adirondack lakes and ponds. Several of these strains occur only in their source waters and are currently threatened with extinction. Further quantifying the extent of this decline, Kretser et al. (1989) reported that less than 4% of the lakes and ponds in the Adirondacks contain unstocked, naturally spawning brook trout. Kretser et al. (1989) also noted a strong negative correlation between acid deposition impacts (low pH) and brook trout abundance, stating that the species is noticeably absent (either as wild or stocked populations) from many acidified Adirondack waters.

An important DEC goal is to preserve wild, native New York strains of brook trout as part of the state's natural resource heritage. The main objective towards achieving this goal incorporates preserving these "heritage" strains in their source waters, while expanding their distribution by establishing new populations in other suitable waters (Keller 1979). As an additional benefit, it is intended that native strain brook trout will provide unique and improved angling opportunities. In the Adirondacks, brook trout management includes a commitment to preserve the genetic integrity of the region' s few remaining wild heritage strains of brook trout. In discussing guidelines relative to the management of wild populations Keller (1979) states that: "Heritage strains of brook trout should be planted only in waters with the best potential for natural reproduction, a reasonable guarantee of genetic isolation, an expectation of continued satisfactory water quality and conditions for good growth and survival." When applied to waters where acidification precludes the survival of brook trout, these guidelines lead to water quality as a primary issue, followed closely by spawning habitat suitability. In these cases, reversing the negative impacts of acid deposition becomes a prerequisite to successful brook trout introduction, while spawning issues will need to be resolved before wild brook trout could be naturally produced (Webster 1962, Schofield 1993, Josephson and Krueger 2000).

In the Adirondacks, whole lake limestone treatments (liming) have been shown to be very successful at restoring suitable pH levels. Post- treatment survival of brook trout in limed ponds has been well documented (Blake 1981, Gloss et al.1989, Schofield 1990, Simonin 1990). Unfortunately, few limed pond brook trout populations have been shown to maintain themselves post-treatment without continued stocking. Schofield et al. (1986) detected natural reproduction in only one of ten limed lakes he studied, while Gloss et al. (1989) reported minimal natural reproduction in Woods Lake following an intensive combination of whole lake and watershed liming. In addition, naturally produced brook trout have been documented in only 4 of 40 lakes included in the current DEC liming program, with only one of these four (Horn Lake) containing a fully naturally sustained wild population.

Schofield (1993) reviewed the relationship between habitat characteristics and brook trout reproductive status, in an attempt to understand why acidic and limed Adirondack waters fail to produce wild brook trout. He concluded that "Adirondack lakes receiving significant groundwater contributions to nearshore zones have the greatest potential for supporting self -sustaining brook trout populations". Indications of groundwater influence, such as high levels of silica (SiO_2), small watershed area, whether a water is a drainage lake (vs. seepage), and high lake flushing rate (number of lake volume changes per year), were found to be positively correlated with successful brook trout spawning. Low pH was negatively correlated with natural reproduction. Schofield (1990) reported that Adirondack lakes with summer surface silica greater than or equal to 2.5 mg/L have a 50% or greater probability of natural brook trout reproduction and would therefore be good candidates if management objectives include wild trout production (eg. heritage strain brook trout guidelines - Keller 1979). Likely, these would be drainage lakes with high flush rates and relatively large watersheds.

Limed Adirondack ponds, although physically and chemically suitable for brook trout survival, typically contain limited groundwater sources needed for successful spawning. This relates to DEC policy which mandates that limed ponds have low flush rates (less than 2 per year) to maximize treatment longevity (Simonin 1990). As a result, lakes and ponds in the Adirondack liming program generally are characterized as either seepage or headwater drainage lakes, with small or non-existent inlet tributary streams, relatively small watershed areas, low silica (less than 2.5 mg/L) and resulting low probability for brook trout spawning.

Despite these limitations, a few acidified and "fishless" Adirondack wilderness area lakes have been limed and targeted for "wild" heritage strain

brook trout population restoration. Management goals for these waters are two-fold:

- Restore lost populations of brook trout.
- Provide unique and high quality sport fishing

It was anticipated that these lakes would eventually produce some wild trout, since the probability of natural spawning is enhanced by the use of a wild strain and the absence of other competitive or predatory fish species (Frazer 1989). However, the degree of trout production in most cases was expected to be minimal without enhancing spawning potential. Pending results for individual waters, the need for supplemental stocking to maintain these new wild strain populations has been recognized both in the short term, and possibly as a long-term management strategy.

This report describes the lime treatments, post-liming water chemistry changes, and preliminary post-treatment brook trout population responses of two chronically acidified Adirondack lakes.

STUDY WATERS

Evergreen and Hidden Lakes, are located in remote areas of New York State's western Adirondack Mountains (Figure 1). Part of the John Brown Tract and the larger Five Ponds Wilderness Area, these lakes were in private ownership until 1982. Historical records specifically describing the lakes or their fauna prior to a 1985 survey which found them severely acidified and fishless, are lacking (ALSC 1986). The New York State Biological Survey (Greeley and Bishop 1931), while not specifically mentioning Evergreen or Hidden Lake, noted that brook trout were present in Evergreen Lake's outlet stream and other nearby lakes and streams of the Five Ponds Wilderness. Since brook trout were historically widespread in the area (George 1980), and the habitat of both Evergreen and Hidden Lakes is suitable for brook trout survival (except for acidification impacts), the species is believed to be native to these waters.

The study waters are headwater drainage lakes, surrounded by mixed hardwood-coniferous forest with thin-till, low fertility soils. Their physical features, such as size and depth, are typical of Adirondack coldwater lakes and ponds (Table 1). Mid-summer dissolved oxygen/temperature profiles, indicate the lakes stratify, providing coldwater refuge for trout in their thermoclines (Tables 2 & 3). High elevation,

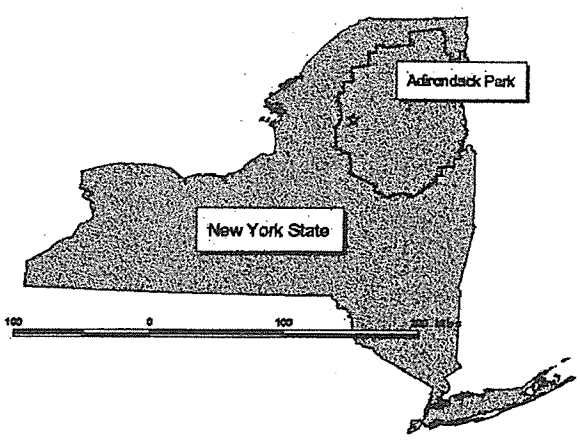


Figure 1.- New York State, Adirondack Park Region and location of study lakes (star).

Table 1.-Physical characteristics of study lakes. [1]

	Evergreen Lake	Hidden Lake
Surface Area - ac (ha)	45 (18.2)	19 (7.5)
Watershed Area - ac (ha)	173 (70.2)	96 (38.7)
Elevation - ft (m)	2011 (613)	1804 (550)
Coordinates	43° 55' N 75° 01' W	43° 55' N 74° 59' W
Flushing Rate - # / year	0.5	0.7
Mean Depth - ft (m)	21 (6.4)	18 (5.6)
Maximum Depth - ft (m)	59 (18.0)	55 (16.8)
Beaver Dam on Outlet	Yes	Yes

[1] Adirondack Lake Survey Corporation (1986)

Table 2. – Evergreen Lake summer chemistry, 1985-2000. Lake limed February, 1997. Sample location given as mid-lake depth or spring-seep (at confluence with lake).

	Depth or Location ft (m) or Seep	Pre Liming 1985 [1]	Pre Liming 1995	Post-Liming 1997	Post-Liming 2000
pH	1.6 (0.5)		4.9	6.4	6.4
	4.9 (1.5)	4.7			
ANC (μeq/L)	1.6 (0.5)		-3.6	37.3	31.1
	4.9 (1.5)	-19.5			
Silica (SiO_2) (mg/L)	1.6 (0.5)				0.9
	4.9 (1.5)	0.3			
	18.0 (5.5)	2.0			
	Seep #1				5.5
	Seep #2				6.2
	Seep #3				6.2
Dissolved Oxygen (ppm)	5 (1.5)	7.9			8.0
	20 (6.1)				8.5
	24 (7.3)				6.0
	37 (12.0)	6.1			
Temp. °F (°C)	5 (1.5)	70 (21)			68 (20)
	20 (6.1)	63 (17)			46 (8)
	24 (7.3)				44 (7)
	37 (11.3)	40 (4)			

[1] Adirondack Lake Survey Corporation (1986).

Table 3. – Hidden Lake summer water chemistry, 1985 - 2000. Lake limed February, 1999. Sample location given as mid-lake depth or spring-seep (at confluence with lake).

	Depth or Location ft (m) or Seep	Pre Liming 1985[1]	Pre Liming 1997	Post-Liming 1999	Post-Liming 2000
pH	1.6 (0.5)		5.3	6.6	6.5
	4.9 (1.5)	4.9			
ANC	1.6 (0.5)		3.2	50.4	30.6
(μeq/L)	4.9 (1.5)	-12.4			
Silica	1.6 (0.5)				2.5
(SiO_2)	4.9 (1.5)	0.3			
(mg/L)	18.0 (5.5)	2.0			
	Seep #1				6.3
	Seep #2				5.1
Dissolved	5 (1.5)	7.8			8.5
Oxygen	20 (6.1)	10.4			8.0
(ppm)	22 (6.7)				5.0
	30 (9.1)				2.2
Temp.	5.(1.5)	72 (22)			66 (19)
°F (°C)	20 (6.1)	50 (10)			46 (8)
	22 (6.7)				46 (7)
	30 (9.1)				41 (5)

[1] Adirondack Lake Survey Corporation (1986).

small watershed area, low summer silica and low flush rates all suggest groundwater sources are limited.

METHODS

Physical and chemical characteristics of the lakes were first evaluated in 1985 and reported by the Adirondack Lakes Survey Corporation (ALSC 1986). Since the late 1990's just prior to liming), summer water chemistry has been monitored annually. Laboratory analysis of water samples for pH, ANC (acid neutralizing capacity) and silica (SiO_2), was provided by the Adirondack Lakes Survey Unit (Ray Brook, NY) after the protocol outlined by the ALSC (1985). Dissolved oxygen and temperature profiles were measured in the field using a YSI Model 57 DO/ Temperature Meter.

Post-liming, brook trout fingerlings have been stocked annually in both lakes (Table 4). Only brook trout originating from Little Tupper Lake stocks, a recognized Adirondack heritage strain, have been stocked in these lakes. To maintain the "wild strain" nature of these hatchery fish, natural brood stock sources were used in their propagation. All stocked trout were fin-clipped to aid in age and hatchery origin identification.

Table 4. – Little Tupper strain brook trout stocking summary for study lakes. All trout stocked as Age 0 fingerlings and fin-clipped for hatchery produced and age identification.

	Brook Trout Stocked	
Water	Year	Number
Evergreen Lake	1997	9075
	1998	6615
	1999	1500
	2000	1800[1]
Hidden Lake	1999	1100
	2000	750[1]

[1] Planned October, 2000 stocking targets

Brook trout populations were sampled during July 1999 and 2000, using experimental mesh gillnets based on protocol established for Adirondack lakes (ALSC 1985). The nets were multifilament green nylon, 150 ft long and 5 ft deep. They were composed of six panels of webbing, 25 ft long each, of stretch mesh and twin sizes, respectively, as follows: 1.5 in, 2 in, 2.5 in, 3 in and 3.5 in, and 110/2, 110/3, 110/3, 210/2 and 210/2. All captured fish were examined for length, weight and fin-clip. A fin-clip would denote a stocked fish, while unmarked fish were assumed to be wild.

LIME TREATMENT

Evergreen and Hidden Lakes were treated with agricultural lime during February of 1997 and 1999, respectively. The lakes were selected, lime dosages calculated and treatments carried out based on protocol outlined in detail by Simonin (1990). Due to their remote locations, aerial application using helicopters was required. The U.S. Army, 10th Mountain Division, out of Fort Drum, New York, assisted with both of these projects. The Army provided two Blackhawk helicopters, cargo nets and a ground crew (Figure 2). The lime dose rate for these treatments was approximately one ton per lake surface acre, for total lime dosages of 50 and 30 tons for Evergreen and Hidden Lakes, respectively. For each of these projects, lime was moved from the staging area, 2-3 miles to the target lakes in less than two hours. On the lakes the cargo nets were unloaded and the lime spread on the ice by DEC personnel.

POST-LIMING WATER CHEMISTRY

Post-liming, both Evergreen and Hidden Lakes are physically and chemically suitable for brook trout survival (Tables 1,2 & 3). For brook trout manage-

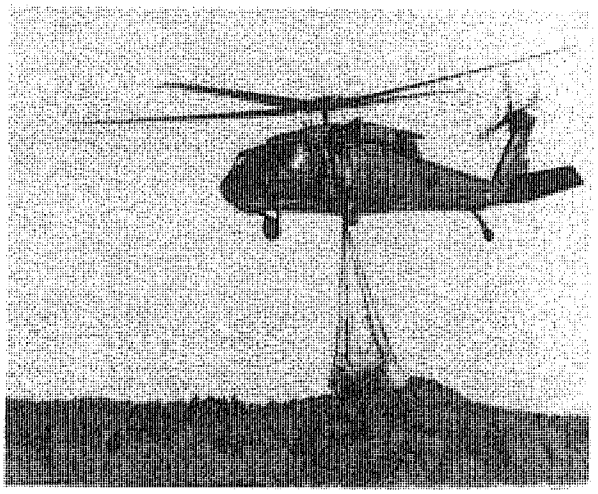


Figure 2.--Blackhawk helicopter moving a load of lime to Hidden Lake

ment, the DEC liming policy calls for a post- treatment target pH of 6.5 or greater (Simonin 1990). In addition, DEC policy calls for post-treatment dissolved oxygen and temperature levels to be greater than 5 ppm (year round), and less then 70°F (21.1°C) (during summer on the bottom). Evergreen Lake's summer surface pH increased substantially from 4.9 to 6.4, missing the target level by only 0.1 unit, while ANC increased from -3.6 to 37.3 µeq/L. Hidden Lake's pH increased from 5.3 to 6.6, exceeding the target level by 0.1 unit. Hidden Lake's ANC also increased substantially, from 3.2 to 50.4 µeq/L. Summer, 2000 water chemistry results indicate both pH and ANC levels are holding for both study lakes. It is anticipated that their pH levels will drop below 6.0 in 2002 or 03. At that point they will need to be re-limed.

Post treatment, both study lakes continue to demonstrate very satisfactory oxygen and temperature levels. Profile data suggests that both lakes stratify producing excellent summer brook trout habitat. Oxygen and temperature levels in the preferred range for brook trout exists between the depths of 10 and 25 ft (3 & 8 m), and 15 and 22 ft (3 & 7 m) for Evergreen and Hidden Lakes, respectively (Tables 2 & 3).

BROOK TROUT POPULATIONS

Little Tupper strain brook trout stocked into Evergreen and Hidden Lakes have survived very well, confirming that acidic conditions were the only hindrance to successful brook trout reintroduction. Summer gillnet catch rates, which averaged 24 trout per net night, indicate brook trout abundance in the study waters is very high (Table 5). Three-year classes

Table 5.- Brook trout catch data for study lakes broken down by age.

Year	Age 1 (n)	Age 2 (n)	Age 3 (n)	Wild (n)	Total (N)	Effort (net-night)
			Summer Gillnet Catch			
			Evergreen Lake			
1985 [1]	0	0	0	0	0	3
1999	9	40	0	0	49	2
2000	14	23	11	0	48	2
			Hidden Lake			
1985 [1]	0	0	0	0	0	2
2000	40	0	0	0	0	2

[1] Adirondack Lake Survey Corporation (1986)

of stocked brook trout were present in the Evergreen Lake sample, while Hidden Lake's one stocked year class was well represented. In contrast, gillnet catch rates for 1123 lakes surveyed by the ALSU between 1984 and 1987 averaged less than 7 brook trout per net night (Kretzer et al. 1989).

Growth appears to be satisfactory as well (Tables 6 & 7). Yearlings, stocked 9 months earlier as 2.5 to 3.5 inch fingerlings, averaged 7.9 in (190 mm) and 9.1 in (232 mm), in Evergreen and Hidden Lakes, respectively. This is very similar to 8.5 in (217 mm), the mean size of yearling brook trout reported by Schofield (1990) for Adirondack ponds in general. In Evergreen Lake, two-year olds averaged 11.7 in (296 mm), while 3-year olds averaged 12.4 in (315 mm), also comparable to other Adirondack waters which averaged 10.8 in (276 mm) and 13.3 in (337 mm) for 2 and 3 year olds respectively (Schofield 1990).

Table 6. – Length distribution, and maximum and mean lengths by age for brook trout captured by gillnet in Evergreen Lake during July, 2000.

Total Length - in (mm)	Age 1 (n)	Age 2 (n)	Age 3 (n)	Total (n)
		Summer Gillnet Catch		
6.0 - 6.9 (152-177)	3			3
7.0 - 7.9 (178-201)	7			7
8.0 - 8.9 (202-226)	4			4
9.0 - 9.9 (227-251)		1		1
10.0 - 10.9 (252-277)		2	1	3
11.0 - 11.9 (278-302)		10	2	12
12.0 - 12.9 (303-327)		10	2	12
13.0 - 13.9 (328 -351)			6	6
Total	14	23	11	48
Max. Length - in (mm)	8.1 (206)	12.8 (325)	13.4 (341)	13.4 (341)
Mean Length - in (mm)	7.5 (190)	11.7 (296)	12.4 (315)	10.6 (96)

Table 7. – Length distribution, and maximum and mean lengths for Age 1 brook trout captured by gillnet in Hidden Lake during July, 2000.

Summer Gillnet Catch	
Total Length - in (mm)	Number
7.0 - 7.9 (178-201)	8
8.0 - 8.9 (202-226)	9
9.0 - 9.9 (227-251)	16
10.0 - 10.9 (252-277)	5
11.0 - 11.9 (278-302)	2
Total	40
Max Length - in (mm)	11.9 (291)
Mean Length - in (mm)	9.1 (223)

SPORT FISHERY

As with other waters in the Five Ponds Wilderness Area, the brook trout sport fishery in the Evergreen and Hidden Lakes are governed by the following general regulations:

- Season: April1 through October 15 .
- Daily creel limit: 5 brook trout .
- Size restrictions: None
- Bait: Minnows (dead or alive) prohibited

Since one of the major objectives of reestablishing brook trout populations in the study waters was to provide unique and high quality public sport fishing opportunities where none existed, angling is permitted and encouraged. Achieving "unique" was a given, as it relates to the intrinsic values associated with angling in the remote, pristine environment of the Five Ponds Wilderness. Quality in a sport fishery can be defined by the origin of the fish (stocked versus wild), size ranges available, and/or the potential catch-rate. Based on Pfeiffer (1979), catching one or more half pound or larger Adirondack pond brook trout is a high quality angling experience.

Evergreen Lake, limed and first stocked during 1997, now supports a popular, sport fishery. Reports of up to six boats on the lake on a busy day suggest the lake receives relatively high angling pressure, at least on weekends during the spring (April-May-June). After two seasons, the 1.5 mile (2.4 km) unimproved up-hill trail from Evergreen Landing on Stillwater Reservoir to the lake is clearly defined. Despite this growing level of effort, which could detract from the uniqueness of a "wilderness" experience, unsolicited angler reports of high catch- rates of brook trout in good physical condition, indicate angler satisfaction and the "quality" of their experiences remain high. As evidence, one angler report states: "...on May 7 we easily limited out (4 *persons*, 5 *trout each*)...*they* ranged in size from 9.5 to 14 inches, averaging 11.5 inches" (T. Barnell, Personal Communication, 5/14/2000). Another report from a group of six anglers simply stated that "fishing *on Evergreen Lake* was very good" (S. Gray, Personal Communication, 8/23/00). A one-day's catch noted in the later report included 16 brook trout, ranging from 10 to 12 in (254 to 305mm) in length (Figure 3). With only one-year-old brook trout present, Hidden Lake's sport fishery has yet to develop. Anglers are expected to start using Hidden Lake in 2001, as more and larger brook trout become available. Hopefully this will attract some of Evergreen Lake's growing angler effort, helping to protect its developing population from over -exploitation. If not, maintenance of high quality fishing may require more stringent angler catch restrictions, such as a reduced creel limit, large minimum size limit, or catch-and- release only (Webster 1972, Keller and Plosila 1981, Josephson et al. 2000).

NATURAL SPAWNING

True restoration of these brook trout populations will include successful natural spawning. Based on observations, suitable brook trout spawning sites, the most important prerequisite to successful spawning (Webster 1962), appears to be limited in both Evergreen and Hidden Lakes. Inlet streams are absent and sources of upwelling groundwater associ-

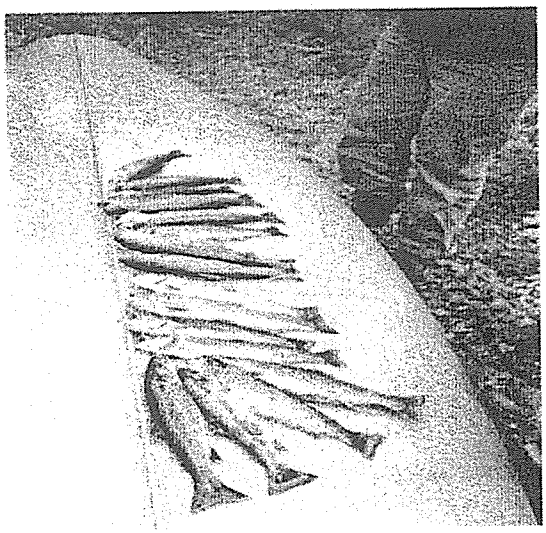


Figure 3 – Brook trout catch from Evergreen Lake (May, 2000). (S.Gray – Personal Communication).

ated with preferred gravel-sand bottom types within the lake basins are difficult to find and beaver impacted. This limitation is confirmed by the lakes' moderately low summer silica (0.90 to 2.5 mg/L) and flushing rates (less than 1.0/ year), which indicate groundwater influence is lacking (Tables 1, 2 & 3) (Schofield 1993). Potential spawning sites which were identified are small shoreline spring seepage areas, characterized by low discharge and silted-over sand-gravel substrate. Despite this size limitation, silica levels taken at the confluence of several of these seeps ranged from 5.6 to 6.3 mg/L, indicate they are strong groundwater sources, suitable for brook trout natural reproduction. According to Webster (1962), limited area of spawning sites does not represent a problem as "...a relatively small amount of good spawning area suffices to maintain adequate populations for fishing." Some improvement of the sites, in the form of cleaning silted-over substrate, may be needed however, before they can be used by brook trout successfully.

To date, naturally produced brook trout have not been documented in either of the study lakes. For Hidden Lake this was expected, as mature trout will not be present in the lake until fall, 2001. In Evergreen Lake, 2-year olds had their first opportunity to spawn during the fall of 1999. They were apparently unsuccessful as wild fish (non fin-clipped) were not detected during the July, 2000 netting assessment (Table 5). This does not signal failure, however, as the number of spawners present in Evergreen is still small. Frazer (1989) suggested four to five years, or more, could be needed before an introduced population begins to spawn successfully. Relative to spawning habitat improvement, a planned effort to lower lake water levels by beaver dam manipulation, is expected to increase discharge-head at the seep areas, and result in some cleaning of the silted-over substrate. In addition to the time and habitat improvement considerations, management actions aimed at increasing the abundance of older fish in the lakes, such as the reduction of both angling mortality and the emigration of mature brook trout from the lake during spawning season, if applied, may enhance the probability of natural spawning. Josephson et al. (2000) reported that preventing emigration can increase the number of older, larger brook trout in Adirondack lakes. One lake in his study, Rock Lake (43° 57′ N, 74° 52″ W), is very similar to both Evergreen and Hidden Lakes. Rock Lake has been limed (1978) and has moderately low lake basin summer silica levels (2.3 mg/L). Similarly, groundwater influence in Rock Lake, and resulting brook trout spawning habitat, comes from a set of spring seepage inlets scattered along its shoreline. After seven years of outlet blocking to prevent fall emigration of mature brook trout, Rock Lake's stocked brook trout population, forced to locate available groundwater within the lake, began to spawn successfully (Josephson and Kreuger, 2000).

CONCLUSION

Wilderness brook trout fisheries are valued highly by anglers who desire to encounter brook trout in a pristine environment (Pfeiffer 1979). Similarly, heritage strain brook trout are also viewed as important, and of high quality due to their wild characteristics and intrinsic values (Webster 1972, Keller 1979).

Preliminary results from efforts to restore brook trout populations in Evergreen and Hidden Lakes have been favorable. Acidification impacts have been reversed in both lakes, and wild strain brook trout have been reintroduced successfully. Survival of stocked trout has been aided by the total absence of competition and the use of a wild strain. Evergreen Lake, fishless and totally ignored by anglers four years ago, now supports an important new sport fishery, while Hidden Lake is expected to be discovered by anglers within the next year.

For true restoration of these brook trout populations, natural spawning must be achieved. Developing adequate populations of mature, spawning age trout is the initial objective in achieving the natural spawning goal. In the short term this will be aided by annual stocking, coupled with spawning habitat improvement efforts. In the longer term, restrictive angling regulations may be needed if angler exploitation is found to be limiting the survival of older trout, while outlet blocking may be needed to keep mature fish from out-migrating during the fall.

REFERENCES

Acid Rain, 2000. Emissions trends and effects in the Eastern United States. U. S. General Accounting Office, Rept. to Congressional Requesters, Washington, DC.

Adirondack Lakes Survey Corporation, 1985. Standard Operating Procedures -Field Operations (2nd Edition). Ray Brook, NY.

Adirondack Lakes Survey Corporation, 1986. ALSC Report for 1985, Vol 8. Ray Brook, NY.

Baker, J., S. A. Gherini, and R. Munson. 1990. Introduction and background. In: Adirondack Lakes Study: An In-

terpretive Analysis of Fish Communities and Water Chemistry, 1984-87. Adirondack Lakes Survey Corporation, Ray Brook, NY.

Blake, L. 1981. Liming acid ponds in New York. NY Fish and Game J. 28:208-214.

Charles,D.F. Editor. 1990. Acidic Deposition and Aquatic Ecosystems, Regional Case Studies. Springer-Verlag, New York, NY.

Cone, R. S. and C. C. Krueger, 1988. Comparison of survival, emigration, habitat use, marking mortality, and growth between two strains of brook trout in Adirondack ponds. N. American J of Fish Management 8:497-504.

Connelly, N. A. , T. L. Brown, and B. A. Knuth. 1996. New York statewide angler survey, 1996. Report I: Angler effort and expenditures. NYS DEC, Adm. Rept.

Fraser. J. M. 1989. Establishment of reproducing populations of brook trout after stocking interstrain hybrids in precambrian shield lakes. N. Amer. J of Fisheries Mgt. 9:352-363.

Gloss S. P., C. L. Schofield, R. L. Spateholts and B. A. Plonski. 1989. Survival, growth, reproduction and diet of brook trout stocked into lakes after liming to mitigate acidity. Can. J. of Fisheries and Aquatic Sciences 46:277-286.

George, C. L. 1980. The fishes of the Adirondack Park. NYS DEC, Technical Report, Albany, NY.

Greeley, J. A. and S. C. Bishop. 1931. Fishes of the area. In: A biological survey of the Oswegatchie and Black River systems. NYS Conservation Dept.

Josephson, D. C. and C. C. Krueger, 2000. Natural spawning by brook trout populations within Adirondack lakes with outlet barriers. Proceedings: Third East Coast Trout Management and Culture Workshop. Frostburg, MD, June,2000.

Josephson, D. C., C. C. Krueger, and P. S. Sullivan. 2000. Changes in catch and age of brook trout in stocked Adirondack lakes: Use of outlet barriers to prevent fall emigration. N. Amer. J. of fish Mgt. (manuscript in review).

Keller, W. T. 1979. Management of wild and hybrid strain brook trout in New York lakes, ponds and coastal streams NYSDEC Adm. Rept, 50 pp.

Keller, W. T. and D. S. Plosila, 1981. Comparison of domestic, hybrid and wild strains of brook trout in a pond fishery. NY Fish and Game J., Vo128, 2:123-137.

Kretser, W. J., J. Gallagher, and J. Nicolette. 1989. Adirondack Lakes Survey, 1984-87. An evaluation of fish communities and water chemistry. Adirondack Lakes Survey Corporation, Ray Brook, NY.

Perkins, D. L. and C. C. Krueger, 1993. Heritage brook trout in Northeastern USA: genetic variability within and among Populations. Trans. Amer. Fish Soc. 122:515-532.

Pfeiffer, M. H. 1979. A comprehensive plan for fish resource management within the Adirondack zone. NYS DEC Adm. Rept.

Schofield, C. L. 1976. Dynamics and management of Adirondack fish populations. Project Report, 1975-1976. NYS DEC Adm. Rept

Schofield, C. L. 1990. Habitat suitability for brook trout natural reproduction in Adirondack lakes. In: Adirondack Lakes Study: An Interpretive Analysis of Fish Communities and Water Chemistry, 1984-87. Adirondack Lakes Survey Corporation, Ray Brook, NY.

Schofield, C. L. 1993. Habitat suitability for brook trout reproduction in Adirondack lakes. Water Resources Research, vol. 294: 875-879.

Schofield, C. L., S. P. Gloss, and D. Josephson. 1986. Extensive evaluation of lake liming, restocking strategies, and fish population response in acidic lakes following neutralization by liming. NEC-86-18, Interim Progress Rept to the US F&W Service, Washington, DC.

Simonin, H. 1990. Final generic environmental impact statement on the NYS Department of Environmental Conservation program of liming selected acidified waters. NYS DEC, Albany, NY.

Webster, D. A. 1962. Artificial spawning facilities for brook trout, *Salvelinus jontinalis.* Trans. of Amer. Fisheries Society 91 :168-174.

Webster, D. A. 1972. Dynamics and management of Adirondack brook trout populations. Dept of Natural Resources, Cornell Univ., Ithaca, NY, Adm. Rept, 29pp.

Personal Communications

Barnell, T. M., May 14, 2000. F AX Transmittal regarding Evergreen Lake angling.

Gray, S. K. III, August 23,2000. Letter and picture regarding Evergreen Lake angling.

Application of a Model to Predict Success of Cutthroat Trout Translocations in Central and Southern Rocky Mountain Streams

Amy L. Harig[1], Kurt D. Fausch[2], and Paula M. Guenther-Gloss[3]

Abstract—Establishing new populations through translocation of genetically pure individuals is a prevalent management strategy in the conservation of native fishes, including cutthroat trout (*Oncorhynchus clarki*) in the western United States. Unfortunately, past success rates for founding self-sustaining populations generally have been <50%, and habitat quality or quantity are frequently cited as the cause of failure. A recent stream-scale habitat model developed by Harig (2000; Harig and Fausch in review) identifies specific habitat attributes correlated with the success of cutthroat trout translocations that can be used to predict success of potential translocation sites or evaluate the risk of extirpation for former translocations. We demonstrate application of the model using data from four streams where cutthroat trout were translocated in northern Colorado. The habitat model predicts that three of these streams are likely to support only low numbers of cutthroat trout due to cold summer water temperatures, lack of deep pools, or narrow stream width. Only one stream is likely to support high numbers of cutthroat trout if nonnative salmonids that invaded the system can be removed.

INTRODUCTION

Native subspecies of cutthroat trout (*Oncorhynchus clarki*) in the western United States have undergone drastic declines in their distributions, nearly all to <5% of their native range, due to habitat degradation, the introduction of nonnative salmonids, and overharvest (Gresswell 1988; Behnke 1992; Young 1995). Of the 14 subspecies recognized (Behnke 1992; three are undescribed), one is extinct, four are listed as threatened or endangered under the Endangered Species Act, and conservation plans have been developed for most others. Establishing new cutthroat trout populations through translocation of genetically pure fish into fishless waters or those treated with toxicants to remove nonnative salmonids is one of the few management strategies available for increasing their range. Unfortunately, success rates for establishing self-sustaining fish populations through translocation generally have averaged <50% (Williams et al. 1988; Hendrickson and Brooks 1991; Harig et al. in press), and habitat quality or quantity are frequently cited as the cause of failure. Isolating barriers, while protecting some cutthroat trout populations from upstream migration of nonnative salmonids, restrict them to headwater areas that may be too small or have insufficient habitat to support a viable population (Moyle and Sato 1991). Until larger watersheds are restored as cutthroat trout habitat, conservation of these subspecies relies largely on the suitability of small fragments. Therefore, managers need tools to help predict the success of translocations in isolated headwater streams. Harig (2000; Harig and Fausch in review) recently developed a stream-scale habitat model for this purpose by comparing attributes of streams where translocations occurred. Here we describe the model and show how mangers can use it to predict chances of success for cutthroat trout translocations, using data from four additional test streams in northern Colorado where translocations were made.

[1] *Bring Back the Natives Program Coordinator, Trout Unlimited, 1966 13th Street, Suite LL60, Boulder, CO 80302*

[2] *Professor, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523*

[3] *Fisheries Biologist, U.S. Forest Service, Arapaho & Roosevelt National Forests, 240 West Prospect, Fort Collins, CO 80526*

MODEL OF TRANSLOCATION SUCCESS

Harig (2000; Harig and Fausch in review) developed a model of translocation success based on four years of extensive field surveys of stream-scale habitat for 27 greenback (*O. c. stomias*) and Rio Grande (*O. c. virginalis*) cutthroat trout translocations in Colorado and New Mexico. Conservation of greenback cutthroat trout, a federally threatened subspecies, and Rio Grande cutthroat trout, a subspecies that has been petitioned for federal listing, has been ongoing for more than 25 years and represent two of the few cases where recovery efforts for any fish are sufficient to evaluate factors influencing success. The model predicts the probability of establishing a population with relatively *high* numbers of cutthroat trout, *low* numbers, or few or no cutthroat trout (*absent* status) determined from basin wide visual estimates of cutthroat trout minimum abundance (Table 1; Harig 2000). These visual fish counts were not intended as population estimates, but as measures of minimum abundance for classifying relative translocation success and developing models. Cutthroat trout generally hold positions in the open water near the surface (Griffith 1972), and most streams were small and clear, so cutthroat trout were easily observed. Moreover, visual fish counts were positively correlated with agency standing stock estimates made by two-pass removal electrofishing for 22 streams for which data were available from natural resource management agencies (r=0.70; P=0.003; from Harig 2000), and in 21 of 22 cases yielded similar status ratings to those designated by fisheries managers (i.e., unstable, potentially stable, stable; Alves 1998; USFWS 1998). Streams supporting relatively *high* numbers of cutthroat trout were assumed to have minimally sufficient habitat (i.e., the translocation is considered a success), streams supporting relatively *low* numbers have marginal habitat, and streams *absent* of cutthroat trout have insufficient habitat (i.e., the translocation is considered a failure).

Polytomous logistic regression analyses of stream-scale habitat from the 27 sites, each ranked as one of the three categories of translocation success, indicated that cold summer water temperature, narrow stream width, and lack of deep pools limited populations of cutthroat trout. The resulting model was:

$$P(absent) = \frac{\exp(11.454 - 0.891t - 1.451w - 0.017d)}{1 + \exp(11.454 - 0.891t - 1.451w - 0.017d)}$$

$$P(low) = \frac{\exp(14.077 - 0.891t - 1.451w - 0.017d)}{1 + \exp(14.077 - 0.891t - 1.451w - 0.017d)} - P(absent)$$

$$P(high) = 1 - \left[\frac{\exp(14.077 - 0.891t - 1.451w - 0.017d)}{1 + \exp(14.077 - 0.891t - 1.451w - 0.017d)}\right]$$

where P=probability that a stream will support no cutthroat trout (*absent*), or a *low* or *high* abundance of cutthroat trout, t = mean daily water temperature for July (°C), w = mean bankfull width of pools (m), and d = total number of deep pools (residual depths [RD] ≥ 30 cm; Tables 1 and 2; Figure 1; Harig 2000). This model is corroborated by other research on similar salmonids that have shown cold summer temperatures can delay spawning and prolong egg incubation, which reduces the growth of fry and likely limits their overwinter survival (Cunjak and Power 1987; Shuter and Post 1990; Hubert et al. 1994; Hubert and Gern 1995). Furthermore, narrow streams with few deep pools may lack the space necessary to promote overwinter survival of a sufficient number of individuals to sustain a viable population (Bustard and Narver 1975; Moyle and Sato 1991; Rieman and

Table 1.—Mean, standard error (in parentheses), and range of the habitat variables used to develop a model that predicts probability of cutthroat trout translocation success (absent, low, or high based on the number of trout visually observed in basin wide surveys) from 27 streams surveyed in 1996-1999 (data from Harig 2000; Harig and Fausch in review).

Category of translocation success	Number of streams	Number of age-1 and older trout basin wide	Mean July daily temperature (°C)	Mean bankfull pool width (m)	Mean number of deep pools (RD ≥ 30 cm)
Absent	6	<4	7.1 (1.0)	2.5 (0.4)	30 (14)
Low Population	8	5-100	7.8 (0.4)	3.4 (0.3)	69 (19)
High Population	13	>100	10.0 (0.6)	3.8 (0.2)	125 (30)
Range of Data for Variables in Model	-	0 – 1278	4.2 – 14.6	1.0 – 5.4	2 – 361

Table 2.—Methods for collecting stream-scale habitat data for predicting cutthroat trout translocation success using the model developed by Harig (2000; Harig and Fausch in review).

Model Variable	Measurement Technique	Data Analysis
Mean July daily water temperature	Place a thermograph (±0.2°C) recording water temperatures at least every 96 minutes in the deepest point of the deepest pool for all of July.	Grand mean of the mean daily water temperature (°C) for all days in July
Mean bankfull pool width	Measure width at the downstream, center, and upstream ends of each pool, at a height where the water surface is level with the floodplain (Dunne and Leopold 1978).	Grand mean bankfull width (m) of all pools
Number of deep pools	Calculate as the maximum depth minus the maximum tail crest depth, measured at the downstream hydraulic control that forms the pool (Lisle 1987).	Number of pools with residual depth ≥ 30 cm[1]

[1] *Depth criterion was based on the median residual depth of all pools surveyed in all 27 streams contributing to model development.*

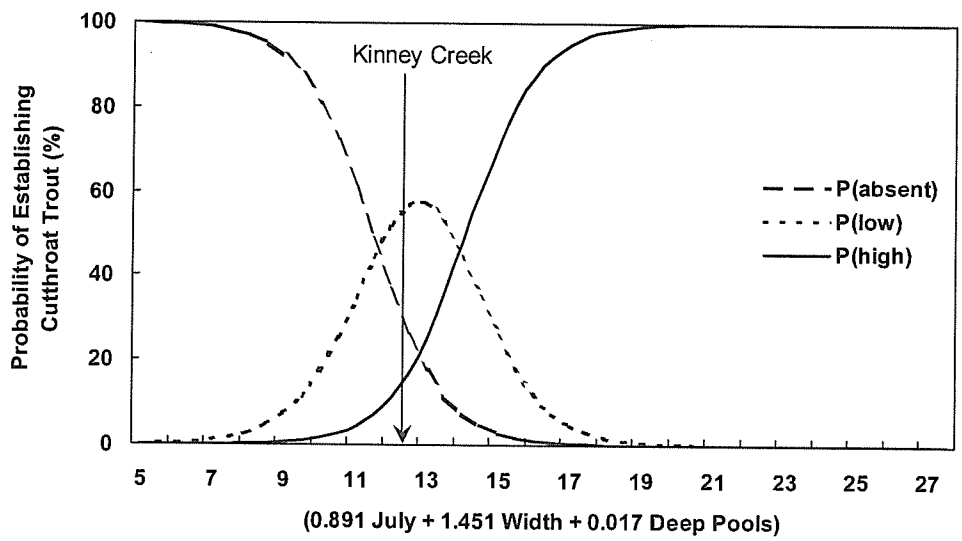


Figure 1.—Stream-scale habitat model for predicting the probability of establishing cutthroat trout in a potential translocation stream based on the mean daily water temperature for July (°C), mean bankfull pool width (m), and number of deep pools (residual depth = 30 cm; from Harig 2000). The model predicts that Kinney Creek has only a 14% probability of supporting high numbers of cutthroat trout, 56% chance of supporting low numbers, and 30% of supporting no cutthroat trout (shown by the arrow).

McIntyre 1993). Harig (2000) reported that the model may also be applicable to other closely related subspecies of cutthroat trout in central and southern Rocky Mountain streams (e.g., Colorado River cutthroat trout, *O. c. pleuriticus*) because similar habitat attributes probably limit their populations. Here we show how this model can be used to evaluate potential translocation sites and identify current populations at greatest risk from extirpation.

APPLICATION OF THE MODEL

To use this stream-scale habitat model for evaluating potential or current translocation sites, data must be collected on bankfull pool width, residual pool depth, and July summer water temperature in a manner consistent with the basin wide techniques used to develop the model (Table 2). Field habitat surveys must be conducted along the entire length of the translocation stream from the downstream fish movement barrier upstream to the end of pool habitat, which is usually where the bankfull channel width is < 2.0 m and wetted width ≤ 1.0 m. Width and depth measurements (Table 2) are recorded for each pool, defined as a channel unit that is at least one channel width long, relatively deep (minimum residual depth of 18 cm) and slow flowing, with a gentle surface water slope (cf., Hawkins et al. 1993). Water temperature needs to be recorded at the deepest point of a relatively deep pool identified during the habitat survey (Table 2). The third author conducted basin wide habitat surveys of four translocation streams in the Arapaho-Roosevelt National Forests, Colorado according to these methods, which allow us to demonstrate application of the model.

Using The Model With Complete Data

For translocation streams with complete data on mean July water temperature, mean bankfull pool width, and number of deep pools collected in the same way as used to develop the model (Table 2), managers can predict the probability of establishing cutthroat trout by entering the data into the equations. As a case example, the third author conducted a basin wide habitat survey on Kinney Creek in 1999, and placed a thermograph in the deepest pool to record summer water temperatures. The headwaters of Kinney Creek were fishless prior to translocation of Colorado River cutthroat trout in 1992 (unpublished data, Colorado Division of Wildlife), but a waterfall barrier protecting this population from invasion by nonnative brook trout (*Salvelinus fontinalis*) isolates them in a small fragment (4.3 km of stream). Analyses of the survey data yielded a mean daily July water temperature of 9.5°C, mean pool bankfull width of 2.4 m, and 21 deep pools (Table 3). Based on these data, the model predicts only a 14% chance of establishing a translocated population with high numbers of cutthroat trout:

$$P(high) = 1 - \left[\frac{\exp(14.077 - 0.891(9.5) - 1.451(2.4) - 0.017(21))}{1 + \exp(14.077 - 0.891(9.5) - 1.451(2.4) - 0.017(21))}\right]$$

$$P(high) = 1 - \left[\frac{\exp(1.773)}{1 + \exp(1.773)}\right] = 1 - \left[\frac{5.900}{6.900}\right] = 1 - 0.855 = 0.145$$

A translocation into Kinney Creek is more likely to establish low numbers of trout (56% probability), or may fail to support a naturally reproducing cutthroat trout population (30% probability; Figure 1). Corroborating our model predictions, Kinney Creek only supported low numbers of cutthroat trout when sampled using a basin wide visual fish count consistent with the methods in Harig (2000; Table 3). Summer water temperatures appear to be suitable, but narrow width and few deep pools likely limit the population.

Using The Model With Incomplete Data

Managers must often make decisions about a potential translocation stream without having collected all the data needed to make accurate predictions with the model. In these cases, the stream-scale habitat model may be useful to estimate the potential for success of cutthroat trout translocations based on average or minimum values or an estimated range. For example, in streams where the number of deep pools is similar to the average for the streams used to develop the model (87 pools), the model predicts that the chances of establishing a population with high numbers of cutthroat trout by translocation into a narrow stream (2.0 m wide) is >50% only if mean July water temperature exceeds about 11°C, whereas in wider streams (≥4.0 m wide) chances are >50% if water temperature exceeds about 8°C (Figure 2). Similarly, in streams of the average width for those used to develop the model (3.4 m bankfull pool width), chances of establishing a high population by translocation are >50% for cold streams (7°C mean July water temperature) only when about 200 or more deep pools are available, whereas chances of

Table 3.—Characteristics of four test streams in the Arapaho-Roosevelt National Forests, Colorado, where cutthroat trout were translocated including subspecies (GB = greenback cutthroat trout, CR = Colorado River cutthroat trout), stream length, total number of pools, and the three habitat variables included in the model of translocation success. Stream length was the amount of stream habitat available in summer, calculated from a USGS 1:24,000-scale quadrangle as the distance from the lower fish movement barrier to the upper terminus of the field survey. Number of age-1 and older trout was determined from basin wide visual fish counts conducted in combination with the habitat survey and consistent with the methods in Harig (2000).

Stream	Sub-species	Stream length (km)	Total number of pools	Mean July daily temperature (°C)	Mean bankfull pool width (m)	Number of deep pools (RD ≥ 30 cm)	Number of age-1 and older trout
Kinney Creek	CR	4.3	26	9.5	2.4	21	30
George Creek	GB	8.4	432	[1]	4.7	278	321[2]
Black Hollow Creek	GB	5.6	115	[1]	2.8	91	43
Bard Creek	GB	6.9	76	[1]	4.0	58	8

[1] *Water temperatures have not yet been measured with thermographs in these translocation streams. Only data from periodic measurements with a hand-held thermometer at pool or riffle surfaces are available for comparison.*

[2] *Total number of trout includes only the number of greenback cutthroat trout in the approximately 6.0-km reach of stream that does not contain nonnative salmonids, and therefore underestimates the minimum number of cutthroat trout that could be supported.*

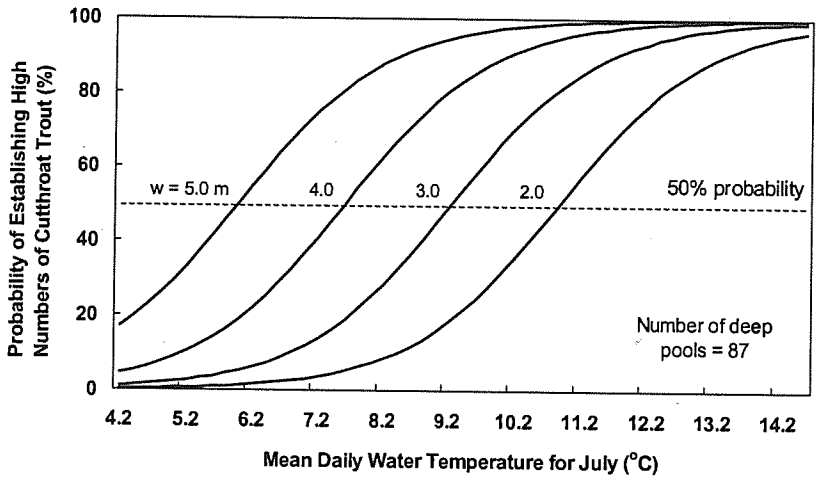


Figure 2.—Model predictions of the probability of establishing high numbers of cutthroat trout in a potential translocation stream based on the mean daily water temperature for July (°C) for streams with 87 deep pools (residual depth = 30 cm) and mean bankfull pool width (w) of 2.0, 3.0, 4.0, or 5.0 m (from Harig and Fausch 2000). The dashed line indicates a 50% probability of establishing high numbers of cutthroat trout.

success are >50% for warmer streams (10°C mean July temperature) when 50 or more deep pools are present (Figure 3). These predictions are made assuming that the three driving variables do not interact to affect the chances of translocation success in ways not included in the model. To further demonstrate application of the model using incomplete data sets, we evaluate three greenback cutthroat trout translocation streams surveyed in June-August 1999 for which thermograph data are not yet available (Table 3).

George Creek

Greenback cutthroat trout were translocated to George Creek in 1983 after removal of nonnative salmonids with multiple rotenone treatments (USFWS 1998; Harig et al. in press). Unfortunately, the chemical treatments apparently did not remove all brook trout from a beaver pond complex above a waterfall barrier, and the translocation is now considered unsuccessful (USFWS 1998). However, the stream-scale habitat model indicates that the 8.4-km reach of George Creek above the waterfall barrier, with a mean bankfull pool width of 4.7 m and 278 deep pools, has a ≥94% chance of supporting a high number of cutthroat trout for mean July water temperature ranging between 6-12°C (Figure 4). The model indicates that George Creek is wide enough with sufficient deep pools to ensure a naturally reproducing population of greenback cutthroat trout under all

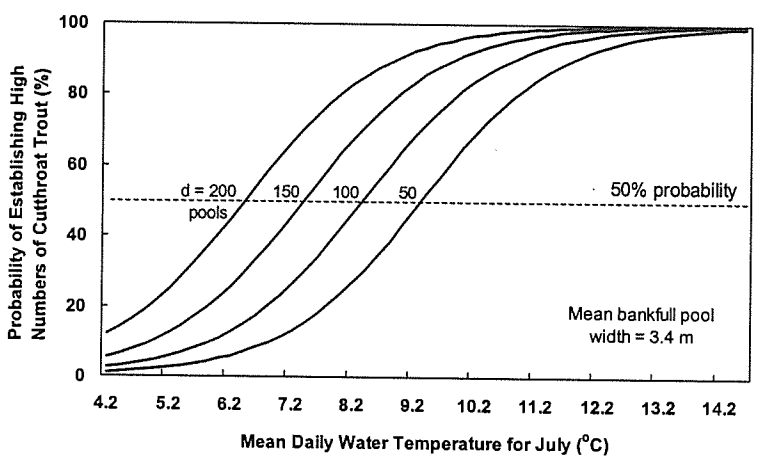


Figure 3.—Model predictions of the probability of establishing high numbers of cutthroat trout in a potential translocation stream based on the mean daily water temperature for July (°C) for streams with 3.4 m mean bankfull pool width and 50, 100, 150, or 200 deep pools (d; residual depth = 30 cm; from Harig and Fausch 2000). The dashed line indicates a 50% probability of establishing high numbers of cutthroat trout.

but the coldest temperature regimes. Point temperatures measured with a hand-held thermometer at riffle or pool surfaces during late June and early July 1999 (i.e., periods that should be colder than average July temperatures) ranged from 8.5°C in early morning to 16.0°C by mid-afternoon (USFS 1999), which suggests that George Creek's temperature regime is not too cold for cutthroat trout reproduction and falls within the temperature range where the model predicts a high number of trout for this stream. In a reach of George Creek occupied exclusively by greenback cutthroat trout, visual estimates indicate a high number of age-1 and older trout and corroborate our model predictions (Table 3). According to these results, George Creek is an excellent candidate for a successful translocation site if the nonnative salmonids could be eliminated from the remainder of the stream.

Black Hollow Creek

The headwaters of Black Hollow Creek above steep cascades were fishless prior to translocation of greenback cutthroat trout in the early 1980s (USFWS 1998; Harig et al. in press). Cutthroat trout were also translocated to downstream reaches of Black Hollow Creek above a wooden dam structure after removal of nonnative salmonids with rotenone in 1967 and 1979, but brook trout reinvaded these reaches through channels eroded around the structure (USFWS 1998; Harig et al. in press). Brook trout have not invaded the headwaters above the steep cascades, so we used only data from this 5.6-km reach for our evaluation.

The stream-scale habitat model indicates that Black Hollow Creek above the isolating cascades, with a mean bankfull pool width of only 2.8 m and 91 deep pools, would have a 50% chance of supporting high numbers of cutthroat trout only if mean July water temperature was at least 9.5°C (Figure 4). Point temperatures measured with a hand-held thermometer during early August 1999 (i.e., a period that should be warmer than average July temperatures) ranged from 6.0°C in the early morning to only 10.0°C by mid-afternoon (USFS 1999), which suggests that Black Hollow Creek does not have temperatures warm enough to ensure an abundant cutthroat trout population. Corroborating our model predictions, basin wide visual surveys identified only a low number of trout (Table 3). It is likely that either narrow stream width or cold summer temperatures limit greenback cutthroat trout most in Black Hollow Creek, but thermograph data are needed to determine July water temperatures for a more accurate prediction of the probability of translocation success prior to additional management efforts.

Bard Creek

The headwaters of Bard Creek were fishless prior to translocation of greenback cutthroat trout in the early 1980s (USFWS 1998; Harig et al. in press). Steep cascades isolate the population from nonnative salmo-

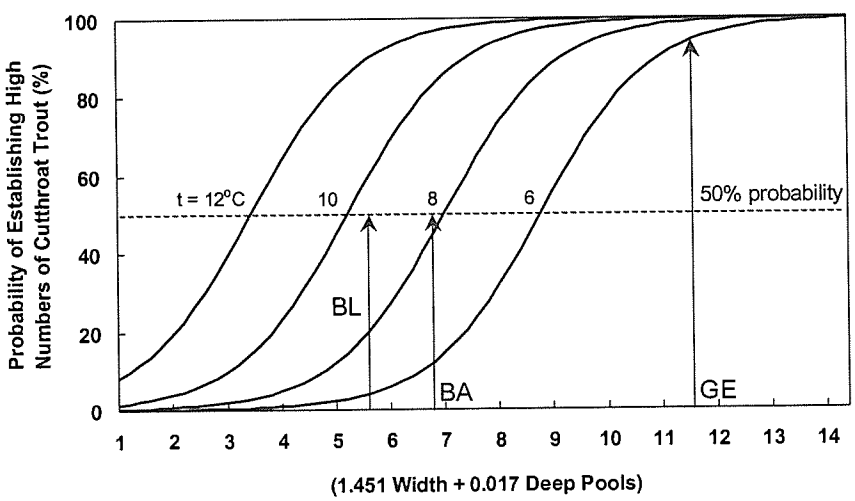


Figure 4.—Model predictions of the probability of establishing high numbers of cutthroat trout in a potential translocation stream based on mean bankfull pool width (m) and number of deep pools (residual depth = 30 cm) for streams with mean July water temperatures (t) of 6, 8, 10, or 12°C. The dashed line indicates a 50% probability of establishing high numbers of cutthroat trout. The model indicates that George Creek (GE) has =94% chance of establishing high numbers of cutthroat trout for mean July water temperatures >6°C, whereas Black Hollow (BL) and Bard creeks (BA) would require a mean July water temperature =9.5°C and =8.2°C, respectively, to have even a 50% probability of establishing high numbers (shown by the arrows).

nids but successful natural reproduction has not been documented, which suggests that habitat may be limiting (USFWS 1998). The stream-scale habitat model indicates that Bard Creek, which is wider (4.0 m mean bankfull pool width) but has fewer deep pools (58) than Black Hollow Creek, would have a 50% chance of supporting high numbers of cutthroat trout only if mean July water temperature was at least 8.2°C (Figure 4). Point temperatures measured with a hand-held thermometer during late July and early August 1999 (i.e., periods that should be warmer than average July temperatures) ranged from 4.5°C in the early morning to only 9.5°C by mid-afternoon (USFS 1999), which suggests that Bard Creek does not have warm enough temperatures to ensure an abundant cutthroat trout population. Corroborating model predictions, basin wide visual surveys identified few cutthroat trout (Table 3), although turbulent water from the steep gradient likely underestimated the minimum abundance of trout relative to surveys on the other test streams. Bard Creek is a relatively wide stream, but lack of overwinter refuges (i.e., few deep pools) and cold summer temperatures may limit cutthroat trout.

Additionally, the Bard Creek watershed has a moderate level of past mining activity, so heavy metals may also limit reproduction in this system (USFWS 1998). With multiple potential factors limiting greenback cutthroat trout, Bard Creek is a poor risk for additional translocation work until each of these factors is evaluated and addressed.

DISCUSSION

The stream-scale habitat model developed by Harig (2000; Harig and Fausch in review) can estimate the probability of establishing cutthroat trout in a potential or current translocation stream and suggest if cold summer water temperatures, narrow stream width, or few deep pools limit their chances. For three of our four test streams in northern Colorado, the model predicted a low probability of establishing high numbers of cutthroat trout. Kinney Creek is narrow with few deep pools, Black Hollow is also narrow but may be limited by cold summer water temperature, and Bard Creek has few deep pools and summer water temperature that is probably too cold. It is important to note that the model predicts the short-term (5-25 years) success of a translocation because this criterion was used to select streams measured to build the model. Although it is assumed that populations established through translocation will be long lasting (e.g., >100 years, Rieman and McIntyre 1993), this may not be true for streams predicted to support only low numbers of cutthroat trout. Small populations have a greater risk of dying out from chance events alone or natural catastrophes (Caughley and Gunn 1996), so it is likely that the trout population will not persist in many streams predicted to support low numbers. Considering their greater risk of extirpation, managers will need to decide whether establishing a small population of cutthroat trout in such streams is worth the time, money, and effort of a translocation project. For Kinney Creek, it may be possible to increase the probability of establishing a high population of cutthroat trout by increasing the number of deep pools. However, it may be difficult to increase water temperature in an ecologically sound manner, and it would not be possible to increase stream width, so Black Hollow and Bard creeks are not likely to support high numbers of cutthroat trout even with further management efforts.

As with any ecological model, this stream-scale habitat model has intrinsic assumptions and sources of error that should be recognized by its users. To make accurate predictions, this model should only be applied to similar stream systems for similar subspecies of cutthroat trout. Data from a test translocation stream should fall within the range of the data used to develop the model (Table 1) and should be collected with the same methods (Table 2; Harig 2000). Furthermore, the model can only estimate the probability of translocation success for streams that are, or will be, free of nonnative salmonids. It does not apply to streams invaded by nonnative salmonids. For example, the model indicates that the cutthroat trout population in George Creek is not limited by cold water temperature, narrow stream width, or few deep pools. It would be likely to support high numbers of cutthroat trout if the nonnative salmonids were eliminated. Finally, model predictions should be used judiciously because they are based on observational data from streams deliberately selected by managers rather than streams subjected to random, controlled, and replicated experimental manipulation. The model is also based on a relatively small sample size of streams, so all possible limiting factors and their interactions may not be included. Some translocation sites are likely to be limited by factors other than water temperature, stream width, and lack of refuges. Despite these limitations, the stream-scale habitat model provides managers with a valuable new diagnostic tool for selecting and evaluating

cutthroat trout translocation sites, particularly if it is included in an active management program that tests and refines the model with data from recent and future translocation sites.

ACKNOWLEDGMENTS

The research on which this analysis was based was funded by the Colorado Division of Wildlife (CDOW) West Region, U.S. Forest Service (USFS) Rocky Mountain Region Fish Habitat Relationships Unit, Pike-San Isabel National Forest, and Trout Unlimited (TU) Coldwater Conservation Fund. We thank D. Langlois and T. Nesler (CDOW); M. Young, N. Schmal, and D. Winters (USFS); and W. Fosburgh (TU) for administering funding. We also thank T. Deem, J. Hawley, K. Huhn, and B. Young for assisting with field stream surveys on the four test sites.

LITERATURE CITED

Alves, J. 1998. Status of Rio Grande cutthroat trout in Colorado. Management Report, Colorado Division of Wildlife, Denver, Colorado, USA.

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, Maryland, USA.

Bustard, D.R., and D.W. Narver. 1975. Preferences of juvenile coho salmon (*Oncorhynchus kisutch*) and cutthroat trout (*Salmo clarki*) relative to simulated winter habitat. Journal of the Fisheries Research Board of Canada 32:681-687.

Caughley, G., and A. Gunn. 1996. Conservation biology in theory and practice. Blackwell Science, Cambridge, Massachusetts, USA.

Cunjak, R.A., and G. Power. 1987. The feeding and energetics of stream-resident trout in winter. Journal of Fish Biology 31:493-511.

Dunne, T., and L.B. Leopold. 1978. Water in environmental planning. W.H. Freeman and Company, San Francisco, California, USA.

Gresswell, R.E. 1988. Status and management of interior stocks of cutthroat trout. American Fisheries Society Symposium 4, Bethesda, Maryland, USA.

Griffith, J.S. 1972. Comparative behavior and habitat utilization of brook trout (*Salvelinus fontinalis*) and cutthroat trout (*Salmo clarki*) in small streams in northern Idaho. Journal of Fisheries Research Board of Canada 29:265-273.

Harig, A.L. 2000. Factors influencing success of cutthroat trout translocations. PhD dissertation, Colorado State University, Fort Collins, Colorado, USA.

Harig, A.L., and K.D. Fausch. 2000. Factors influencing success of cutthroat trout translocations. Final Project Report submitted to the Colorado Division of Wildlife, U.S. Forest Service, and Trout Unlimited. Fort Collins, Colorado, USA. 140 pp.

Harig, A.L., and K.D. Fausch. *In review*. Minimum habitat requirements for establishing translocated cutthroat trout populations.

Harig, A.L., K.D. Fausch, and M.K. Young. *In press*. Factors influencing success of greenback cutthroat trout translocations. North American Journal of Fisheries Management.

Hawkins, C.P., and 10 coauthors. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18(6):3-11.

Hendrickson, D.A. and J.E. Brooks. 1991. Transplanting short-lived fishes in North American deserts: review, assessment, and recommendations. Pages 283-298 *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, USA.

Hubert, W.A., and W.A. Gern. 1995. Influence of embryonic stage on survival of cutthroat trout exposed to temperature reduction. The Progressive Fish-Culturist 57:326-328.

Hubert, W.A., R.W. Stonecypher, W.A. Gern, and J. Bobbit. 1994. Response of cutthroat trout embryos to reduced incubation temperatures at different developmental stages. The Progressive Fish-Culturist 56:185-187.

Lisle, T.E. 1987. Using "residual depths" to monitor pool depths independently of discharge. Research Note No. PSW-394, USDA Forest Service, Berkeley, California, USA.

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, USA.

Rieman, B.E., and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. General Technical Report INT-302, USDA Forest Service, Ogden, Utah, USA.

Shuter, B.J., and J.R. Post. 1990. Climate, population viability, and the zoogeography of temperate fishes. Transactions of the American Fisheries Society 119:314-336.

USFS (USDA Forest Service). 1999. Unpublished population and habitat inventory data for greenback and Colorado River cutthroat trout streams on the Arapaho and Roosevelt National Forests, Fort Collins, Colorado, USA.

USFWS (US Fish and Wildlife Service). 1998. Greenback cutthroat trout recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado, USA.

Williams, J.E., and 12 coauthors. 1988. American Fisheries Society guidelines for introductions of threatened and endangered fishes. Fisheries 13(5):5-11.

Young, M.K., editor. 1995. Conservation assessment for inland cutthroat trout. General Technical Report RM-256, USDA Forest Service, Fort Collins, Colorado, USA.

The Grand Portage Project, A Successful Model for the Reintroduction of Lake Superior Coaster Brook Trout Populations.

Lee E. Newman[1]

Abstract—This cooperative project of the Grand Portage Tribe and the U.S. Fish and Wildlife Service employed a comprehensive approach toward reestablishing a naturally reproducing coaster brook trout *Salvelinus fontinalis* population in reservation waters. Lake Superior basin, native coasters (Nipigon strain) were stocked as eyed eggs or fry in three small streams that were historic coaster production habitats. Concurrent with the reintroductions, the Grand Portage Tribal Council and Natural Resources Department effectively mobilized community support for the restoration effort and for self regulation of the harvest. Adult, spawning stage coasters as large as five pounds have entered the stocked streams in five consecutive years and natural reproduction has been documented. This small project provides encouraging evidence of the feasibility of rehabilitation of coaster stocks and may serve as a model for reintroductions in suitable habitats throughout the Lake Superior basin and possibly the Lake Michigan and Lake Huron basins as well.

INTRODUCTION

Brook trout *Salvelinus fontinalis*, were once abundant and widespread along most of Lake Superior's 4,385 km of shoreline and entered more than 120 tributary stream systems to reproduce. They were also abundant in Lake Nipigon and common along the shoreline of, and in the tributaries of approximately the northern half of Lake Huron and Lake Michigan. Locally called "coasters", these large, anadromous or shoal spawning brook trout were prized for their size, beauty and food qualities (Shiras 1935, Roosevelt 1865).

Beginning with the arrival and colonization of the Lake Superior region by Europeans during the 1800's, coaster populations were heavily over exploited. Their qualities as a game fish created a world class fly fishery that attracted an international following and their qualities as a food fish fueled an intense local hook and line fishery, and to a lesser degree, a commercial net fishery (Newman and DuBois 1996). These unregulated fisheries decimated native coaster stocks in the time period from 1850 to 1900. As further development of the area proceeded, logging, wildfire, agriculture, mining and other land uses may have also contributed to their decline.

Exotic salmonids (rainbow trout, brown trout, and coho, chinook, pink and Atlantic salmon) were introduced to Lake Superior and may have competed with the coaster populations. Access to springs providing critical spawning habitats (Curry and Noakes 1995) was blocked by road construction and dams for public and private fish hatcheries (Smith and Moyle 1944).

By the early 1900's, only a few, small remnant populations of coasters remained, usually in remote areas, isolated from large human populations. At present, the only known coaster brook trout populations of significant size are found in Ontario's Nipigon District, around Isle Royale and in the private land holdings of the Huron Mountain Club in the Upper Peninsula of Michigan (Newman and DuBois 1996).

Attempts have been made to restore coaster populations in Lake Superior by stocking fingerling and yearling hatchery brook trout on a sporadic basis for more than 100 years. These attempts have consistently produced very low return rates and have not resulted in the establishment of natural reproduction (Smith and Moyle 1944). Wisconsin DNR (B. Swanson,

[1]*Fishery Biologist, U.S. Fish and Wildlife Service Fishery Resources Office, Ashland, WI 54806.*

WI DNR, Bayfield WI, person. commun.) also reports low return rates from stockings made from about 1980 to 1994. Participants in a 1992 Workshop on Lake Superior brook trout speculated that the lack of success of past stockings may have been due to stocking the wrong life stage or genetic strain, overharvest of juveniles, the lack of fitness of hatchery reared fish, or that homing or spawning instincts were not properly imprinted, (Minutes, Workshop on Lake Superior Brook Trout, Grand Portage, MN July 27-28, 1992).

Coaster brook trout have been extirpated from Grand Portage Reservation waters since about 1950. Causes of the decline were overfishing, habitat degradation and possibly competition with introduced salmonids (Smith and Moyle 1944).

The fish community objectives for Lake Superior (Busiahn 1990) call for the restoration of depleted stocks of native fish species, and the Lake Superior Brook Trout Rehabilitation Plan (Newman *et al.*, 1999) specifically outlines an approach to coaster brook trout rehabilitation. In accordance with these objectives, the Ashland Fishery Resources Office (FRO) of the U.S. Fish and Wildlife Service and the Grand Portage Natural Resources Department have initiated a cooperative project to reintroduce coaster brook trout to reservation waters.

OBJECTIVES

The ultimate objective of this project is to restore one or more viable, self-sustaining stocks of coaster brook trout in the waters of Lake Superior and its tributaries at Grand Portage. As specific biological information regarding coaster brook trout is virtually non-existent, adaptive management techniques were employed, and methodology designed to evaluate the innovative stocking techniques used and to provide information regarding the biology, habitat use and life cycle of the coaster. We also designed the evaluation to provide information regarding the interaction of coaster brook trout with the naturalized stocks of rainbow trout and coho salmon using the stream and lake habitat of the study area.

STUDY SITES

At Grand Portage three streams with suitable coaster habitat were selected as study sites. The streams all supported coaster brook trout populations in the past, but no brook trout have been reported from them in the last 40 years, except for a few in the 1970's that resulted from stockings made during that period (USFWS, Ashland FRO-unpublished file data).

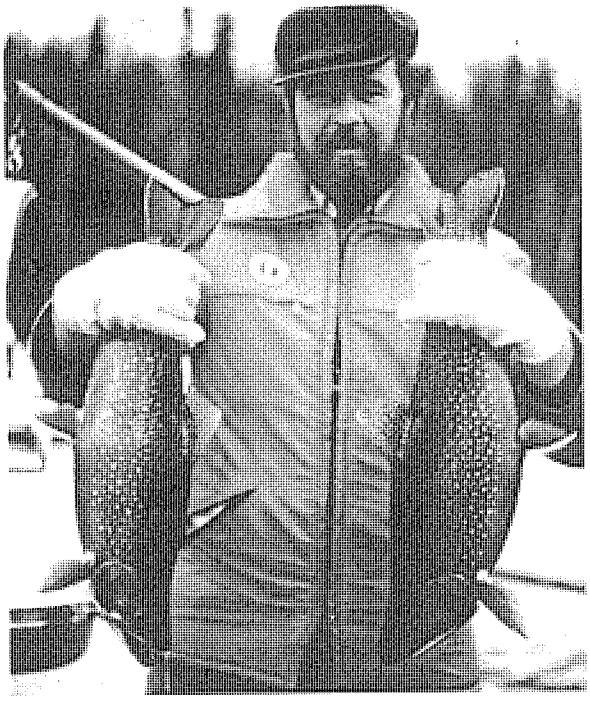


Figure 1.—Lake Nipigon coasters captured by the Ontario Ministry of Natural Resources for broodstock development.

The streams selected for the reintroductions are typical of the Minnesota north shore of Lake Superior. They are primarily fed by surface water and have low groundwater inputs. They have steep gradients, predominantly freestone and bedrock substrates and have highly variable flow and temperature regimes. In general, they have long been considered as marginal trout streams (Smith and Moyle 1944). Two of the streams (Grand Portage Creek and Little Lake Creek) discharge into Lake Superior in Grand Portage Bay, a sheltered bay of 500 hectares surface area with a maximum depth of 7 meters. The other stream (Hollow Rock Creek) discharges into Lake Superior along an unprotected shoreline with steep cliffs and abrupt drop offs to depths of 20 to 50 meters.

Water is supplied to Little Lake Creek by a small watershed (81 ha) through several springs with a combined output of < 1.0 cfs. Length from headwaters to Lake Superior is 0.5 km, and access to anadromous fish is blocked by a perched highway culvert barrier at the mouth and by beaver dams. Maximum flow rates are unknown.

Grand Portage Creek has a total length of 7.0 km and a watershed of 2055 ha. The only barrier to upstream movement of anadromous fish is the box culvert under Minnesota Highway 61 which is 1.4 km from the mouth. A fish passage tube installed in the culvert in 1959 has not provided consistent upstream access for the steelhead population, but modifications made to the structure in late 1993, have allowed steelhead to pass upstream. The average annual flow rate is 3.5 cfs, and maximum rates may exceed 100 cfs.

Hollow Rock Creek is subject to more extreme flow fluctuations than Grand Portage Creek. Maximum and minimum flows are unknown but an average flow for 1984 was recorded as 3.0 cfs, based on four measurements during the year (all spring readings). During 1998 low flows of <1.0 cfs were observed during August and January. A natural falls 0.4 km from the mouth is a barrier to fish passage.

METHODOLOGY

This reintroduction effort focused on a number of areas suspected of being important to coaster brook trout:

- To maximize early acclimation and imprinting, the earliest life stages possible were used for the experimental reintroductions (eyed eggs and early stage fry).
- The one regional native broodstock available, the Lake Nipigon strain, was selected for use in this reintroduction.
- Reintroductions were made into historic habitats where we believed suitable conditions still existed.
- Survival, growth and distribution of stocked fish were measured as frequently as could be achieved.
- An intensive effort was made by the Grand Portage Tribal Natural Resources Department to provide tribal members and local residents with information on coaster brook trout biology and their needs for extraordinary protection to achieve spawning sizes and ages.

Stocking

The study streams were stocked with Nipigon Strain brook trout during the time period from 1992 through 2000 (Newman 1995). Eyed eggs were stocked in Little Lake Creek and early stage fry in Grand Portage and Hollow Rock Creeks. Egg stocking was done directly into stream substrates where groundwater upwellings occurred using a technique similar to that described by Gustafson-Marjanen and Moring (1984). Incubators placed in the substrates were used to evaluate hatch success (Newman 1995). Fry (from the same lot of broodstock that produced the eggs stocked in Little Lake Creek) were stocked into stream segments on Hollow Rock and Grand Portage Creeks where habitat potentially suitable for coaster reproduction was present. Fry were stocked both below and immediately above barriers to anadromous fish passage. No stocking of brook trout on reservation waters was done in 1997 to provide a definitive opportunity to evaluate any natural reproduction resulting from the introductions.

Assessment

To monitor the abundance, growth and maturation of brook trout produced by the introductions, data was collected from several sources:

- Annual monitoring of juvenile salmonid populations in the study streams was done by backpack electrofishing during the second week of August each year from 1992 through 2000, and at least twice more each summer as personnel were available.
- Compilation of catch data by Grand Portage tribal personnel was done periodically by interviewing sport fishermen and tribal commercial fishermen during 1995 to approximate catches of brook trout in reservation waters of Lake Superior from June 1 to November 1, 1995. Brook trout caught by Grand Portage Natural Resources Department personnel, incidental to other fisheries projects during biological assessments in 1995, were also included.
- Annual spawning stream sampling, below barriers, was conducted from October through early November 1994 through 1999. Stream segments below barriers on Hollow Rock Creek and Grand Portage Creek were sampled by backpack electrofishing to determine if adult brook trout were returning to spawn. All sexually mature fish were measured and scale sampled for age composition.
- Distribution, movement and habitat use by adults was monitored by radio telemetry.

RESULTS

Egg stocking

The survival rate (eyed egg to swim up fry) found in test incubators ranged from 84% to 100% where incubators were properly placed (Newman 1995). In Little Lake Creek, numerous brook trout fry were observed in the areas stocked when the incubators were lifted and young of the year (yoy) were observed to be common (1993-1996 and 1998-2000), and adults were captured annually in the stream from 1994 through 1999. As this stream had no brook trout population before eggs were introduced, the only likely source was the egg stocking. This stream has an impassable fish barrier (perched road culvert) at the outlet and fish can not re-enter from Lake Superior.

Fry stocking

Fry stocking resulted in yoy and yearling brook trout year classes in Hollow Rock and Grand Portage Creeks in each year stocked. Monitoring in stream and in Lake Superior has shown that:

- The number of brook trout observed per station was lower than the number of rainbow trout in all stations where lake access is available.
- Juvenile rainbow trout abundance and growth rates have not changed since the introduction of brook trout in 1992.
- Abundance of yoy brook trout was generally higher in stream samples above migration barriers (without rainbow trout), than below barriers where they competed with rainbow trout.
- Brook trout yoy growth above barriers was slightly better than below barriers (by an average of 0.76 cm by August 10). Yearlings averaged 1.52 cm larger than their cohorts below barriers. The difference is likely the result of competition with the rainbow trout below barriers.
- Age 1 fish in Lake Superior on August 10 were 2.58 cm longer than their cohorts in the streams. Either the lake caught fish had begun to grow faster than those staying in streams, or fish emigrating to Lake Superior were the larger and faster growing individuals in the population.
- Coloration and markings of the lake caught brook trout were markedly different from those in stream. Markings (vermiculations and spots) were pale and indistinct while silver color was pronounced, particularly in age 2 or older fish.
- Emigration of juvenile brook trout from the streams was usually complete during the yearling year, but emigration and immigration occurred whenever stream conditions warranted.
- Radio tagged adults in Lake Superior used shallow water (< 7 m) and nearshore areas (<150 m from shore) exclusively, and usually did not travel more than 20 km from there capture location.
- YOY brook trout captured in Hollow Rock Creek (a year when no brook trout were stocked).

Production of adult fish

No means were available for conducting an accurate survey of the number of coasters produced by these reintroductions, either in the streams or Lake Superior. However, it was observed that:

- A total of 20 "adult" brook trout (> 305 mm) were reported caught in Lake Superior during 1995 in tribal subsistence nets and 18 caught by anglers in the tribal marina (the only place where anglers were sampled). A total of 60 brook trout were caught in Lake Superior by tribal natural resources department personnel incidental to other fisheries projects. The 98 brook trout were all age 2^+ to 4^+. These 98 fish represent an unknown portion of the total population.
- Fall sampling of Hollow Rock and Grand Portage Creeks on a few occasions each year from 1995 through 1999 produced from 10 to 25 individual, adult fish in each stream per year.

Age and length at maturity:

Table 2.—Length and sex data, 52 sexually mature coasters captured in Hollow Rock and Grand Portage Creeks from 1995 through 1999.

Scale age of fish	Males, Number in sample/average length	Females, Number in sample/average length
1+	N=2 23.1 cm	N=0
2+	N=3 31.7 cm	N=1 28.9 cm
3+	N=20 43.2 cm	N=22 46.2 cm
4+	N-2 49.2 cm	N=2 52.3 cm

Public education and community involvement

Personnel of the Grand Portage Natural Resources Department were highly successful in generating interest in and support for restoration of coaster brook trout. The effort included educational presentations and personal contact with all age groups. Special emphasis was placed on elementary and high school students who were provided field and class room experiences with the project. Tribal members and local residents developed a strong sense of ownership and pride in this project and a solid understanding of coaster biology. This understanding was vital to the voluntary catch and release program that allowed coasters to survive to reproductive size and ages.

DISCUSSION

We have concluded that the technique of stocking eyed eggs on created or improved spawning substrates is a promising method for the reintroduction of extirpated stocks of brook trout, particularly where good spawning and rearing habitats exist. These tests demonstrated that high hatch rates can be produced in a variety of substrates and habitats.

We theorize that brook trout produced by stocking eyed eggs will have substantial survival advantages over those stocked as fingerlings or yearlings from hatchery sources. Acclimation to natural conditions, synchronization of life cycle with natural food supplies and the imprinting of homing instincts will be nearer to that of naturally reproduced wild fish. Costs are low for the eyed egg stocking technique in streams. This method also compares favorably to the use of Vibert boxes where substantial costs are involved and regular maintenance and cleaning are required while in use. We saw no evidence of fungus or disease in any of the egg stockings.

Employing the technique of stocking early stage fry may provide many of the same benefits as stocking eyed eggs. Costs are only slightly higher and early acclimation and imprinting could also be good, but has not yet been proven.

Among sexually mature fish returning to streams, the dominance of the age 3^+ year class, especially in females, indicates that most coasters of the Nipigon strain will not mature sexually in the wild until this age, a pattern consistent with that found in the Nipigon River (R. Swainson, OMNR, Nipigon, person. commun.). Nipigons are known to be 95% sexually mature at age 2^+ when grown in hatchery conditions at the Dorion (OMNR) Fish Culture Station (J. Sagar, Manager). However, sexual maturation in the wild environment appears to be delayed by anadromy as suggested by Thorpe (1987). This maturation pattern may be the key element in managing coaster populations. With the obvious vulnerability of all brook trout to over harvest, protection of adults to allow for spawning twice before harvest will likely require size limits over 50 cm (20 inches) as suggested in the Lake Superior Brook Trout Rehabilitation Plan (Newman *et al.*, 1999).

The total number of coaster brook trout in Lake Superior produced by the introductions at Grand Portage and how those fish have distributed in Lake Superior is largely unknown. The stream habitats used are so small that total production is not very high. We believe however, that at least 3 year classes (ages 2 through 4) are fairly abundant along about 20 km of shoreline in the vicinity of Grand Portage and assume that perhaps 30 to 50 adults are returning to attempt to spawn in each of the two streams.

Conclusive evidence was found in 1997 to show that the reintroduced coasters at Grand Portage are reproducing. The standard stations on Hollow Rock Creek produced about 40 yoy, that were concentrated below the falls that is the first anadromous fish barrier. We suspect, but can not be sure, that this may be the site where successful spawning occurred. In 1998 and 1999, yoy brook trout sampled in Grand Portage Creek showed an unusual bi-modal distribution of lengths. We suspect that this was the result of having both a hatchery and a naturally reproduced year class of yoy present. If successful reproduction of coasters is occurring in both of these marginal trout streams, it is an indicator that spawning habitat may not be as severely limited as expected, either here or in other Lake Superior streams.

Our results suggest that vital elements of future successful coaster brook trout population reintroductions will include biological factors such as using native strains and stocking appropriate life stages in suitable habitats. Most importantly, stocks will require protection to reach the unusual sizes and ages that are needed by coasters. The protection may be possible through special regulations, but ideally it might be best provided by an informed and motivated community as was the case at Grand Portage.

POTENTIAL APPLICATIONS

The scale of this project was so limited that the area affected is only about 1.8 km of anadromous habitat and 30 km of Lake Superior shoreline. The populations involved are so small that their continued existence is tenuous at best. However, the exciting possibility does exist that the techniques applied here might be applicable to many of the 120 historic coaster streams and much of the 4,385 km of shoreline on Lake Superior where coaster stocks have been extirpated. There may also be potential for reintroductions in some habitats on Lake Huron and Lake Michigan.

ACKNOWLEDGMENTS

The author acknowledges that the success of this project is fully due to individual members of the Grand Portage Reservation, the Tribal Council and the personnel of the Grand Portage Natural Resources Department. Without their enthusiastic support and hard work, none of it would have been possible. Thanks are also extended to the Ontario Ministry of Natural Resources personnel for their technical advise, for supplying the eggs and fry stocked in this project, and for their enthusiastic support of coaster brook trout restoration at both Grand Portage and throughout Lake Superior.

LITERATURE CITED

Busiahn, T.R.(ED). 1990. Fish Community Objectives for Lake Superior. Great Lakes Fishery Commission Special Publication 90-1. 23 pages.

Curry, R.A. and D.L.G. Noakes. 1995. Groundwater and the selection of spawning sites by brook trout, *Salvelinus fontinalis*. Canadian Journal of Fisheries and Aquatic Sciences 52:1733-1740.

Gustafson-Marjanen, K.I. and J.R. Moring. 1984. Construction of artificial redds for evaluating survival of Atlantic salmon eggs and alevins. North American Journal of Fisheries Management 4(4A):455-461. SFA 30(1)

Hokanson, K.E.F., J.H. McCormick, B.R. Jones, and Tucker. 1973. Thermal requirements for maturation, spawning, and embryo survival of the brook trout, *Salvelinus fontinalis*. Journal of the Fisheries Research Board of Canada 30(7):975-984.

Newman, L.E. 1995. Creating upwellings for incubation of eyed stage brook trout, *Salvelinus fontinalis*, eggs. Pages 69-72 in Kelso, J.R.M. and Hartig, J.H. 1995. Methods of modifying habitat to benefit the Great Lakes ecosystem. CISTI Occas. Pap. 1:294 p.

Newman, L.E. and R.B. DuBois (ED). 1996. Status of brook trout in Lake Superior. Prepared for the Lake Superior Technical Committee by the Brook Trout Subcommittee.27 pp.

Newman, L.E., and J. Johnson.1996. Development of a reintroduced, anadromous brook trout population at Grand Portage, Minnesota. Ashland Fishery Resources Office, Ashland, WI.

Newman, L.E., R.B. DuBois and T.N. Halpern (ED). 1999. A brook trout rehabilitation plan for Lake Superior. Great Lakes Fish.Comm. 28 p.

Piper, G.R., I.B. McElwain, L. Orme, J.P. McCraren, L.G. Fowler and J R. Leonard.1982. Fish Hatchery Management. U.S. Dept. of the Interior, Fish and Wildlife Service.Washington, D.C.

Roosevelt, Robert Barnwell. 1865. Superior Fishing. Originally published by G.W. Carlton. New York. New publication by Minnesota Historical Society. 1985

Smith, Lloyd L. and John B. Moyle. 1944. A biological survey and fishery management plan for the streams of the Lake Superior north shore watershed. Minnesota Department of Conservation, Division of Game and Fish. Technical Bulletin No. 1.1944

Shiras, G.1935. Hunting wild life with camera and flashlight; a record of sixty-five years' visits to the woods and waters of North America. Chap. 20, the Huron Mountain District; Fishes of Lake Superior. National Geographic Society. Vol.1, Lake Superior Region. Washington, D.C.

Thorpe, J.E.1987. Smolting versus residency: developmental conflict in salmonids. American Fisheries Society Symposium 1:244-252.

Recovery Status of Apache Trout *Oncorhynchus apache*

Leslie D. Ruiz[1] and James R. Novy[2]

Abstract—The Apache trout *Oncorhynchus apache*, is currently listed as a threatened species. In recent years, cooperative efforts between the U.S. Fish and Wildlife Service (USFWS), White Mountain Apache Tribe (WMAT), Arizona Game and Fish Department (AGFD), and the U.S. Forest Service (USFS) to protect extant populations, restore historical habitat, replicate pure populations, and establish the Apache trout as a recreational sport fish have advanced the recovery of the species. To date recovery accomplishments on federal and tribal lands include: 1) Genetic analysis of 48 populations, resulting in the identification of 15 genetically pure populations of Apache trout; 2) Construction of 26 artificial barriers to prevent upstream migration of non-native salmonids; 3) Renovation of 19 streams with Fintrol® to eradicate hybridized and non-native salmonids from historical habitats; 4) Reintroduction of 11 Apache trout populations into renovated habitats; 5) Habitat protection measures implemented in 19 streams; and, 6) Management of the Apache trout as a sport fish in 14 lakes and 11 streams. De-listing will be proposed when at least 30 self-sustaining populations have been established, all known natural stocks are replicated and all threats that initiated protection through listing under the Endangered Species Act of 1973 (ESA) are adequately addressed.

BACKGROUND

Prior to the 1900's, the Apache trout was the only salmonid resident to headwaters of the upper Salt River (Black and White rivers) and the headwaters of the Little Colorado River, in the White Mountain region of east-central Arizona (Miller 1972). The native Apache trout were known from the region since 1873 when the first European settlers to the area reported abundant populations of "yellow-bellied, speckled" trout in pristine montane habitat. Cope and Yarrow (1875) identified three specimens from "White River, Arizona" as "large and small spotted variety" of the Colorado cutthroat trout, *Salmo pleuriticus*. Jordan and Evermann (1896) also identified specimens from the Little Colorado River as the same cutthroat trout. Initially Miller (1950) included the "Arizona" trout in the description of Gila trout *Salmo gilae;* however, he later described the trout as a distinct species, *S. apache* (Miller 1972). Recent general changes in the nomenclature of North American trouts included changing *Salmo apache* to *Oncorhynchus apache* (Robins et al., 1991).

Apache trout historically inhabited most of the streams in the White Mountains above 1800 meters elevation (Harper 1976). Historic distribution is confirmed by present hybrid populations and documented collections (Loundenslager et. al 1986; Carmichael et. al 1993). Loss of habitat, over-harvesting, and predation by, competition with, and hybridization with, non-native salmonids rapidly reduced or eliminated reduced most populations of the Apache trout within a span of about 50 years. These factors continue to be the principal threats to the species= continued existence (USFWS, 1983). In the 1950's the range of Apache trout was thought to have dropped to a low of about 48 km of stream habitat or less of headwater streams, reduced from an estimated original range of about 965 linear km (Harper 1978).

Current distribution of extant Apache trout populations is limited to isolated headwater reaches of tributary streams upstream from natural and manmade barriers in the White Mountain region of

[1] *Arizona Fishery Resources Office-Pinetop, U.S. Fish and Wildlife Service, P.O. Box 39, Pinetop, Arizona 85935*

[2] *Arizona Game and Fish Department, 2878 East White Mountain Blvd. Pinetop, Arizona, 85935*

Arizona. This region includes lands managed by the White Mountain Apache Tribe (WMAT) and the U.S. Forest Service (USFS). These streams include the headwaters and tributaries of the White and Black rivers. The present distribution is at least 141 km within the headwaters of the White and Black rivers on the FAIR and approximately 50 km within the Apache and Sitgreaves National Forests.

The Apache trout was listed as endangered in 1969 and brought under protection of the ESA in 1973, as amended and was down listed to threatened status in 1975 (USFWS 1979). Members of Apache Trout Recovery Team (ATRT) from the White Mountain Apache Tribe (WMAT), Arizona Game and Fish Department (AGFD), U.S. Forest Service (USFS), U.S. Fish and Wildlife Service (USFWS), and U.S. Bureau of Reclamation (USBR), all agree that additional recovery steps must be implemented that include protection and replication of all naturally occurring pure Apache trout stocks and implementation of adequate habitat protection measures on all Apache trout streams to secure the survival of Apache trout (USFWS, 1983; Carmichael, et al., 1995). In addition, consensus was reached by the ATRT members that Apache trout should regain status as a dominant sport fish in historical habitats.

When all recovery actions are fully implemented, Apache trout will exist in at least 39 stream systems providing approximately 500 kilometers (km) of stream habitat. Thirty-one of these streams totaling approximately 375 km will be actively managed for recovery, requiring maintenance of genetic purity and elimination of non-indigenous fish species. Ten additional streams with approximately 250 km of habitat and 14 small coldwater reservoirs will be managed primarily for sport fishing for Apache trout requiring periodic stocking of hatchery-reared fish.

APACHE TROUT RECOVERY PROGRAM

Conservation of Apache trout was first attempted by the WMAT in the late 1940s and 1950s when the only known populations existed on the Fort Apache Indian Reservation (FAIR). On March 24, 1955, WMAT resolution resulted in the closure of all streams within the reservation boundaries of the Mount Baldy Wilderness Area to fishing. Subsequently, other streams considered important to Apache trout conservation were added. Interest in Apache trout continued and substantially increased during the early 1960s, resulting in fishery surveys carried out by USFWS and AGFD in cooperation with WMAT to determine status. In conjunction with these surveys, AGFD, again in cooperation with

WMAT and USFWS, entered into a controlled propagation program. As part of the federal and state Apache trout recovery effort, stocking of Apache trout in streams began in 1963. In a WMAT resolution dated November 10, 1964, the tribe adopted a management plan proposed by USFWS that called for the construction of fish barriers and renovation of streams for the reintroduction of Apache trout (Andersen 1965).

The ESA passed in 1973 and the Apache trout was brought under its protection (Public Law 93-205). In 1974, all Arizona waters were closed to the Ataking@ of Apache trout. The USFWS directed a recovery team be formed and in 1975, the Apache trout was down listed to threatened status. The APRT prepared an initial recovery plan for Apache trout in 1979, which was updated in 1983 (USFWS 1979; USFWS 1983). Recovery actions have been guided by these documents and have focused on: 1) surveying and addressing the genetic status (purity) of existing populations, and protecting those populations; 2) renovating selected streams in historic habitat and reintroducing Apache trout following elimination of non-native trout species; 3) surveying populations and habitat conditions, and developing and implementing habitat recovery measures; and, 4) development of a hatchery broodstock and enhancement sport fisheries for the species. In the spring of 2001, a revised recovery plan will be submitted to the USFWS for review and approval.

RECOVERY GOALS

The primary goal of the Apache trout recovery program is to delist the Apache trout. Recovery criteria, as outlined in the Apache Trout Recovery Plan (USFWS, in draft), includes the protection and replication of all naturally occurring pure Apache trout stocks and implementation of adequate habitat protection measures on all Apache trout streams. De-listing will be proposed when at least 30 self-sustaining populations have been established, all known natural stocks are replicated and all threats that initiated protection through listing under the ESA of 1973 are adequately addressed. In addition to these criteria, the Apache Trout Recovery Team has also identified that this same level of protection be applied to any additional populations that may be

discovered after de-listing. Any new populations will be replicated. When all recovery actions have been implemented, Apache trout will exist in at least 39 stream systems providing approximately 478 kilometers (km) of stream habitat (over 1/2 the estimated historic distribution of 965 km.). Thirty-one of the streams, totaling 374 km, will be actively managed for recovery, requiring maintenance of genetic purity and protection from non-native salmonids. Ten additional streams, totaling 250 km, and 14 small coldwater reservoirs will be managed primarily for sport fishing for Apache trout that will require continued stocking of hatchery reared fish.

IMPLEMENTATION OF RECOVERY ACTIONS

De-listing of Apache trout can be accomplished if the species can be established in streams that provide suitable habitat and are isolated from intrusion by non-indigenous trout species. Apache trout recovery efforts are systematically implemented by all management agencies involved. The Apache Trout Recovery Team outlined actions needed to effect recovery of the Apache trout and are as follows: 1) Conduct comprehensive surveys to insure that all extant populations of Apache trout have been identified; 2) Conduct genetic analysis of all extant and replicated Apache trout populations; 3) Construct artificial barriers to isolate Apache trout from hybridized and non-native salmonids; 4) Chemically renovate streams to remove hybridized and non-native salmonids; 5) Replicate all current stocks to assure that any localized catastrophic event will not eliminate a valuable strain of Apache trout; 6) Physical and genetic monitoring of stocks on a continual basis to secure Apache trout populations that are critical to the recovery and maintenance of the species; 7) Habitat protection measures implemented in areas of degraded habitats to protect resident fish; and, 8) Fish hatcheries must be utilized to provide specific strains of Apache trout for both restoration and recreation.

RECOVERY ACHIEVEMENTS

Inventories

Over 50 streams in the White Mountains have been surveyed for Apache trout. The initial efforts in the recovery of the Apache trout involved intensive surveys of historical Apache trout habitat and fragmented genetic analysis. The majority of the streams on the FAIR within the historical range suspected to be inhabited by extant populations, either pure or hybridized, of Apache trout have been identified, surveyed (entire or partial), and mapped. All streams categorized as "critical" (known to contain genetically pure populations) by the Apache Trout Recovery Team have been surveyed. All streams in historic Apache trout habitat that currently contain non-native salmonids have been evaluated for their potential as replicate streams and will be renovated as needed.

Barriers

A total of 26 artificial barriers have been constructed in 21 streams to protect extant and replicated populations of Apache trout. In some streams, two and three barriers have been constructed to provide additional protection from re-invasion of non-native salmonids. These barriers are monitored, and repaired as needed, on an annual basis to insure the continued protection of the Apache trout populations upstream (USFWS, unpublished data).
In addition to the construction of artificial barriers, surveys completed within the last few years resulted in the location and mapping of 18 natural fish barriers that isolated or could be used to establish Apache trout populations. These barriers are also annually monitored.

Genetics

Biochemical genetic analysis has been conducted on 48 populations (Table 1). This has resulted in the verification of 15 unhybridized populations (USFWS unpublished data Starch Art Unpublished data). Several populations are considered potentially pure, but because of recent reintroduction efforts or low trout numbers require sampling within the next five years to confirm status (Table 1).

Renovation

Nineteen streams have been chemically renovated to remove nonnative brook and brown trout and hybrids (Table 1). Renovation techniques using Fintrol® (antimycin-A) are detailed on the product label (Aquabiotics 1986), and in Lee, et. al., (1971), Schnick (1974), Gresswell (1991), Rinne and Turner (1991), Steffereud et. al., (1992), and Tiffan and Bergersen (1996).
Replication

Table 1.—Summary of all streams, to date, involved in management and recovery of Apache trout *Oncorhynchus apache* in Arizona. Management areas involved include the Apache/Sitgreaves National Forest (ASNF), Kaibab National Forest (KNF), Coronado National Forest (CNF), and Fort Apache Indian Reservation (FAIR). Total available habitat (in kilometers) is generally upstream of an artificial or a natural barrier (noted by a superscript). Stream classification is either extant, replicate, candidate, or Apache trout predominant. Management needed indicates actions required to propose delisting of the species.

Stream (Management Agency)	Total Habitat (km) Barrier Type[1,2]	Stream Classification[3]	Management Needed[4]
Bear Wallow Creek (ASNF)	17.7[1]	Candidate	Barrier, Renovate, Replicate (Little Bonito Creek)
Big Creek (ASNF)	4.8[1]	Hybrid	Genetics, Monitor
Big Bonito Creek System (FAIR)	34.7[1]	Extant	Monitor
Boggy/Centerfire creeks (ASNF)	23.3[1]	Hybrid	Genetics, Monitor
Boggy/Lofer creeks (FAIR)	14.0[2]	Extant	Monitor
Conklin Creek (ASNF)	10.5[1]	Hybrid	Genetics, Monitor
Corduroy Creek (ASNF)	28.9[1]	Hybrid	Genetics, Monitor
Crooked Creek (FAIR)	4.0[2]	Extant	Monitor
Coyote Creek (FAIR)	3.0	Extant	Monitor
Coyote/Maime creek s (ASNF)	22.5[2]	Replicate	Genetics, Monitor
Deep Creek (FAIR)	16.0[2]	Extant	Monitor
East Fork Little Colorado River (ASNF)	14.5[1]	Candidate	Barrier, Renovate, Replicate (Big Bonito Creek)
East Fork White River (FAIR)	8.0[2]	Extant	Monitor
Elk Canyon Creek (FAIR)	13.0[2]	Extant	Monitor
Firebox Creek (FAIR)	12.0[2]	Extant	Monitor
Flash Creek (FAIR)	10.0[1]	Extant	Monitor
Grant Creek (CNF)	4.8[1]	Replicate (Ord Creek)	Genetics, Monitor
Hannagan Creek (ASNF)	6.4[1]	Replicate (East Fork White River)	Genetics, Monitor
Hayground Creek (ASNF)	6.4[1]	Replicate (East Fork White River)	Genetics, Monitor
Home Creek (ASNF)	12.8[1]	Replicate (East Fork White River)	Genetics, Monitor
Lee Valley Creek (ASNF)	3.2[1]	Candidate	Barrier, Renovate, Replicate (East fork White River and Elk Canyon creeks)
Little Bonito Creek (ASNF)	2.0[1,2]	Extant	Monitor
Little Diamond Creek (FAIR)	9.7[1]	Candidate	Barrier, Renovate, Replicate (Crooked Creek)
Marijilda Creek (CNF)	4.8[1]	Replicate -Ord Creek	Genetics, Monitor
Mineral Creek (ASNF)	4.8[1]	Replicate -East Fork White River	Genetics, Monitor
North Canyon Creek (KNF)	8.0[2]	Replicate -Ord Creek	Monitor
Ord Creek (FAIR)	6.5[1]	Replicate -North Canyon and Coyote/Maime creeks	Genetics, Monitor
Paradise Creek (FAIR)	6.5[1]	Candidate	Renovate, Replicate (Smith Creek)
Pistol Butte Creek (FAIR)	3.0[2]	Candidate	Replicate (Coyote -FAIR)
Reservation Creek (FAIR)	22.5	Hybrid	Genetics, Monitor
Smith Creek (FAIR)	1.3[2]	Extant	Monitor
Snake Creek (FAIR)	4.8	Candidate	Renovate, Replicate (Soldier Creek)
Soldier Creek (ASNF-FAIR)	3.2[2]	Extant	Monitor
South Fork Little Colorado River (ASNF)	13.7	Candidate	Barrier, Renovate, Replicate (Boggy/Lofer creeks)
Stinky Creek (ASNF)	4.0[1]	Replicate -East Fork White River	Genetics, Monitor
Squaw Creek (FAIR)	15.0[1]	Replicate (Flash Creek)	Genetics, Monitor
Thompson Creek (FAIR)	4.0[1, 2]	Replicate (Firebox Creek)	Genetics, Monitor
West Fork Black River/Burro (ASNF)	33.8[1]	Replicate (East Fork White River)	Genetics, Monitor
West Fork Little Colorado River (ASNF)	14.5	Candidate	Barrier, Renovate, Replicate (Deep creek)
Wildcat (ASNF)	8.0[1]	Replicate (Est Fork White River)	Genetics, Monitor
Wohlenberg Draw (FAIR)	8.0[1]	Candidate	Replicate (Coyote Creek-FAIR),

[1] Natural barrier defined as geologic structure (rock fall, bedrock slide, etc.) that inhibits upstream migration of non-native salmonids.
[2] Artificial barrier is constructed of gabion cages and river rock, and generally structure is covered in concrete.
[3] Streams are classified as Extant (naturally existing population), Candidate (scheduled to receive fish from an extant population), Replicate (has been stocked with fish from an extant population), or Hybrid (contains an ? Apache trout predominant? population).
[4] Management needed includes Barrier (construction of artificial barrier required), Renovate (chemically eliminate nonnative salmonids from Apache trout habitat), Replicate (stock stream with fish from an extant population), Genetics (analyze for genetic purity), and Monitor (monitor population status and habitat conditions).

To date there are 13 replicate populations representing 5 pure Apache trout populations. It is one of the goals of the Apache Trout Recovery Team and outlined in the Recovery Plan (USFWS 1979,1983,) that the 13 pure populations will be replicated into renovated streams.

Monitoring

Study protocol for the monitoring of reintroduced/introduced and replicated Apache trout populations are presently being developed. All protocol will be submitted for peer review prior to implementation.

Recreational fishing

In 1992, all rainbow trout stocking was halted from streams within historic Apache trout range. These streams are now stocked with hatchery produced Apache trout Hatchery programs to assist with recovery and provide sport fishing opportunity in selected waters within historic range should be maintained. At least ten streams will be managed as Apache trout sport fisheries requiring periodic stocking.

It will be necessary to maintain current levels of hatchery production to provide sport fishing opportunity for Apache trout and assist with recovery. Development of a hatchery brood stock to preserve observed genetic variability should be evaluated.

Habitat Protection

A total of 19 streams on federal and tribal lands have had either entire or partial reaches fenced to exclude grazing ungulates. In addition to grazing, present land uses and alterations in historical Apache trout watersheds include logging, impoundments for livestock watering, recreation, and associated roads. Efforts to minimize the impacts associated with these land management activities are being incorporated into Section 7 consultation recommendations to the USFS, WMAT and the Bureau of Indian Affairs (BIA) by the USFWS.

Monitoring

Habitat and fish populations will be monitored in all Apache trout streams at least once every 10 years to determine status. Surveys should include detailed estimates of population size, species richness and genetics, water quality characterization, benthic macroinvertebrate analysis and riparian condition. Physical barriers, instream structures and fencing installed to protect Apache trout habitat should be assessed and maintained on an annual basis. A detailed monitoring plan will be prepared.

Monitoring of fish populations and habitat at regular intervals will be necessary to evaluate the effectiveness of habitat protection measures implemented on Apache trout streams. Fish barriers, instream structures and fencing installed to protect Apache trout habitat should be inspected and maintained annually. A detailed monitoring plan will be prepared.

CURRENT STATUS

The Apache trout is currently listed as threatened. At least 14 unhybridized populations exist within historic range in Gila, Apache, and Greenlee Counties of Arizona on lands of the Fort Apache Indian Reservation (FAIR) and Apache-Sitgreaves National Forests (ASNF). These 14 populations represent 13 discrete natural stocks of pure Apache trout. One introduced population (North Canyon Creek), established on the Kaibab National Forest (KNF), outside of the species historic range, has been confirmed as unhybridized through genetic analyses. Nine additional introduced populations await genetic testing to confirm their status.

RECOVERY NEEDS TO DELIST

De-listing will be proposed when at least 30 self-sustaining populations have been established, all known natural stocks are replicated and all threats that initiated protection through listing under the Endangered Species Act of 1973 (ESA) are adequately addressed. Any additional populations discovered after delisting will also be replicated. When all recovery actions described in this plan are fully implemented, Apache trout will exist in at least 39 stream systems providing approximately 478 kilometers (km) of stream habitat. Thirty-one of these streams totaling 374 km will be actively managed for recovery, requiring maintenance of genetic purity and elimination of non-indigenous fish species. Ten additional streams with approximately 250 km of habitat and 14 small coldwater reservoirs will be managed primarily for sport fishing for Apache trout requiring periodic stocking of hatchery-reared fish. Current actions needed to further the recovery of the Apache trout so that delisting may be proposed are also outline in the Apache Trout Recovery Plan and are as follows: 1) Complete National Environmental Policy

Act (NEPA) and ESA documentation and coordination for required actions; 2) Sample and/or increase sample size to 50 for genetic analyses in 11 populations known and/or suspected to contain solely Apache trout and monitor hybridized Apache trout populations in 8 stream systems; 3) Construct fish barriers on 4 streams that will hold Apache trout and reconstruct barriers on 8 streams that currently contain Apache trout; 4) Renovate (remove all fish by poisoning) all or portions of 13 streams; 5) Replicate all 13 known natural stocks of pure Apache trout--5 have been replicated, 8 require replication; 6) Monitor fish populations and habitat conditions in all Apache trout streams; and 7) Maintain hatchery program to assist with recovery and enhance sport fishing opportunity in selected waters within historic range. If the priority tasks outlined in this plan are completed the ATLCRSRT believes that delisting of Apache trout could be initiated in 2003.

LITERATURE CITED/REFERENCES

Aquabiotics Corporation. 1986. Fintrol® fish toxicant. Aquabiotics Corporation, 3386 Commercial Avenue, Northbrook, Illinois, 60062 (EPA Reg. No. 39096-2).

Andersen, J. K. 1965. Fishery management program, Fort Apache Indian Reservation, Arizona. Special Report, U.S. Fish and Wildlife Service, Pinetop, AZ, 1-8.

Behnke, R. J. and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. U.S. Department of Agriculture, Forest Service Technical Report RM-28, 1-45. Rocky Mountain Forest and Range Experimental Station, Fort Collins, CO.

Carmichael, G. J., J. N. Hanson, M. E. Schmidt, and D. C. Morizot. 1993. Introgression among Apache, cutthroat, and rainbow trout in Arizona. Transactions of the American Fisheries Society 122:121-130.

Carmichael, G. J., J. N. Hanson, J. R. Novy, K. J. Meyer, and D. C. Morizot. 1995. Apache trout management: cultured fish, genetics, habitat improvements, and regulations. American Fisheries Society Symposium 15:112-121.

Cope, E. D. and H. C. Yarrow. 1875. Report upon the collection of fishes made in portions of Nevada, Utah, California, Colorado, New Mexico, and Arizona, during the years 1871, 1872, 1873, and 1874. Report Geography Geology Exploration Survey W. 100th Meridian (Wheeler Survey), 5:635-703.

Genean Laboratories. 1995-2000. Unpublished data. Starchart Corporation, Smithville, TX.

Greenwalt, L. A. 1975. "Threatened" status for three species of trout. Federal Register 40 (137):29863-64.

Gresswell, R.E. 1991. Use of antimycin for removal of brook trout from a tributary of Yellowstone Lake. North American Journal of Fisheries Management 11:83-90.

Harper, K. C. 1976. On the biology of *Salmo apache* and its management implications. MS Thesis, University of Arizona, Tucson, AZ, 31 pp.

Harper, K. C. 1978. Biology of a southwestern salmonid, *Salmo apache* (Miller 1972). Pages 99-111 in J. R. Moring, editor. Proceedings of the wild trout-catchable trout symposium. Oregon Department of Fish and Wildlife, Research and Development Section, Eugene, Oregon.

Jordan, D. S. and B. W. Evermann. 1896. The fishes of north and middle America. Bulletin of the United States Natural History Museum, Part 1, 47:i-ix - 1-1240.

Lee, T.H., P.H. Derse, and S.D. Morton. 1971. Effects of physical and chemical conditions on the detoxification of antimycin. Transactions of the American Fisheries Society 100:13-17.

Loudenslager, E. J., J. N. Rinne, G. A. E. Gall, and R. E. David. 1986. Biochemical genetic studies of native Arizona and New Mexico trout. Southwestern Naturalist 31:221-234.

Miller, R. R. 1950. Notes on the cutthroat and rainbow trouts with the description of a new species from the Gila River, New Mexico. Occasional Papers of the Museum of Zoology, University of Michigan, 529:1-42.

Miller, R. R. 1972. Classification of the native trouts of Arizona with the description of a new species, *Salmo apache*. Copeia 1972:401-422.

Morizot, D. C., and M. E. Schmidt. 1990. Starch gel electrophoresis and histochemical visualization of proteins. Pages 23-80 in D. H. Whitmore, editor. Electrophoretic and isoelectric focusing techniques in fisheries management. CRC Press, Boca Raton, Florida.

Rinne, J.N., and P.R. Turner. 1991. Reclamation and alteration as management techniques with a review of methodology in stream renovation. In Minckley, W.L., and J.E. Deacon, editors. Battle against extinction: native fish management in the American west. University of Tucson Press, Tucson, Arizona.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. B. Lea and W. B. Scott. 1991. Common and scientific names of fishes from the United States and Canada (Fifth Edition). American Fisheries Society Special Publication No. 20. Bethesda, MD. 183 pp.

Schnick, R.A. 1974. A review of the literature on the use of antimycin in fisheries. U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Fish Control Laboratory, LaCrosse, Wisconsin. 85 pp.

Steffereud, J.A., D.L. Propst, and G.L. Burton. 1992. Use of antimycin to remove rainbow trout from White Creek, New Mexico. Proceedings of the Desert Fishes Council 23:55-66.

Tiffan, K.F., and E.P. Bergersen. 1996 Performance of antimycin in high gradient streams. North American Journal of Fisheries Management 16:465-468.

USFS (U.S. Forest Service). 1985. Fisheries Habitat Survey Handbook. USFS, Region 4-2609.23.

USFWS (U.S. Fish and Wildlife Service). 1979. Recovery plan for Arizona trout, *Salmo apache*, Miller, 1972. Apache Trout Recovery Team. USFWS, Albuquerque, NM, 36 pp.

USFWS (U.S. Fish and Wildlife Service). 1983. Recovery plan for Arizona trout, *Salmo apache*, Miller, 1972. Apache Trout Recovery Team. USFWS, Albuquerque, NM, 38 pp.

Blackfoot River Restoration: A Private Land Fisheries Initiative

Ron Pierce[1]

Abstract—The Blackfoot River drainage, located in west-central Montana, is the site of a comprehensive fisheries restoration program. The program began with the initiation of studies that identified 1) mining impacts in the headwaters, 2) fishery over-exploitation, 3) and degradation of tributaries as primary reasons for significant fishery declines. From these findings, a restoration initiative evolved into a basin-wide resource conservation effort largely dedicated to improving wild trout populations and particularly native westslope cutthroat trout (*Onchorynchus clarki lewisi*) and bull trout (*Salvelinus confluentus*) populations. The program focus is the foundation of all healthy fisheries-quality habitats. Restoration includes improving migration corridors, restoring damaged habitat, improving stream flows, protecting critical spawning habitat, improving riparian livestock management and enrolling landowners in conservation easement programs. To date, we have completed restoration on 34 tributaries; most are located on private agricultural ranchlands. Blackfoot River fish population monitoring have shown substantial increases in cutthroat trout densities and increasing bull trout densities. Tributary monitoring has shown a regional improvement in wild trout populations including native salmonids. The Blackfoot River initiative demonstrates that solutions to significant fish population declines can occur among diverse interest groups and multiple landowners over a large spatial scale.

INTRODUCTION

Fish population studies in the late 1980s and early 1990s identified that 1) mining impacts in the headwaters, 2) over-exploitation of the fishery, and 3) extensive degradation of tributary habitats contributed to historic declines in Blackfoot River fish populations. These studies also documented low densities of native westslope cutthroat (*Onchorynchus clarki lewisi*) trout at the mid- to low elevations of the Blackfoot Watershed (Peters and Spoon 1989, Peters 1990). Bull trout (*Salvelinus confluentus*) densities were low basin-wide, with local populations extirpated in several streams. Fisheries investigations found that early life stages of salmonids in the lower Blackfoot River rely on tributaries. Tributary assessments reported extensive problems that spanned multiple land ownerships and resulted in fish population declines at a regional scale (Peters and Spoon 1989, Peters 1990, Pierce et al. 1997, Pierce and Schmetterling 1999).

Low numbers of adult rainbow (*O. mykis*) and brown trout (*Salmo trutta*) at the low to mid elevations of the watershed, combined with high winter mortality of young-of–the–year (YOY) and poor tributary habitats resulted in weak recruitment to river populations for these species (Peters and Spoon 1989, Peters 1990, Pierce et al. 1997). Reliance of native fish on upper tributaries at early life stages indicates adaptation to the severe environment of the Blackfoot River. However, due to poor tributary conditions, long migrations and more extensive use of the tributaries, fluvial native fish are also more subject to human impacts in the tributary system than introduced fish species.

In 1990, following two years of basin-wide habitat and fish population assessments, recovery efforts began with the basin-wide adoption of catch-and-release fishing regulations for both bull trout and westslope cutthroat trout (cutthroat trout hereafter). Since then, recovery has been directed to habitat

[1] *Fisheries Research Specialist, Montana Fish Wildlife and Parks, 3201 Spurgin Road Missoula, MT 59804.*

restoration on tributaries to the lower Blackfoot River from the North Fork down river.

During this effort, 34 tributaries to the Blackfoot River received special riparian and upland restoration activities that provide for the needs of riparian-dependant species including wild trout populations. Priority for restoration was given to streams supporting populations of native cutthroat trout and bull trout, within the focus area of the lower to middle Blackfoot River. Restoration tools include reconstructing stream channels and restoring habitat features to damaged streams, developing low impact grazing systems and removing streamside feedlots, planting native riparian vegetation, improving stream flows, restoring fish migration corridors and enrolling landowners in perpetual conservation easement programs. Cooperators included private landowners, non-profit groups, and state and federal agencies.

STUDY AREA

The Blackfoot River, located in west-central Montana, flows 132 miles in a westerly direction from its headwaters near the Continental Divide to its confluence with the Clark Fork River at Bonner Montana (Figure 1). Mean annual discharge is 1,597 cubic-feet-per-second (cfs). This river system drains 2,400 square miles through a 3,700-mile stream network of which 1,900 miles are perennial streams capable of supporting fish populations. The physical geography of the watershed ranges from high elevation glaciated alpine meadows to prairie pothole topography on the valley floor. Glacial landforms, moraine and outwash, glacial lake sediments and erratic boulders cover the entire floor of the Blackfoot River valley and exert a controlling influence on the habitat features of the Blackfoot River. The Blackfoot River is a free flowing river to its confluence with the Clark Fork River where Milltown dam, a run-of-the-river hydroelectric facility, has blocked upstream fish passage since 1907.

Land ownership in the Blackfoot watershed is 44% National Forest, 5% Bureau of Land Management, 7% State of Montana, 20% Plum Creek Timber Company and 24% other private ownership. In general, public lands and large tracts of Plum Creek Timber Company properties comprise the forested mountainous areas while private lands are located in the foothills and lower valley areas. Traditional land-use in the basin includes mining, timber removal and agricultural activities, all of which have contributed to habitat degradation and fish population declines. Of 61 inventoried streams, 50 have been altered or otherwise identified as degraded. The majority of degradation occurs on floor of the Blackfoot Valley on private agricultural ranchlands (Pierce and Podner, 2000).

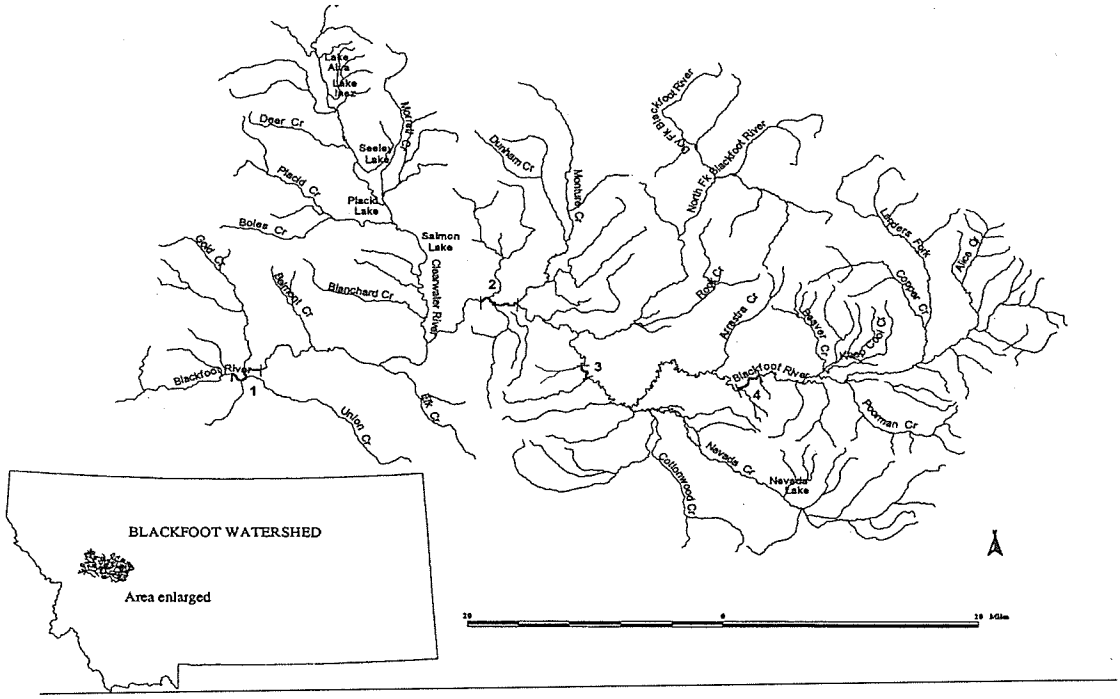


Figure 1.—Blackfoot River Watershed and Ifour long-term fish population monitoring stations: 1) Johnsrud Section, 2) Scotty Brown Bridge Section, 3) Raymond Bridge Section, and 4) Canyon Section.

The Blackfoot River and tributaries are managed for "Wild Trout" and support a diversity of wild trout populations. Distribution patterns of most salmonids generally conform to the physical geography of the landscape, with species richness increasing longitudinally in the downstream direction. Species assemblages and densities of fish can also vary greatly at the lower elevations of the watershed

Most salmonids (westslope cutthroat trout, bull trout, rainbow trout and brown trout) in the river system exhibit migratory life-history characteristics. Westslope cutthroat trout has a basin-wide distribution and is the most abundant species in the upper reaches of the tributary system. Bull trout distribution extends from the mainstem Blackfoot River to extreme headwaters of larger tributaries north of the Blackfoot River; however, juvenile bull trout will rear in several smaller "non-spawning" tributaries, some of which are located in the Garnet Mountains (Pierce and Schmetterling 1999). Both fluvial westslope cutthroat trout and bull trout migrations have been documented in excess of 50 miles between the Blackfoot River and tributary spawning sites (Swanberg 1997, Schmetterling 2000). Rainbow trout distribution is limited to the lower Blackfoot River and lower reaches of the lower river tributaries; this species occupies approximately 8-10% of the perennial streams in the Blackfoot Watershed and reproduces primarily in the lower portions of larger south flowing tributaries. Brown trout inhabit approximately 15% of the perennial stream system with a distribution that extends from the Landers Fork down the length of the Blackfoot River and into the lower foothills of the tributary system. Although some mainstem brown trout spawning occurs in the upper Blackfoot River, lower river brown trout reproduce in lower reaches of tributaries. Brook trout are widely distributed in the watershed although rarely found in the mainstem Blackfoot River below Landers Fork.

Because of extensive tributary use by these species and poor habitat conditions at the low- to mid elevations, much of the restoration has been directed to the private agricultural ranchlands, located in the foothills and valley floor (Figure 2).

WORKING WITH PRIVATE LANDOWNERS: THE KEY TO SUCCESSFUL RESTORATION

Restoration efforts in the Blackfoot River watershed focus on restoring degraded tributaries by improving riparian areas and fish habitat. Typically

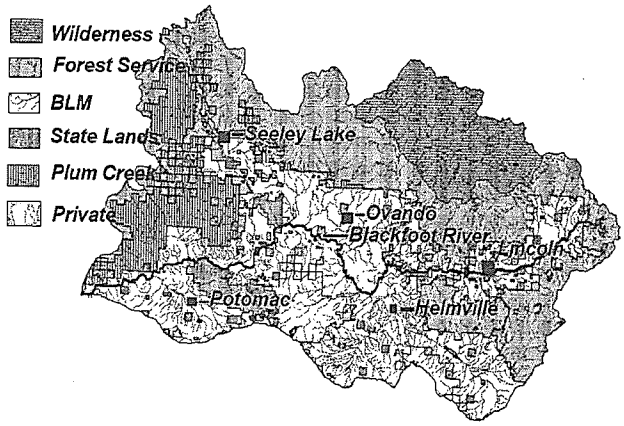


Figure 2.—Generalized landownership for the Blackfoot watershed.

each tributary project involves multiple landowners, multiple professional disciplines, more than one funding source and the involvement of a watershed group. Restoration has focused on addressing obvious impacts to fish populations such as migration barriers, stream de-watering, fish losses to irrigation canals and degraded riparian areas. All projects are cooperative efforts between private landowners and the restoration team, and occur throughout the drainage although the majority of effort has focused on tributaries from the North Fork down river. All projects are voluntary, incorporate landowner needs (such as irrigation and grazing objectives), and are administered at the local level by a core group of agency resource specialists in cooperation with local watershed groups (non-profit 501©(3)), including both the Big Blackfoot Chapter of Trout Unlimited and the Blackfoot Challenge, or local government groups such as the North Powell Conservation District. Tax incentives associated with a non-profit status of the watershed group are considered critical to private fund-raising efforts.

Two full-time restoration biologists help coordinate restoration efforts (wildlife biologist from the U. S. Fish and Wildlife Service-Partners for Fish and Wildlife Program, and a fisheries biologist from the Montana Fish, Wildlife and Parks). A lead biologist generally enlists help from interagency personnel including range conservationists, hydrologists, engineers and water rights specialists as necessary. In turn, the watershed groups help prioritize projects, administer budgets, solicit bids and assist with landowner contracts, resolve conflicts and help address other local social issues.

Cost sharing of projects is arranged by project personnel and comes from many sources including

landowner contributions, private donations, foundation grants, and state and federal agency programs. Project biologists and/or the watershed group undertakes grant writing and fund-raising. The lead biologist usually writes environmental assessments and obtains project permits on behalf of the cooperating landowner.

Project bids for consulting and construction services follow State and Federal procurement policies. These policies included the development of Blackfoot Watershed qualified vendors lists (QVL) derived through a competitive process. A minimal project cost triggers the use of the QVL. The watershed groups solicit bids from the QVL for both consulting and contractor services. Bid-contracts are signed between the watershed group and the selected vendor upon bid acceptance.

Depending on the specific project, landowners are responsible for much of the construction and maintenance of projects. Addressing the source of stream degradation usually requires developing riparian/upland management options sensitive to the requirements of fish and other riparian-dependent species. Written agreements with landowners to maintain projects for a 15-30 year period are arranged with cooperators on each project. These agreements vary by funding source and may include either agencies, the North Powell Conservation District and/or the Fish and Habitat Committee of the Big Blackfoot Chapter of Trout Unlimited.

Landowner awareness of the habitat requirements of fish and wildlife and their full participation in projects are considered crucial to the long-term success of the restoration initiative. Landowners are encouraged to participate in all project phases from fish population data collection, to problem identification and restoration, to monitoring of completed projects. Although many restoration projects have been completed in the Blackfoot River watershed, this effort is considered educational at a broad level and is far from complete.

NATIVE FISH RESTORATION OVERVIEW

Most of the restoration effort is directed toward the recovery of bull trout and westslope cutthroat trout; both are considered sensitive species. Bull trout is currently a Threatened species under the Endangered Species Act. Westslope cutthroat trout is classified a "species of special concern" in Montana as designated by the American Fisheries Society.

Bull Trout Recovery

The primary goals of the bull trout recovery effort are to restore metapopulations, conserve genetic diversity, and restore and maintain connectivity within and between all restoration and seven conservation areas.

The Blackfoot River currently supports one of the better populations of fluvial bull trout within the range of the species (Peters 1985). Nevertheless, fisheries investigations in the mid-to late 1980s indicated declining populations. Excluding the Clearwater drainage, fluvial bull trout currently inhabit 20 Blackfoot River tributary streams. Currently, fluvial bull trout inhabit approximately 120 miles of the Blackfoot River mainstem and approximately 335 miles of tributaries. Bull trout presence has not been documented in the Blackfoot River between the North Fork and Nevada Creek. Beginning in 1994, radiotelemetry studies of bull trout have documented extensive movements between river and tributary habitats, for both spawning and thermal refugia. The mean distance for the upstream spawning migration for 30 Blackfoot River bull trout was 39 $\pm$ 13 river miles in 1994 (Swanberg 1997). Juvenile bull trout generally rear for two to three years before out-migrating to the mainstem Blackfoot River. By far the majority of fluvial bull trout reproduction and rearing occurs in Monture Creek and the North Fork Blackfoot River, while most of the reproduction for a smaller upper Blackfoot River population occurs in Copper Creek.

Bull trout recovery efforts began in 1990 with the adoption of catch-and-release fishing regulations. Throughout the decade of the 1990s, bull trout recovery efforts were undertaken in five of seven "core" area drainages, and several streams historically supporting bull trout (Pierce et al. 1997, Pierce and Schmetterling 1999). To date, the majority of bull trout recovery has been directed to the Monture Creek and the North Fork Blackfoot River watersheds which include eight tributary streams. Major efforts included: 1)fish screening on nine irrigation ditches; 2) riparian livestock management changes on 32 miles of riparian corridor; 3) removing seasonal migration barriers in three rearing tributaries, 4) instream habitat restoration and erosion control efforts on 15 miles of severely degraded stream; 5) increasing stream flows on 5 streams; 6) protection of spawning areas from livestock (Figure 3); and 7) enlisting landowners in perpetual conservation easements programs along 16 miles of riparian corridor.

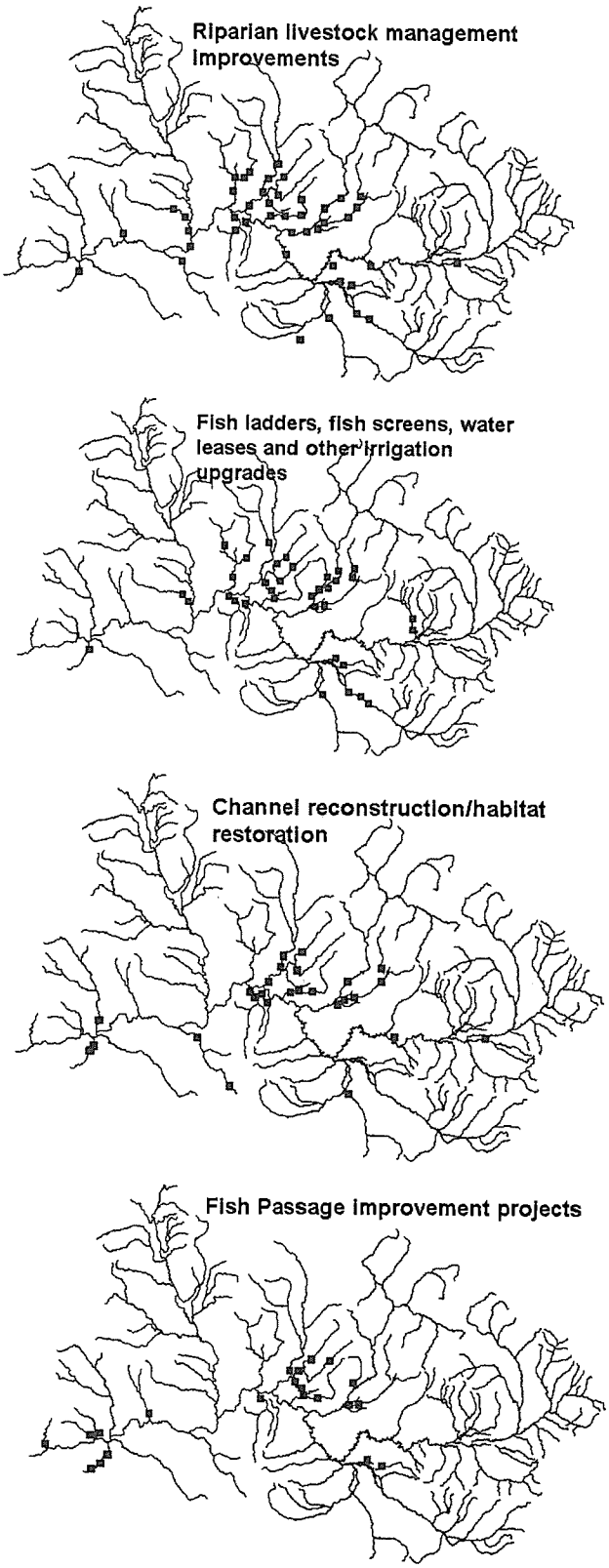


Figure 3.—Location map of principle restoration activities.

As a result of these efforts, reproduction and rearing have increased in both Monture Creek and the North Fork. From 1989 to 2000, redd counts increased from 10 to 74 in the index reach of Monture Creek and from 7 to 123 in the North Fork Blackfoot River. Juvenile bull trout densities were increasing in both Monture Creek and the North Fork (Figure 4). Juvenile bull trout also appear to be expanding into several restored smaller "non-spawning" tributaries including Bear, Chamberlain, East Twin, Rock, Kleinschmidt and Spring Creeks (Pierce et al. 1997, Pierce and Schmetterling 1999). From 1989 through 2000, bull trout densities in two lower river sampling locations (Johnsrud and Scotty Brown Sections) have increased as well (Figure 5). In contrast, the upper population river (upstream of the North Fork) show a static 10 year for redd counts trend in Copper Creek and very low population densities in the upper Blackfoot River (Pierce and Podner, 2000).

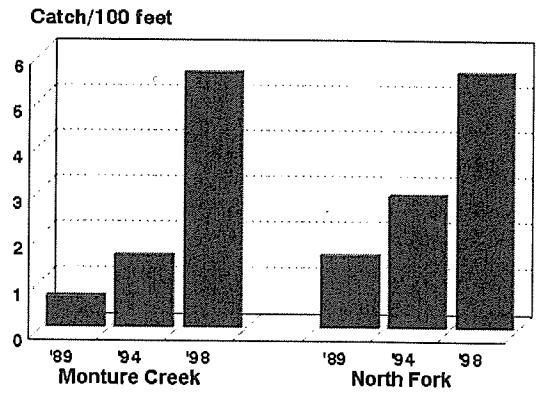


Figure 4.—Electrofishing catch for juvenile bull trout in Monture Creek and North Fork Blackfoot River, 1989, 1994 and 1998.

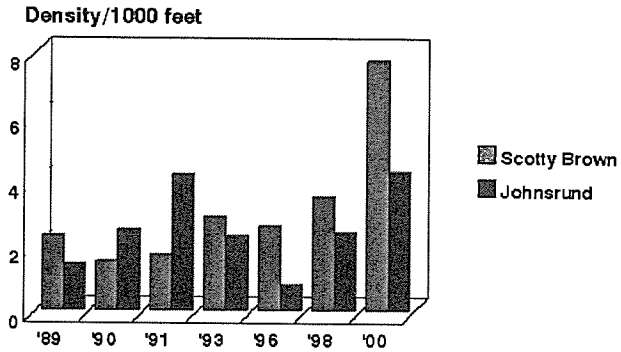


Figure 5.—Estimated bull trout densities (fish >6.0 inches) for two sections of the Blackfoot River, 1989-2000.

Westslope Cutthroat Trout Recovery

Westslope cutthroat trout like bull trout rely on high quality habitat in tributaries for spawning, rearing and over-wintering. Free access from large river systems to headwater spawning streams is also necessary for the fluvial life-history form. Cutthroat trout migrate into headwater tributaries for spawning purposes. Seventy mile upstream movements have been recorded in the Blackfoot Basin (Schmetterling, 2000). Juvenile westslope cutthroat trout generally rear two to four years in small tributaries before migrating downstream to the large river system. Most of the migration cooridors, plus much of the spawning and rearing habitat are found on private lands.

Due to their reliance on tributaries at early life stages, significant restoration activity has been directed toward 1st through 3rd order tributaries. In conjunction with fluvial bull trout recovery efforts, the focus of fluvial cutthroat trout restoration is reestablishing the fluvial life-history form by: 1) reducing or eliminating "controllable" sources of mortality; 2) maintaining or restoring existing spawning and rearing habitats; 3) restoring damaged habitats; and 4) reestablishing connectivity for the Blackfoot River to spawning areas. Restoration projects targeting these features have been completed throughout the tributaries of lower Blackfoot River drainage.

Cutthroat trout are currently increasing in abundance in the lower elevations, including 108 miles of the mainstem Blackfoot River downstream of Poorman Creek. And similar to bull trout, the largest density increases for the Blackfoot River cutthroat trout are occurring downstream of the North Fork Blackfoot River (Pierce and Podner 2000). Between 1989 and 2000, fluvial cutthroat trout (fish >6.0") in the lower Blackfoot River have increased from 1.7 to 17.4 fish/1,000' in the Johnsrud Section and from 2.9 to 24.9 fish/1,000' in the Scotty Brown Bridge section (Figure 6). Monitoring of tributary restoration projects show increased cutthroat trout densities in sections of the North Fork Blackfoot River, Monture, Chamberlain, Gold, McCabe, Pearson, Dunham, Spring, Warren and Cottonwood Creeks (Pierce and Schmetterling, 1999, Pierce and Podner, 2000). Radiotelemetry studies confirm several of these restored tributaries support fluvial cutthroat trout.

Catch-and-release regulations initiated in 1990 contribute to fluvial cutthroat trout throughout the mainstem Blackfoot River, including both the Canyon and Raymond Bridge sampling locations. These upper river reaches have received limited restoration

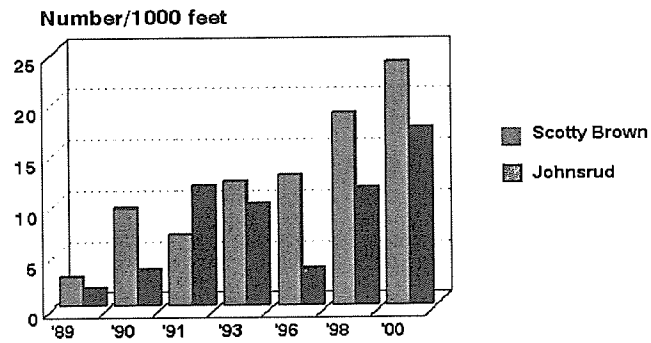


Figure 6.—Estimated westslope cutthroat trout densities (fish >6.0 inches) for two sections of the Blackfoot River, 1989-2000.

activities. Recent population surveys for these two locations, particularly the Raymond Bride section, indicate continued weak recruitment and much lower overall densities compared to the lower Blackfoot River recovery area (Pierce and Podner, 2000).

Located between Nevada Creek and the North Fork, survey results from the Raymond Bridge fish population section outline the importance of tributary function and habitat restoration to the fish population recovery in this section of river. Low fish population densities and habitat problems in this river reach initially were identified in 1988 (Peters and Spoon 1989). In 1999 a duplicate sample recorded comparable low densities. In 1999, only eight cutthroat trout were captured in a 1.1 mile of river after three electrofishing passes. No YOY or age 1 rainbow trout or brown trout were recorded in the 1999 sample. Furthermore bull trout have not been documented in this river reach (Peters and Spoon 1989, Pierce and Podner 2000). The 1999 survey at the Raymond Bridge section show much lower total trout densities (fish >6.0 inches) compared to up and downstream river reaches (Figure 7).

Recruitment problems and low native fish numbers seem to result largely from degraded and dewatered tributaries in this river reach. Several small streams enter this reach from the Garnet Mountains, all of which support populations of westslope cutthroat trout in the headwaters; yet, populations decline in lower reaches of all tributaries in this river reach. These tributaries all suffer chronic dewatering, degraded riparian areas, and water quality problems and/or fish losses to irrigation ditches in lower reaches (FWP several studies). If fish populations in this section of river are to improve, the clearly the river corridor and the lower reaches of these tributaries will require restoration efforts like those undertaken in the restoration focus area.

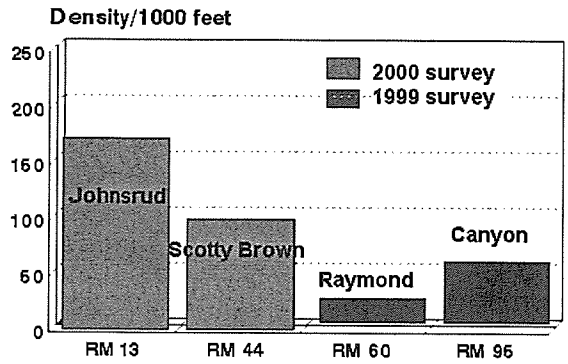


Figure 7.—Total trout densities (fish >6.0 inches) for four sections of the Blackfoot River.

SUMMARY

A major private lands fisheries restoration initiative is currently in process in the Blackfoot River Watershed. The effort relies on one-on-one contact between the landowner and project biologist with support from a watershed group and other agency professionals. The effort attempts to meet both landowner and fish population recovery objectives, and rely heavily upon mutual cooperation to meet restoration objectives. The Blackfoot River initiative demonstrates that solutions to significant environmental challenges can occur among diverse interest groups and multiple landowners over a large spatial scale. To date, this initiative has completed restoration efforts on 34 streams and has influenced approximately 300 miles of tributary stream. The results of which further include:

- 40 cubic-feet-per-second of increased Blackfoot River flows during base flow periods
- 28 miles of enhanced stream flows in tributaries
- 2,600 surface acres of restored wetland
- 1,800 acres of restored native prairie
- 35,000 acres of improved grazing management
- 72,000 acres of perpetual easements placed on private land

Restrictive fishing regulations combined with restoration efforts have contributed to broad improvements in native fish populations at the low to mid-elevations of the watershed. Several restoration tributaries are supporting increased densities of cutthroat trout. Fluvial cutthroat trout recruitment has increased substantially in river reaches influenced by the restoration effort. Fluvial cutthroat trout densities have increased approximately 1,000% in the lower to middle reaches of the Blackfoot River downstream of the North Fork confluence. Bull trout densities, although low, are increasing in two primary spawning streams (Monture Creek and the North Fork Blackfoot River); these improvements contribute to increased recruitment of bull trout to the lower Blackfoot River population. Upstream of the restoration focus area, bull trout population surveys show low densities and a static population trend through the decade of the 1990s.

Although native fish populations are improving in the lower watershed, addressing major environmental issues such as mining impacts and habitat problems is far from complete. Most of the Blackfoot Watershed has received limited restoration effort; these areas include the upper Blackfoot River drainage upstream of Nevada Creek, the Garnet Mountains, the Clearwater River drainage and the upper Nevada Creek drainage. In addition, several issues beyond the original scope of identified problems have emerged in the last several years. These additional challenges to the conservation of native fishes include: 1) the introduction of exotic fishes including northern pike (*Exos lucius*) to the Blackfoot River drainage; 2) the remediation of Milltown dam impacts; 3) the introduction and rapid escalation of whirling disease; and 4) significant upward trends in recreational river use, combined with the inability of anglers to identify bull trout and unintentional illegal harvest (Schmetterling and Long 1999, Bohneman and Schmetterling 2000).

ACKNOWLEDGMENTS

Many agencies, organizations and individuals contributed to the Blackfoot River restoration effort. Above all, the Big Blackfoot Chapter of Trout Unlimited, Chutney Foundation, Montana Power Company, the North Powell Conservation District, Bureau of Land Management and the U. S. Fish and Wildlife Service deserve special thanks for funding the field positions, special projects and much of the restoration efforts. The private landowners deserve the most credit for accepting new ideas, mending fences, and maintaining fish screens and all the additional work they have incorporated into their daily lives. Their stewardship is the key the long-term recovery of the native fish species.

LITERATURE CITATIONS

Bohneman, M., and D. A. Schmetterling. 2000. 1999 Blackfoot River crel survey Montana Fish, Wildlife and Parks. Missoula, Montana.

Marler, M. 1998. Riparian vegetation and health on the Blackfoot River between Nevada Creek and the North Fork confluence. Report prepared for the North Powell Conservation District and Montana Fish, Wildlife and Parks, Missoula, Montana.

Montana Fish, Wildlife and Parks. 1991, 1997. Statewide Fishing Pressure Estimates. Bozeman, Montana.

Peters, D. 1985. Current status of bull trout in the headwaters of the Clark Fork River, Montana. Page 37 in D. D. MacDonald, editor, Proceedings of the Flathead River basin bull trout biology and population dynamics modeling Information exchange Fisheries Branch, Brithish Columbia Ministry of Environmental. Cranbrook, British Columbia.

Peters, D. and R. Spoon. 1989. Preliminary fisheries inventory of the Big Blackfoot River. Montana Department of Fish, Wildlife and Parks, Missoula, Montana.

Peters, D. 1990. Inventory of fishery resources in the Blackfoot River and major tributaries to the Blackfoot River. Montana Department of Fish, Wildlife and Parks, Missoula, Montana.

Pierce, R, 1991. A stream habitat and fisheries analysis for six tributaries to the Blackfoot River. Montana Department of Fish, Wildlife and Parks, Missoula, Montana.

Pierce, R., D. Peters and T. Swanberg. 1997. Blackfoot River restoration progress report. Montana Fish Wildlife and Parks, Missoula, Montana.

Pierce, R., and D. Schmetterling. 1999. Blackfoot River restoration project monitoring and progress report 1997-1998. Montana Fish, Wildlife and Parks, Missoula, Montana.

Pierce, R., and C. Podner. The Blackfoot River fisheries inventory, monitoring and restoration report 2000. Montana Fish, Wildlife and Parks, Missoula, Montana.

Schmetterling D. and M. Long. 1999. Montana anglers inability to identify bull trout and other salmonids. Fisheries Vol. 24 No. 7, pp. 24-27.

Schmetterling, D. A. 2000. Seasonal movement of fluvial westslope cutthroat trout in the Blackfoot drainage. Montana. Montana Fish, Wildlife and Parks, Missoula, Montana.

Swanberg, T. R. 1997. The movement and habitat use of fluvial bull trout in the Blackfoot River. Transactions of the American Fisheries Society 126:735-746.

Swanberg, T. and L. Burns. 1997. Movement and habitat use of radioed tagged bull trout in the upper Blackfoot River drainage, Special report Region 2 Fisheries. Montana Fish, Wildlife and Parks, Missoula, Montana.

A Plan to Gain Public Support for Native Trout Restoration by Improving Sport Fishing

Dale K. Hepworth, Charles B. Chamberlain, and Michael J. Ottenbacher[1]

Abstract—Efforts to conserve native trout in Utah have often been controversial. Local governments, resource managers, special interest groups, and anglers have expressed concern over the consequences of expanding populations of any species which could be potentially listed under the Endangered Species Act. The concerns of governments, managers, and organized groups have been addressed through their inclusion in work groups which have developed formal conservation agreements, completed plans to satisfy state law, and conducted National Environmental Policy Act processes. The general angling public has, for the most part, not been highly involved in planning efforts and is often apprehensive when native trout conservation projects are proposed. Anglers often view such projects as conflicting with popular sport fisheries for nonnative trout. Because public support is essential to continued conservation efforts, a strategic plan to build angler support should be a part of any conservation plan or recovery effort. In southern Utah, that plan includes the use of native trout to improve sport fisheries in areas which presently contain poor fisheries for nonnative brook trout *(Salvelinus fontinalis)*. Between 1969 and 1982, rotenone was used to eliminate stunted brook trout from three lakes on Boulder Mountain. These waters were subsequently stocked with nonnative cutthroat trout, with a resulting increase in the mean size of trout available to anglers. Similar projects are planned at as many as 16 waters in southern Utah where fisheries of stunted brook trout will be replaced with locally native Bonneville and Colorado River cutthroat trout (*Oncorhynchus clarki utah* and *O. c. pleuriticus*, respectively), which are now available from wild brood stocks.

INTRODUCTION

Fishery managers in western states are faced with the dilemma of maintaining sport fishing recreation for popular nonnative trout while at the same time conserving and expanding native cutthroat trout populations in an attempt to prevent the need to federally list these subspecies under the Endangered Species Act (ESA). These objectives can be in conflict when the fishing public perceives that popular sport fisheries are being jeopardized by native trout restoration projects. Within southern Utah, sport fish conflicts on restoration projects for Bonneville and Colorado River cutthroat trout (*Oncorhynchus clarki utah* and *O. c. pleuriticus*, respectively) conducted over the past 24 years were largely avoided by restricting projects to small isolated streams where little fishing pressure occurred. Nevertheless, as restoration programs have grown, become more publicized, and expanded into larger drainages that contain popular sport fisheries, the potential for conflict has increased. Conflicts have been minimized with local governments, land management agencies, and organized groups by the inclusion of these groups in the development of State plans, Conservation Agreements, and National Environmental Policy Act (NEPA) processes as they pertain to native trout, but the majority of anglers are not involved in such efforts and some anglers remain apprehensive.

Future success and direction of native trout restoration projects will be largely dependent on public support. Fishery management plans for the Boulder Mountain, in south-central Utah, include the use of

[1] *The authors are the Aquatic Program Manager and Regional Biologists, respectively, for the Southern Region Utah Division of Wildlife Resources, P.O. Box 606, Cedar City, Utah 84720 E-mail: dhepwort@email.state.ut.us*

native trout to improve fishing in small lakes and thereby gain support and credibility with sport fish anglers. Approximately 80 small lakes, reservoirs, and ponds are managed as sport fisheries on the Boulder Mountain, many of which provide exceptional fishing for brook trout *(Salvelinus fontinalis)*. Up to 16 of these lakes and ponds, however, are being considered for renovation where stunted brook trout have failed to provide acceptable levels of sport fishing. The plan is intended to improve sport fishing on Boulder Mountain without impacting popular sport fishing waters, and includes the expanded use of native trouts as a secondary benefit. The purpose of this paper is to describe the plan, including the affected resource and expected benefits, particularly as it applies to native cutthroat trout.

PROJECT AREA

The Boulder Mountain, technically named the Aquarius Plateau on U.S. Geological survey maps, includes headwaters of the Fremont River drainage on its north and east slopes, the Escalante River drainage on the south and east slopes, and a small portion of the East Fork Sevier River drainage on the west slope. The project area includes the Teasdale and Escalante Ranger districts of the Dixie National Forest. Colorado River cutthroat trout are native to the Fremont and Escalante River drainage and Bonneville cutthroat trout are native to the Sevier River drainage. Remnant populations of Colorado River cutthroat trout are found in five isolated headwater tributaries to the Escalante River drainage on the Boulder Mountain (Hepworth et al. in press). One remnant population of Bonneville cutthroat trout is located on Boulder Mountain in the East Fork Sevier River drainage (Hepworth et al. 1997), and no remnant populations of native cutthroat trout are presently known from the Fremont River drainage on Boulder Mountain.

Geologically, Boulder Mountain is a relatively productive basalt and sandstone formation that extends to elevations over 3350 m (msl). Numerous lakes and ponds, generally < 24 ha in size are found both on top of the plateau and around the mountain just under the rim of the plateau. Sport fisheries have been developed in many of these waters as well as in a number of small irrigation storage reservoirs that were constructed 40-60 years ago. Because of the general remoteness of the location, the plateau was not explored until 1872 and the Escalante River was noted as the last large river drainage added to the map of the continental United States (Stegner 1954). Stocking of nonnative trouts was first recorded in the 1940s and sport fishing thereafter became popular. Many remote lakes were first stocked by pack horse or airplane, which are still the primary means of stocking many of these lakes today.

Despite introductions of rainbow trout (*O. mykiss*), brown trout *(Salmo trutta)*, and nonnative cutthroat trout (primarily the Yellowstone subspecies *O. c. bouvieri*), Boulder Mountain is most notable for its exceptional brook trout fishing. Brook trout in the 0.7 to 1.4 kg range are common, and some brook trout in excess of 2.3 kg are harvested almost every year. Boulder Mountain lakes are generally more productive than many other alpine lakes, especially those in granitic formations. When fingerling-size (> 75 mm) brook trout are stocked at the rate of 125 fish per ha, growth can exceed an average of 0.5 kg per fish in a year, with some fish exceeding 2.0 kg by the third summer (surviving two winters). Mean condition (K_{TL}) for brook trout populations can exceed 1.3. Brook trout are often larger than other nonnative trouts, including cutthroat trout within the same lake. The Utah state record brook trout is a 3.4 kg fish caught on Boulder Mountain in 1971.

Although brook trout have been successful in many Boulder Mountain locations, they have over-populated in some waters and stunted. Natural reproduction has been so extensive in some lakes that brook trout do not exceed a total length (TL) of 260 mm, and in some lakes brook trout have a mean condition factor as low as 0.86. At least nine rotenone treatment projects have been conducted on Boulder Mountain lakes containing stunted brook trout populations between 1969 and 1984 (Table 1).

Treatment projects either temporarily reduced brook trout numbers and improved growth, or allowed complete replacement of brook trout with nonnative cutthroat trout. Because cutthroat trout reproduced to a lesser extent than brook trout (or were stocked in controlled numbers) and because of the general high productivity of the lakes, restored fisheries produced larger trout than under pre-treatment conditions. Increased recreation occurred after treatment at all renovated lakes.

Table 1.— Waters treated for stunted brook trout on Boulder Mountain and results, 1969-1984. Results: Complete kill = eradication of all brook trout successful; Incomplete kill = eradication of all brook trout unsuccessful; Planned partial kill = no attempt made to remove all brook trout.

Water	Year	Results	Comments
Crescent Lake	1969	Complete kill	Good fishing to present for cutthroat trout.
Fish Creek Res	1970	Incomplete kill	Good fishing for about 3 years for brook trout.
Beaver Dam Res	1970	Planned partial kill	Good fishing for about 10 years for brook trout.
Round Willow Res	1971	Incomplete kill	Good fishing for about 3 years for brook trout.
Oak Creek Res	1973	Complete kill	Good fishing to present. *
Short Lake	1982	Incomplete kill	Good fishing for about 3 years for brook trout.
Moseman Lake	1982	Complete kill	Good fishing to present for cutthroat trout.
Fish Creek Res	1984	Planned partial kill	Good fishing for about 3 years for brook trout.
Beaver Dam Res	1984	Planned partial kill	Declining but good fishing to present for brook trout.

* Good fishing until about 1990 for cutthroat trout but brook trout were afterwards found in the reservoir, possibly from an incorrect aerial fish stocking, and the fishery is now declining.

METHODS USED TO DEVELOP THE PROJECT

Public involvement in the proposed Boulder Mountain project occurred from its inception. Part of formal public oversight of the Utah Division of Wildlife Resources (UDWR) includes five Regional Wildlife Advisory Councils (RAC), each representing a different geographic area and composed of 13 private citizens representing diverse segments of public interest. The proposed fishery management plan for the Boulder Mountain was initiated as a result of public comments made at a 1998 southern RAC meeting. Concerns were expressed about perceived increases in fishing pressure and declines in quality of fishing on Boulder Mountain. The southern RAC advised UDWR to study the situation for a year and make recommendations. At the 1999 southern RAC meeting UDWR made a recommendation to develop a plan to renovate stunted brook trout fisheries on Boulder Mountain, and at the 2000 meeting the formal plan was approved by the southern RAC.

Because the project area is within national forest lands, NEPA processes were enacted to allow review and approval of chemical rotenone treatments and construction of fish migration barriers. The NEPA process was conducted during 2000 along with state review processes and included publication of legal notices in local newspapers, mailing of over 600 letters to potentially interested parties, key contacts with local county commissioners, and eventual writing and public review of an Environmental Analysis (EA; Chamberlain 2000). Public attention also was drawn to the EA by articles in local and state-wide newspapers, magazines, and radio shows.

The EA included plans to treat up to 18 lakes over a 6-year period starting in fall 2001. Two-four lakes are planned to be treated per year. Lakes are scheduled to be treated twice (once a year on consecutive years) to increase the probability of complete removal of brook trout. Several of the lakes in the plan presently offer marginal fishing. Two of the marginal lakes have been treated in the past and have since provided good fishing, but condition and size of brook trout has declined and is expected to get worse as overall number of brook trout continue to increase. Waters which are currently providing some sport fishing are scheduled for treatment near the end of the 6-year period, and will only be treated if existing fisheries decline to an unacceptable condition (generally when maximum brook trout length does not exceed 290 mm TL or mean condition is < 1.00).

To determine which lakes should be included in the plan, most brook trout fisheries on Boulder Mountain thought to contain stunted fish or marginal fisheries were surveyed during 1999 (Table 2). For comparison, a number of other lakes with more popu-

Table 2.— Brook trout statistics, sport fish status, and management classification of waters surveyed during 1999. Status: Stunted = K_{TL} < 1.0 or maximum length < 290 mm TL; Marginal = K_{TL} > 0.99 and < 1.15 or maximum length < 360 mm TL; Quality = K_{TL} > 1.14 and maximum length > 359 mm TL. Management classification: Conservation population = CP; Sport fish population = SF.

Lake, reservoir, or pond	Area (ha)	Number fish in sample	Hours gill-netted (number nets)	Mean length (mm) (range)	Mean weight (g)	K_{TL}	Source of trout (wild or stocked)	Status and Classification
Bear Creek Pond	0.7	54	2.0 (1)	271 (206-352)	210	1.01	Wild	Marginal SF
Beaver Dam Res	5.4	56	18.5 (1)	307 (200-461)	341	1.10	Wild	Marginal *1 SF
Blue Lake (GT)	2.8	23	22.0 (1)	281 (174-327)	228	1.00	Stocked	Marginal SF
Blue Lake (NC)	0.6	30	1.3 (1)	226 (191-279)	100	0.87	Wild	Stunted *1 SF
Bullberry Lake #1	0.2	15	1.3 (1)	239 (183-287)	153	1.06	Wild	Stunted *2 SF
Bullberry Lake #4	0.4	16	1.0 (1)	227 (199-261)	102	0.86	Wild	Stunted *2 SF
Chuck Lake	2.1	27	18.0 (1)	259 (223-295)	223	1.26	Stocked	Marginal SF
Cooks Lake	4.6	13	16.0 (1)	246 (189-320)	166	1.02	Stocked	Marginal SF
Donkey Lake	9.3	99	19.0 (1)	260 (155-354)	221	1.05	Wild	Marginal *1 SF
Fish Creek Res	10.4	30	2.3 (1)	270 (171-305)	177	0.88	Wild	Stunted *1 SF
Heart Lake (N)	0.2	18	1.0 (1)	239 (193-273)	129	0.93	Wild	Stunted *1 SF
Heart Lake (S)	0.1	22	1.0 (1)	219 (163-254)	103	0.97	Wild	Stunted *1 SF
Joe Lay Res	1.4	28	18.0 (1)	281 (193-425)	266	1.20	Stocked	Quality SF
McGath Lake	19.2	16	18.0 (1)	390 (221-490)	779	1.36	Stocked	Quality SF
Oak Creek Res	15.0	62	14.0 (2)	326 (188-410)	439	1.14	Wild	Marginal *1 SF
Pacer Lake	8.3	55	13.5 (2)	320 (230-435)	456	1.28	Stocked	Quality SF
Pine Creek Res	1.3	96	21.0 (1)	246 (159-335)	164	0.97	Wild	Stunted *1 CP
Purple Lake	5.8	36	18.0 (1)	307 (235-380)	315	1.02	Stocked	Marginal SF
Raft Lake	5.4	14	20.0 (1)	318 (235-365)	420	1.22	Stocked	Quality SF
Robs Res	0.8	30	1.3 (1)	249 (189-297)	151	0.95	Wild	Stunted *1 CP
Round Willow Res	3.4	47	2.0 (1)	222 (202-289)	97	0.89	Wild	Stunted *2 CP
Short Lake	0.7	30	2.0 (1)	239 (152-282)	145	1.01	Wild	Stunted *1 SF
Solitaire Lake	1.9	34	1.0 (1)	237 (211-257)	117	0.87	Wild	Stunted *1 SF
Surveyors Lake	1.7	23	19.0 (1)	280 (203-341)	238	1.03	Stocked	Marginal SF
Tall Four Lake	0.3	21	12.0 (1)	295 (147-403)	444	1.23	Wild	Quality CP

**1. Water considered for treatment to remove wild brook trout population.*
**2. Water considered for treatment to remove wild brook trout population along with interconnected pond or reservoir not listed in survey.*

lar brook trout fisheries also were surveyed. Trout populations were sampled in 26 lakes using experimental gill nets. An attempt was made to capture at least 30 fish per lake and record TL, weight, and condition for each fish. At the smaller Heart and Bullberry lakes where a series of ponds were interconnected, samples were combined among ponds for a total of 30 fish. At Tall Four Lake the sample was limited to 21 brook trout because of its development for brood stock of native cutthroat trout. Data on brook trout size and condition were used to rank waters and list their status as stunted, marginal, or quality. In addition, physical data on lake area, depth, and volume was measured, and information was collected on lake inflows and outflows, the presence of other fish species besides brook trout, occur-

rence of natural fish migration barriers, and connectivity of streams and lakes. Physical data were used to determine the feasibility of treatment projects and the extent to which lakes and connected streams should be treated. Lakes where treatments were feasible were classified in regard to native cutthroat trout restoration as either "conservation populations" or "sport fish populations" (Lentsch et al. 1997, Lentsch and Converse 1997). Conservation populations are managed specifically for preservation of the species, but not usually to the exclusion of sport fishing, while sport fish populations of native cutthroat trout are maintained by stocking.

Streams proposed for treatment and analyzed in the EA included sections associated with lakes where brook trout need to be completely removed to prevent these lakes from being re-populated, and which will be important for natural recruitment of native trout. Fish migration barriers will be constructed at several sites to prevent brook trout or other nonnative trouts from gaining access back into treated areas and to expand areas where native trout can be re-established. Migration barriers will be constructed from local rocks and boulders to form falls of 1.5 to 2.5 m that will prevent upstream movement of fish.

FISHERY MANAGEMENT PLANS

Cutthroat trout will be restocked into treated waters from a locally native brood stock of Colorado River cutthroat trout developed at Dougherty Basin Lake (located on Boulder Mountain; Hepworth et al. 2000a) and a native brood stock of Bonneville cutthroat trout developed at Manning Meadow Reservoir (located in southern Utah; Hepworth et al. 2000b). The appropriate subspecies will be stocked into its native range depending on whether treated waters are located in either the Colorado River or Bonneville basin. Colorado River cutthroat trout will be used most extensively because all project waters except one lake and stream are within the Colorado River basin.

Classifying lakes as "conservation populations" was based on the availability of spawning habitat and lake connectivity to streams capable of sustaining cutthroat trout populations. Of the 18 lakes considered candidates for treatment, four are planned to be managed as conservation populations for native cutthroat trout (Table 2). These include Round and Long Willow Bottoms reservoirs at the head of Twitchell Creek in the Escalante River drainage (Colorado River cutthroat trout), Pine Creek Reservoir at the head of Pine Creek in the Fremont River drainage (Colorado River cutthroat trout), and Robs Reservoir at the head of Center Creek in the East Fork Sevier River drainage (Bonneville cutthroat trout). In addition, conservation populations will include about 27 km of renovated streams (6.8, 12.1, and 8.5 km of Twitchell, Pine, and Center creeks, respectively). Natural barriers will prevent movement of nonnative trout back into Center Creek and part of Twitchell Creek. Construction of an additional barrier on Twitchell Creek will nearly double the length of this stream managed exclusively for native trout. Construction of a barrier upstream from a de-watered section of Pine Creek will prevent upstream movement of nonnative trout into this stream during non-irrigation periods of the year when stream flows are seasonally restored.

Several additional lakes in the plan (such as Short Lake and Blue Lake NC, Table 2) could support self-sustaining populations of native Colorado River cutthroat trout if habitat improvements were made to establish spawning areas. These lakes will be stocked with Colorado River cutthroat trout, or sterile hybrid tiger trout (female brown trout x male brook trout) and splake (female lake trout *S. namaycush* x male brook trout), allowing this option for future consideration.

The remainder of the renovated lakes will not likely support self-sustaining populations of wild trout (aside from brook trout) and are planned to be periodically stocked as needed with fingerling-size Colorado River cutthroat trout or tiger trout, splake, and rainbow trout to maintain sport fisheries. The sport fishing benefits of using native trout in appropriate waters will be evident by improved fishing compared to pre-treatment conditions. Tiger trout and splake have some characteristics similar to brook trout, will offer variety, and can be managed by stocking without over-crowding or hybridizing with native fishes. Rainbow trout will be stocked as a last option in areas where they will not threaten native trout and if other species are not available.

DISCUSSION

Overall, support for the project among anglers has been mixed with some fishermen expressing a desire for expanded use of native cutthroat trout and others indicating a continued preference for brook trout. The majority of anglers have expressed little opinion,

but some anglers do not believe that lake renovations will be restricted to stunted brook trout populations and feel that even the best brook trout fisheries might be treated. Public scepticism exists over use of native cutthroat trout because of their "sensitive" status and potential for listing under the ESA. Some anglers fear that increased stocking of native cutthroat trout into new areas will result in additional land management restrictions, including reductions in sport fishing opportunities with more regulatory closures and special rules.

An important objective of the plan for Boulder Mountain is to eventually dispel angler concerns about native trout by using native fish to improve fishing, and at the same time maintain other popular fisheries for nonnative trout. The unique appearance of Colorado River cutthroat trout should help promote their use and popularity. Local fishermen are not generally familiar with Colorado River cutthroat trout because of their scarcity during the last half of the twentieth century. Anglers are more familiar with nonnative trouts, including nonnative cutthroat trout that have been widely introduced. Colorado River cutthroat trout are more colorful than most other subspecies of cutthroat trout (Behnke 1992), with larger and older males typically displaying brilliant orange and red ventral regions that extend from the slash marks under the jaw posterior to the anal fin. Increased interest among fisherman has already become evident in a few southern Utah locations where angling occurs for these fish, with positive comments made about their distinct appearance. If the project is implemented in fall of 2001, improved fishing could result at several locations by fall of 2003.

Complete eradication of brook trout has not always been achieved with past treatment projects when only a single application of rotenone was made (Table 1). Treatments planned under the proposed project include applications of rotenone on two consecutive years to increase the probability of completely removing brook trout. Experience on Boulder Mountain lakes and other treatment projects have shown that incomplete kills usually result from missing young trout that are still located in close proximity to spawning areas where there is an abundance of spring water. A second treatment after young fish have grown to larger sizes and moved outside of spawning areas is usually effective in making contact between the remaining fish and the toxicant.

In the past, native trout conservation projects often depended on transplanting a few hundred wild trout per year. Wild brood stocks of locally native trout from southern Utah have increased supplies of hatchery cultured native trout and allowed expanded conservation and sport fish programs for Bonneville and Colorado River cutthroat trout. Although transplants are still an important part of restoration efforts and are used to replicate specific wild populations, large numbers of native trout produced from wild brood stocks make larger projects possible. For example, larger drainages that include interconnected lakes and streams can now be considered for native trout restoration without requiring excessive amounts of time between removal of nonnative fishes and re-establishment of sport fisheries for native fish. In addition, hatchery production of sterile hybrids such as tiger trout and splake have added other options to native trout management. Even if sufficient numbers of native trout are not immediately available to restock renovated areas, sterile hybrids can be temporarily stocked for recreational purposes and can then be phased out as native cutthroat trout re-colonize areas and increase in abundance through natural reproduction. Also, the option exists to routinely stock limited portions of a drainage with sterile trout to satisfy sport fish recreational demands, while not jeopardizing native trout that occupy other parts of a drainage. Nevertheless, changes in management need to be implemented in ways to elicit support for native trout programs rather than opposition.

Additional native trout restoration projects on Boulder Mountain that are in progress include habitat improvements on Ranch Creek, the single stream with a remnant population of Bonneville cutthroat trout on Boulder Mountain (Wheeler 2000) and the expansion and protection of three remnant populations of Colorado River cutthroat trout on Boulder Mountain (Ottenbacher 1999). Also, transplants of Colorado River cutthroat trout were made into Dougherty Basin Lake and Tall Four Lake on Boulder Mountain, including a short section of interconnecting stream, in order to develop a wild brood stock of native trout. None of these projects, however, had or will have major impacts on popular sport fisheries.

The proposed Boulder Mountain project provides an opportunity to expand naturally reproducing native cutthroat trout into several lakes and streams, while at the same time improving sport fishing. We believe this is a positive and efficient management plan that does not require separate native and sport

fish management efforts, nor does it create conflict by replacing popular sport fisheries with native fish. The project will promote native cutthroat trout as an important sport fish and hopefully, create support for additional projects.

LITERATURE CITED

Behnke, R.J. 1992. Native trout of western North America. American Fisheries Society Monograph 6, Bethesda, MD. 275 pp.

Chamberlain, C.B. 2000. Environmental assessment for sport fish enhancement projects on the Boulder Mountains. Unpublished report. Utah Division of Wildlife Resources, Cedar City. 68 pp.

Hepworth, D.K., M.J. Ottenbacher, and L.N. Berg. 1997. Distribution and abundance of native Bonneville cutthroat trout (*Oncorhynchus clarki utah*) in southwestern Utah. Great Basin Naturalist 57: 11-20.

Hepworth, D.K., M.J. Ottenbacher, and C.B. Chamberlain. 2000a. Trapping and spawning Colorado River cutthroat trout at Dougherty Basin Lake, 1999, an initial effort. Publication number 00 - 16. Utah Department of Natural Resources Division of Wildlife Resources, Salt Lake City. 17 pp.

Hepworth, D.K., M. J. Ottenbacher, and C.B. Chamberlain. 2000b. Summary of Bonneville Cutthroat trout spawning at Manning Meadow Reservoir, 1992-1999. Publication number 00 - 17. Utah Department of Natural Resources Division of Wildlife Resources, Salt Lake City. 21 pp.

Hepworth, D.K., M. J. Ottenbacher, and C.B. Chamberlain. in press. Occurrence of native Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in the Escalante River drainage, Utah. Western North American Naturalist.

Lentsch, L. and Y. Converse. 1997. Conservation agreement and strategy for Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in the state of Utah. Publication number 97 - 20. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City. 61 pp.

Lentsch, L., Y. Converse, and J. Perkins. 1997. Conservation agreement and strategy for Bonneville cutthroat trout (*Oncorhynchus clarki utah*) in the state of Utah. Publication number 97 - 19. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City. 73 pp.

Ottenbacher, M.J. 1999. Environmental assessment for native trout enhancement projects in southwestern Utah waters. Unpublished report. Utah Division of Wildlife Resources, Cedar City. 58 pp.

Stegner, W. 1954. Beyond the hundredth meridian John Wesley Powell and the second opening of the west. Houghton Mifflin Company, Boston, MA. 438 pp.

Wheeler, R.D. 2000. Ranch Creek restoration project environmental assessment comment and review. Unpublished report. United States Department of Agriculture, Dixie National Forest, Escalante Ranger District, Escalante, Utah. 65 pp.

Mitigating Stream Acidification in a Wilderness Watershed Using Limestone Sand

Larry O. Mohn, Paul E. Bugas, Jr., Dawn M. Kirk, and Daniel M. Downey[1]

Abstract—The Virginia Department of Game and Inland Fisheries has been studying the impacts of acid deposition on the biota of the St. Mary's River in Augusta County, Virginia for the past 25 years. Reliable data on aquatic macroinvertebrates is available from as early as the mid-1930's providing an excellent database for evaluating long-term impacts. During the study period, invertebrate diversity has decreased by over 50% and the number of fish species has dropped from 12 to 4 with only native brook trout still present in significant numbers. From 1994 through 1996, the stream experienced reproductive failure of brook trout for two of the three years. The Department, along with the U.S. Forest Service who administers the area, agreed that water quality manipulation was needed to protect the remaining aquatic species as well as restore species which had already been extirpated. It was determined that the application of limestone sand would be the best method for water quality improvement. This procedure was developed by the James Madison University, Department of Chemistry and the U. S. Forest Service and has been used successfully in a number of other Virginia waters to provide economical and effective treatment for acidification. However, the St. Mary's River is located within a federally designated wilderness area, which complicated implementation of the recovery plan. After much environmental analysis and public debate, the project was approved and implemented in March of 1999. Improvements to water quality occurred immediately, aquatic invertebrate response was noted within three months and upstream re-colonization of some fish species was noted within six months.

INTRODUCTION

Acid deposition has been impacting aquatic resources in the mid-Atlantic and southeastern United States for at least the past two decades (Herlihy, et al., 1993; Webb, et al., 1994). The pH of pre-industrial precipitation in Virginia has been estimated to be in the 5.3 to 5.6 range (Webb, 1987) while recent readings in the Shenandoah National Park averaged 4.4 (U.S. EPA, 1998). This represents a tenfold increase in precipitation acidity since the beginning of the 20th century.

Acid deposition is not necessarily harmful to aquatic life. A watershed's ability to buffer acid deposition determines whether the system suffers long-term biological degradation. In western Virginia, most of the larger stream systems are well buffered due to underlying limestone geology, but most of the wild trout resource occurs on mountain slopes composed of sandstone, quartzite and shale. These slopes provide limited buffering capacity and are subject to acidification. In 1987, a synoptic survey of water quality parameters in 350 of Virginia's 450 wild trout streams, was funded by the Department of Game and Inland Fisheries. The result of that investigation indicated that 78% of the sampled waters had ANC (acid neutralizing capacity) of less than 100 ueq/L, meaning they were sensitive to acidification. Of these acid sensitive streams, 11% were already acidified (ANC< 0). One of these acidified streams was the St. Marys River, once considered one of the state's premier wild trout fisheries.

[1] *Larry O. Mohn, Regional Fisheries Manager, Virginia Department of Game and Inland Fisheries, P.O. Box 996, Verona, Va. 24486*

Paul E. Bugas, Jr., Senior Fisheries Biologist, Virginia Department of Game and Inland Fisheries, P.O. Box 996, Verona, Av. 24486

Dawn M. Kirk, Forest Fisheries Biologist, George Washington/Jefferson National Forest, P.O.Box 10, Natural Bridge Station, Va. 24579

Daniel M. Downey, Professor of Chemistry, MSC 7701, James Madison University, Harrisonburg, Va. 22807

STUDY AREA

St. Marys River is a third order coldwater stream that drains the west slope of the central Blue Ridge Mountains in southeastern Augusta County, Virginia. It's 27 km^2 watershed is the centerpiece of the 4000 hectare St. Marys River Wilderness Area. St. Marys River originates at 951 m above sea level and descends at a gradient of 39 m/km to its confluence with Spy Run, 11.4 km downstream. The stream is very scenic with numerous falls, cascades, large boulders and deep clear pools. The watershed includes five major tributaries (Figure 1). St. Marys River's low ANC levels can be traced to the geologic formations that underlie the upper watershed. Antietam quartzite is the primary rock formation while formations of Hampton quartzite underlie the upper watersheds of Sugartree Branch, Mine Bank Creek, Bear Branch, Chimney Branch, and lower reaches of St. Marys (Werner, 1966). Both formations are known to have low solubility, thus providing few base cations and carbonate to neutralize acidic input (Downey, 1994).

St Marys River has had a long history of commercial, scientific and recreational interest. As with most of the Appalachian Mountains the area was extensively logged during the late 19th or early 20th century. In the 1910's, the Pulaski Iron Company built a railroad spur along the St. Marys gorge to Chimney Branch. This railroad served to transport manganiferous iron ore from excavated surface mines in the watershed to the N&W Railroad siding downstream (Stose, et al., 1919). The operation was abandoned after World War I but resumed briefly during World War II. Although environmental degradation would likely to have been significant during the height of these operations, the stream was reported to be well recovered with a diverse aquatic macroinvertebrate population and a good rainbow trout population by 1935 (Surber, 1951). It is not known when the railroad spur was removed but the railroad bed, used as an access road, was reduced to a hiking trail by the floods of 1969 and 1972. The surface mines are still evident by their topography but most are well vegetated and have no measurable impact on water quality.

The St. Marys River has long been recognized as one of Virginia's premier wild trout fisheries. As early as 1935 (Surber, 1951), it was reported to support a good population of wild rainbow trout. By 1948, the lower portions of the stream began receiving stocked trout as part of the federal/state effort to expand trout fishing opportunity. The floods of 1969 and 1972 eliminated access for stocking and the stream reverted back to wild trout management. At that time, St. Marys River was one of the few streams in the state that contained reproducing populations of brook, brown and rainbow trout. It became one of the state's earliest special regulation streams when the Department so designated it in 1974 after study and recommendations by Trout Unlimited. The drainage was later proposed as a federally designated wilderness and in 1984 became one of Virginia's first wilderness areas. The primary feature of the area that drew support for wilderness designation was the wild trout fishery and the scenic qualities of the St. Marys River.

BIOLOGICAL SURVEYS

Surber (1951) provided the earliest data on biological communities in the St. Marys River. He collected detailed aquatic macro-invertebrate data from a number if sites in both 1936 and 1937. This early data provides a valuable baseline which precedes likely impacts due to industrial based acidification. The Department of Game and Inland Fisheries collected extensive fisheries and invertebrate data as part of a statewide trout stream inventory in 1976 (Mohn & Bugas, 1980). With the designation of St. Marys River as an acidified trout stream by Webb, 1987, the Department began a program of intensive fisheries and invertebrate data collection on a biennial basis from 1986 through 1998. In support of this effort, the USFS Coldwater Fisheries Research Unit from Virginia Tech conducted basinwide snorkel and electrofishing surveys in St. Marys and its tributaries in 1989, 1994 and 1997 (Flebbe, pers. com.).

The 1976 survey by the Department of Game and Inland Fisheries provided the first recorded fisheries survey of the St. Marys River. Six sample stations were established on the mainstem. These stations were established at approximately equal intervals along the mainstem from the lower wilderness boundary to the headwaters (Figure 1). Stations varied in length from 76 to 171 m and included at least three riffle, pool, and run sequences. Block nets were placed at each end of the sample stations and three-run depletions were used to estimate fish abundance and biomass. In addition, a Carle sampler (Carle, 1976) was used to collected three 0.26 m^2 invertebrate samples from riffle areas at each site. This collection

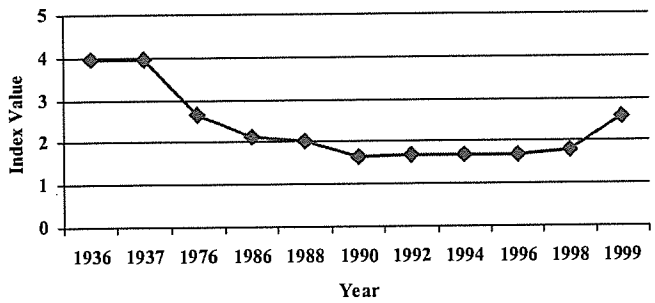


Figure 1.—Shannon Diversity Index for macroinvertebrates St. Marys River, 1936-1999

technique and the sample locations compared favorably with methods used by Surber in 1936/37. Surveys were repeated at established stations in 1977, and biennially from 1986 through 1998 (Bugas, et al., 1999).

Fourteen species of fish have been collected from the St. Marys River since 1976 but several are considered transient. The most species collected in any one survey year was 12 in 1976 (Table 1). During the survey period 1976 – 1998, the number of fish species has steadily declined from 12 to 4. In addition, several species which were found throughout large portions of the drainage in 1976, such as blacknose dace, fantail darter, and mottled sculpin, have had their ranges and numbers severely reduced. Rainbow trout, for which the St. Marys River was best known, were extirpated from the drainage by 1994. Due to its greater acid tolerance, the native brook trout remained abundant through 1994. However, the 1996 survey indicated year class failures in two of the previous three years and a sharp drop in brook trout population numbers. The magnitude of this drop in population prompted the Department to immediately begin discussions with the USFS on acid mitigation.

The aquatic invertebrate data has shown a more gradual but no less significant reduction in both species numbers and diversity (Kauffman, et. al, 1999). Many genera of stonefly, mayfly and caddisfly were extirpated from the drainage by the mid-1980s while populations of acidophobic taxa such as the plecoptera, *Leuctra/Alloperla* and Chironomidae showed significant increases. The invertebrate diversity as measured by the Shannon Diversity Index showed a significant decline throughout the study period (Figure 1).

ACID MITIGATION METHODOLOGY

The USFS, Chemistry Department at James Madison University and Virginia Department of Game and Inland Fisheries have been working on development of a low cost methodology for treating stream acidification since 1989 (Downey, et al., 1994, Hudy, et al., 2000). The use of limestone sand, introduced directly into the stream has been documented as an effective treatment to improve water quality and recover aquatic populations and is now used routinely as a management tool in Virginia as well as several surrounding states. For best results, the

Table 1.--Fish distribution in St. Marys River by sample year and sample station.

Letter denotes uppermost station in the watershed where individual species was collected

Fish Species	1976	1986	1988	1990	1992	1994	1996	1998	1999	2000
Brook Trout	F	F	F	F	F	F	F	F	E	F
Blacknose Dace	E	E	E	C	A	B	A	A	A	B
Fantail Darter	C	C	C	C	C	B	B	B	B	B
Mottled Sculpin	B	B	B	B	B	B	B	B	B	B
Rosyside Dace	B	B	B	B	A	B	A			
Torrent Sucker	C	B	B	B	B		A			A
Rainbow Trout	E	E	C	C	C					
Longnose Dace	B	A			A					
Johnny Darter	A					A				
White Sucker	B	A								
Bluehead Chub	A			A						
Central Stoneroller		A								
Smallmouth Bass			B							
Brown Trout	C					A				
Total Species	12	10	8	8	8	7	6	4	4	5

treatment is dependent on high grade (>99%) calcium carbonate sand that is 0.25 to 1.0 mm in diameter. Application rates are calculated based on dissolution rates of the limestone in relation to existing stream chemistry, annual rainfall, stream discharge and acid loading. Total amount of limestone sand that is placed in a stream can then be adjusted to cover treatment for a pre-determined number of years.

For St. Marys River, it was estimated that 125 tons of limestone sand would be necessary to provide a minimum of five years of treatment for the river and its tributaries. To maximize the impact of this treatment, it was decided to place limestone at sites on five tributaries and at one site on the mainstem (Figure 2). A total of 140 tons, which includes 15 tons above the estimated value to allow for transport loss, was to be distributed as follows: 50 tons in the upper St. Mary's River (main stem), 25 tons in Hogback Creek, 15 tons in Chimney Branch, 20 tons in Bear Branch, 15 tons in Mine Bank Creek and 15 tons in Sugartree Branch. The limestone would be placed far enough upstream to provide the maximum length of treated stream, yet not at sites of intermittent flow. Stream gradient was 2-5% at all the liming sites. A total of over 12 miles of stream wws treated as a result of this distribution.

WILDERNESS ISSUES

Although the use of limestone sand has become a commonly used treatment method in this region of the country, the St. Marys River project was unique in that it would occur within a federally designated wilderness area. In this instance, there are not only biological and chemical aspects to limestone mitigation, but social, political, economic, and legal aspects as well.

The recommendation to lime St. Marys River was made only after the aquatic biota showed such a dramatic decline that recovery was unlikely unless action was quickly taken. Specific concerns with St.

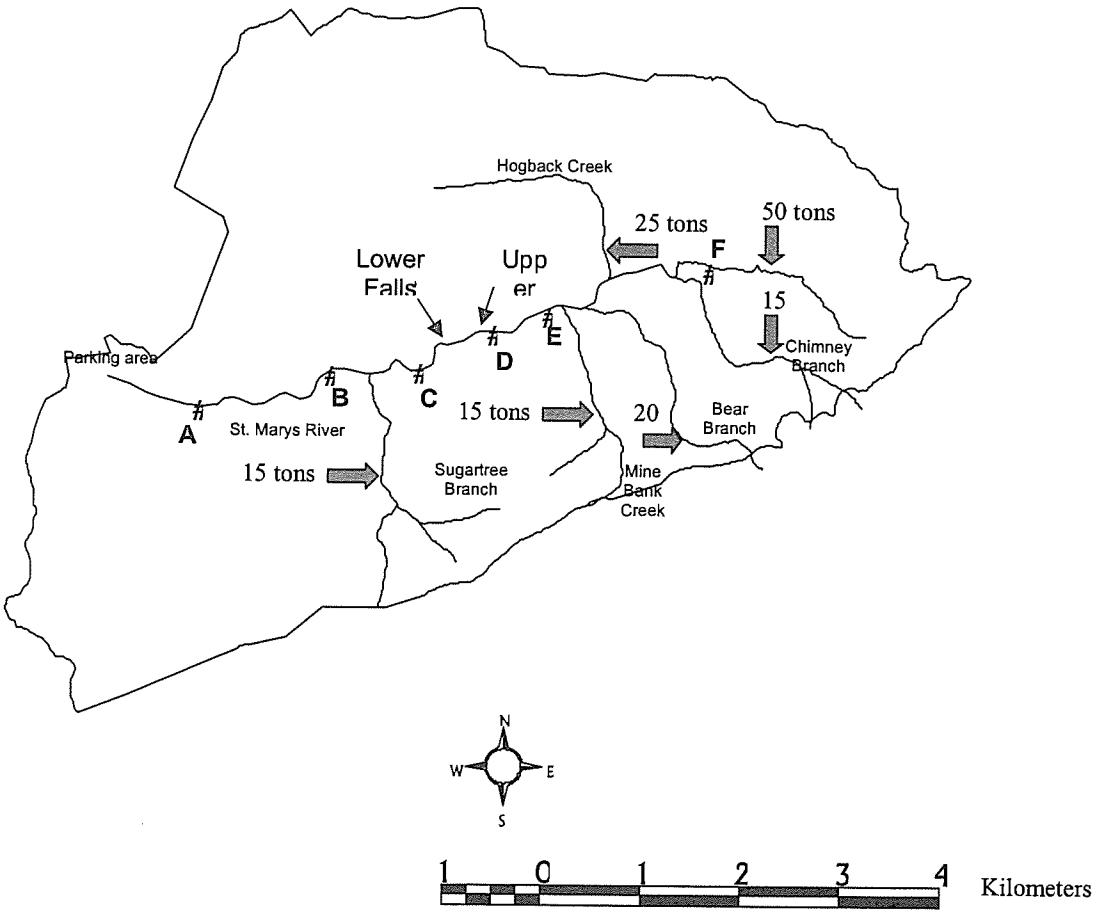


Figure 2.—St. Marys River biological sample stations and liming sites.

Marys involved the fact that it was in a designated wilderness area, it was a larger watershed than had been treated in Virginia in the past (with more treatment points), and there was severely limited access. The environmental analysis for the project was started with a Forest Service Scoping Notice on August 27, 1997. The proposed goal was to restore the aquatic ecosystem health and biodiversity of the river within St. Marys Wilderness by preventing the elimination of additional aquatic species and reintroducing some aquatic species that were once indigenous to the Wilderness area. The proposed action was to treat the river and 5 tributaries with 140 tons of limestone sand using a helicopter during low use time and season. Several issues surfaced during the environmental analysis process that ensued for over a year. The following five issues illustrate the controversial nature of this project.

The first issue revolved around the idea that the proposal is an inappropriate and illegal action in a designated Wilderness, and that it may degrade the wilderness character. In reading the Forest Service Manual, Chapter 2320 on Wilderness Management, it states that "chemical treatment may be used to prepare waters for reestablishment of indigenous species...or to correct undesirable conditions caused by human influence", as approved by the Regional Forester. In addition, the Wilderness Act gives direction that Wilderness Areas are to be managed to "protect and preserve natural condition". Human-induced acid deposition was determining what species of aquatic life could exist in the St. Marys Wilderness, and the deciding official (the Regional Forester) saw limestone mitigation as an effective tool to implement Wilderness Act direction, and try to restore and maintain the biological integrity of this Wilderness river. Because of the short-term duration for implementation of this project and the use of natural material, the Regional Forester additionally decided that the imprint of human work would be substantially unnoticeable.

A second issue was "Why St. Marys, and not another acidified, but more accessible river?" The response to this issue was that there was extensive documentation of the chemical and biological decline caused by anthropogenic acid deposition, and since St. Marys River is located in the heart of a Wilderness, special effort should be taken to maintain natural conditions as directed by the Wilderness Act. In addition, St. Marys Wilderness enjoyed widespread support for wilderness designation in 1984 in part because of the outstanding aquatic resource. In was the natural condition of this outstanding aquatic resource that the liming project was trying to preserve.

The legality of using a helicopter in the Wilderness was a third issue. Although the use of mechanized equipment in a wilderness is generally prohibited, the Forest Service Manual states that use of a helicopter in a wilderness can be approved by the Regional Forester when a delivery or application problem necessary to meet wilderness objectives cannot be resolved, within reason, through the use of non-motorized methods. Following an analysis on the cost and amount of time it would take to complete the proposed project using non-mechanized means of transportation (mules), it was determined that using a helicopter for several days in the wilderness would be far cheaper and less impact than using 10 mules for 187 days and building 5 miles of new trail to accommodate them.

A fourth issue involved aspects of the effects of limestone treatment on biota. When the pH of a stream drops below 5.5, aluminum may go into solution at levels toxic to aquatic life. Liming would raise the pH of a stream to levels where the aluminum precipitates out and is no longer in solution at toxic levels. Total aluminum and monomeric aluminum values in stream water have been shown to decrease with lime application and the associated increase in pH (Downey 1991, Downey 1997a, Olem 1991, Menendez et al 1996, Simmons and Cieslewicz 1996). The concern that aluminum values would be higher once the effects of liming declined because of the build up of precipitated aluminum has not been observed in other liming projects on the Forest (Downey 1997b).

Another biological aspect was the concern that non-indigenous species, such as rainbow or brown trout, would be introduced following treatment of the water. Since the stated purpose of the liming project was to restore as much as possible the biological integrity of the river, the intent was to reintroduce only indigenous species to their historic distribution if they are unable to re-colonize the area by themselves.

The last major issue was that this project is a band-aid technique and does not address the long-term problems of acidification. In response, the Forest Service is involved with other projects that do address air pollution at its source. These include reviewing proposed emissions of new or existing per-

mits to determine effects on natural resources and make recommendations, reviewing and commenting on State air regulations, and developing strategies for reducing regional air pollution emissions in order to protect natural resources through involvement in the Southern Appalachian Mountains Initiative. Looking specifically at the St. Marys Aquatic Restoration Project, the Regional Forester felt that society has already compromised eastern wilderness values by allowing emissions to continue that lead to acid precipitation, and that liming would not further compromise the wilderness values of St. Marys, but would help to preserve one of the values that led to its wilderness designation in the first place. It would hold the pieces of the aquatic ecosystem together until something can be done about the larger issue of air pollution.

PROJECT IMPLEMENTATION

The Decision Notice was signed on November 16, 1998 to begin the implementation of this project. At that point, the funds to pay for the project needed to be secured as well as all of the details of implementation, with the hopes of completing the project that winter or early spring.

An acceptable base site was chosen through cooperation with private landowners and the Blue Ridge Parkway and 140 tons of the correct size and grade limestone was bought and delivered. From 0 to 3 trees were cut at each drop point, with a crosscut saw (chainsaws were not allowed in the Wilderness). A Vertol helicopter was contracted since that type helicopter could lift several tons of material, providing maximum efficiency. Two hydraulic release buckets were also used for the project. A grant from the National Fish and Wildlife Foundation with matching contributions from the Virginia Department of Game and Inland Fisheries, James Madison University, Fly Fishers of Virginia, Washington and Lee University, and Blue Ridge Parkway was applied for and received. The Wilderness was signed and closed to camping 3 days prior to the project, and closed to day use during that day for safety reasons.

Implementation was on March 20, 1999. Two front-end loaders were used to alternately load lime into the two buckets. With 40 mile per hour rotor wash off the helicopter, a pumper truck was also present to spray down the lime once it was in the bucket so that it would not blow out. Turn around time was between 2 and 8 minutes. It took 56 trips and 6 ½ hours for all of the 140 tons of limestone sand to be moved. The total cost was $40,000. The benefit was 12 miles of stream treated for at least 5 years for a cost of about $666 per stream mile per year.

WATER QUALITY RESPONSE

Water chemistry monitoring of the St. Mary's River began in January, 1999, three months before the date of the liming treatment. A sampling site was located at the lower boundary where the stream exits the Wilderness Area. A staff gauge was installed here for recording stream discharge on sampling days. Samples have been collected no less frequently than once a week since the date of liming. The first graph in Figure 3 below provides the observed pH for the 21 months since the project started. The data points are connected for clarity. A value of pH 5.5 was chosen as a minimum for protection of certain aquatic insects and fishes that were native to the St. Mary's drainage. Figure 3 shows that the pH values were often less than the minimum acceptable value at the sampling site prior to the introduction of limestone. The average value for this period was pH 5.51 ± 0.28. In the 17 months that have elapsed since the liming, the average has been pH 6.30 ± 0.20. The second graph in Figure 3 also shows the peaks and valleys in measured discharge, which accompanied wet and dry periods. The liming date (March 20, 1999) is marked

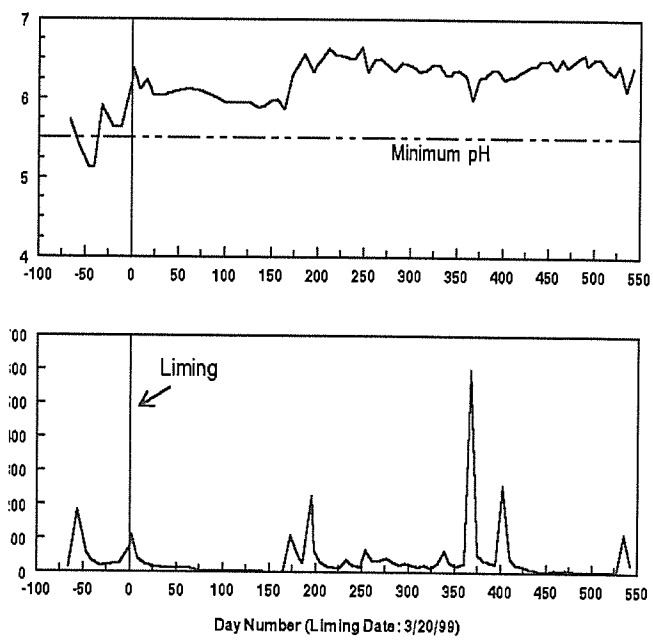


Figure 3.—Observed pH for the 21 months since the project started (first graph) and peaks and valleys in measured discharge (second graph).

with a vertical line on this graph. The spring and summer of 1999 were extremely dry with discharge decreasing significantly. When the limestone was added to the streams, there was significant flow. On the day the limestone was added, the pH values increased dramatically. However, the initial pH increase was short lived due to low flows, which minimized water contact with the limestone sand. In September 1999, several tropical depressions produced significant rainfall that increased discharge. The pH increased above pH 6, where it remained, even when low flow conditions returned. Storm events generally cause short-term decreases in pH as shown by the graphs, but even the decreases are significantly mitigated compared to the pre-liming conditions.

Another water quality parameter of interest is the acid neutralizing capacity (ANC) observed for the stream. Figure 4 provides the weekly ANC data on the first graph. The second graph in Figure 4 shows the calculated parameter of calcium to hydronium ion (Ca/H) ratio versus time. These are included in the same figure because both parameters are important for assessing the impact of acidity on aquatic life. The ANC values were quite low for the St. Mary's River prior to liming, often showing negative values. The pre-liming ANC average was 2.1 ± 5.0 :eq/L. The low values are the result of a lack of carbonate bearing mineral in the Antietam formation of quartzite rock that makes up most of the St. Mary's wilderness watershed. Thus little natural buffer is available to mitigate acidic inputs. The post-liming ANC values have increased due to the slow dissolution of the introduced limestone sand to an average 46.0 ± 12.0 :eq/L. There was an ANC decrease during the 1999 drought coincident with the pH decreased described above, but the levels are now steady and above the target ANC value of 25 :eq/L (marked on the graph), except for a few depressions caused by storm events.

The Ca/H ratio is important because it indicates a level of protection for the gills of fish from aluminum absorption. A generally accepted minimum value of 10 was chosen for this parameter. Prior to liming, the Ca/H averaged 8.5 ± 4.8. Post-liming the average was 110.2 ± 65.4.

Figure 5 shows the observed concentration of calcium (first graph) and magnesium (second graph) versus time. The calcium concentration was low prior to liming; the average was only 22.0 ± 1.6 :eq/L. After the liming the average increased to 46.0 ± 12.0 :eq/L. The dramatic increase is due solely to limestone dissolution, not natural effects. This conclusion is confirmed by examining the magnesium concentration. Like calcium, magnesium is a base cation and a group II metal that enters the stream water naturally from the weathering of the minerals

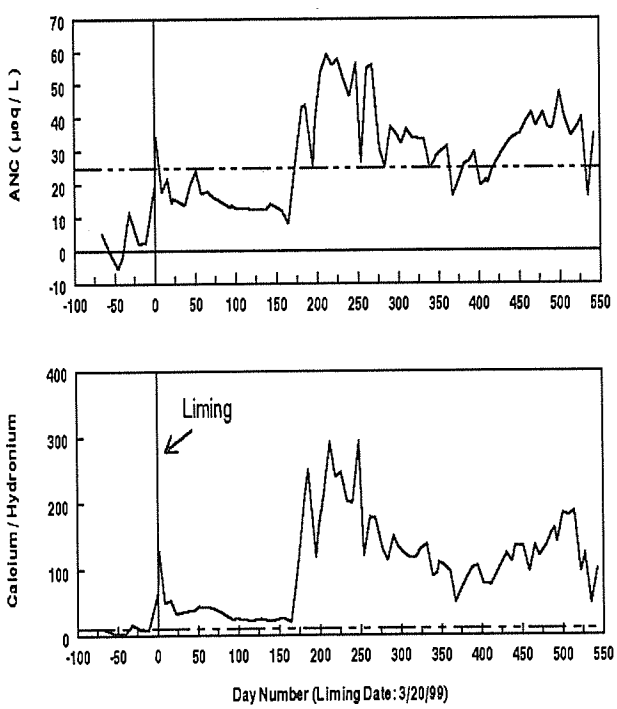


Figure 4.—Weekly ANC data (first graph) and the calculated parameter of calcium to hydronium ion (Ca/H) ratio versus time (second graph).

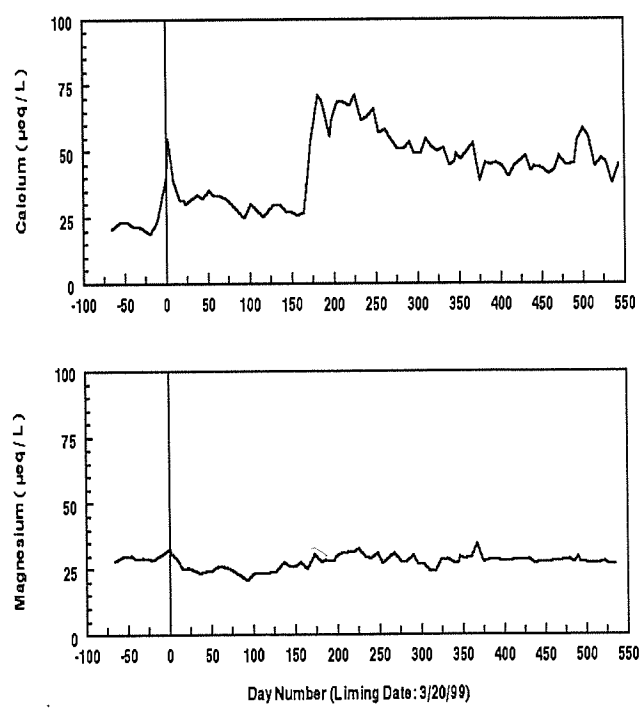


Figure 5.—Observed concentration of calcium (first graph) and magnesium (second graph) versus time.

in the soils and bedrock. It was not present in the limestone sand used for this study. Prior to liming, magnesium concentration averaged 29.5 ± 0.8 :eq/L. The post-liming concentration of 27.9 ± 2.5 :eq/L is the same within the limits of random scatter due to stream fluctuations and sample processing.

Aluminum is a toxin as described above. Total aluminum concentration levels above 130 :g / L are considered hazardous for aquatic life. Figure 6 shows the total aluminum concentration for St. Mary's River on the first graph and a nearby control stream, Cole's Run, on the second graph for comparison. Both streams have similar forest timber stands, bedrock geology and soils in their watersheds. The first sample from Cole's Run was taken several months after the sampling began for St. Mary's as the original selected control stream was dry in the drought of 1999. The graphs show that aluminum was mobilized during storm events due to low pH and flushing. Episodic short term spikes in aluminum concentrations as well as the base flow concentrations are reduced in St. Mary's compared to the control stream and the upstream (untreated) section of the stream. Aluminum concentration averaged 40.4 ± 17.7 prior to liming and 27.3 ± 19.9 since the liming.

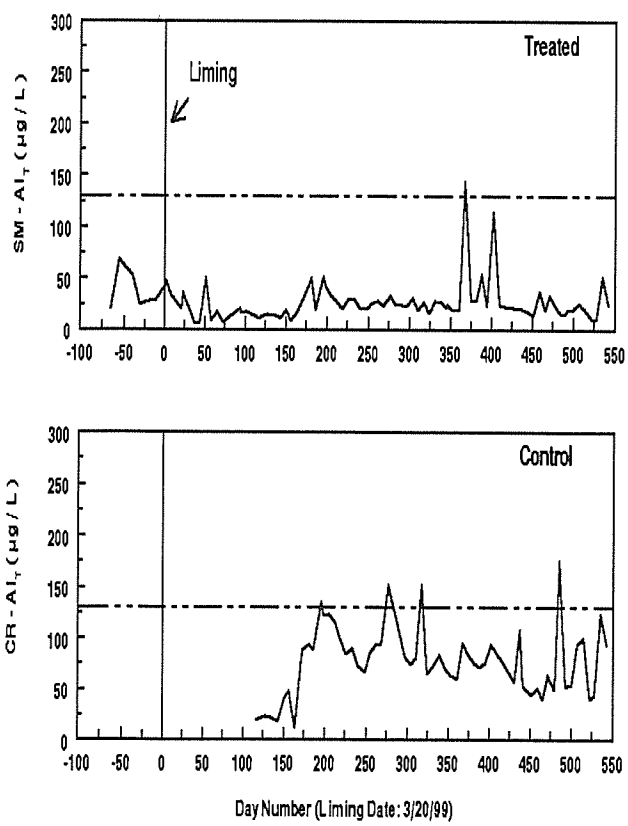


Figure 6.—Comparison of total aluminum concentration for St. Mary's River (first graph) and Cole's Run (second graph).

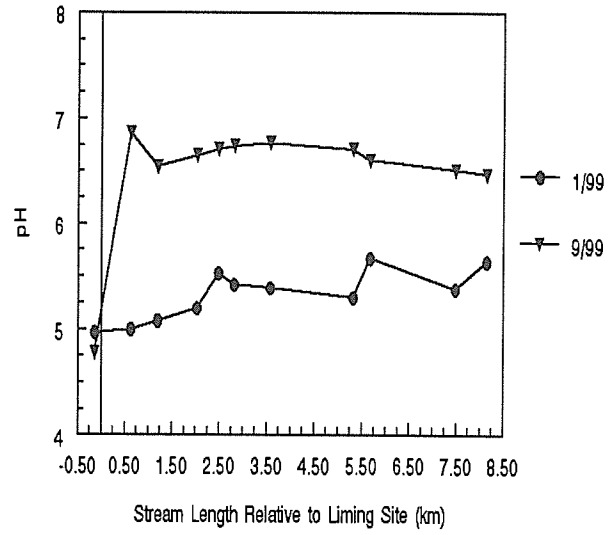


Figure 7.—Comparison of two of the quarterly sampling results that shows before and after liming pH values at selected locations in St. Mary's River.

The data above describe the weekly results obtained for the sampling site at the Wilderness Boundary where St. Mary's River exits onto private land. In addition to the weekly monitoring, samples were collected throughout the watershed on a quarterly basis. Figure 7 provides a comparison of two of the quarterly sampling results that shows before and after liming pH values at selected locations in St. Mary's River. The upstream reach of the creek is extremely acidic with a pH 4.92 ± 0.09. Prior to liming there was a small pH increase to the point where the stream exited the wilderness. After the liming, the pH increased below the liming site. Treatment of the acidic tributaries has helped maintain the pH downstream of the liming site. Downstream pH values averaged pH 6.45 ± 0.28 for all samples taken after the liming.

BIOLOGICAL RESPONSE

Post treatment trout biomass and number estimates show a dramatic response (Figure 8). However, all of this response cannot be attributed to the limestone treatment as populations began recovery in 1998. Virginia has experienced a prolonged drought period that resulted in stable, low flow, mild winters from 1997 through early 2000. These conditions generally produce exceptional year-classes of brook trout. In the case of St. Marys River and other acidified streams, the low flows not only produced good flow conditions for reproduction and recruitment but the lack of significant rainfall resulted in

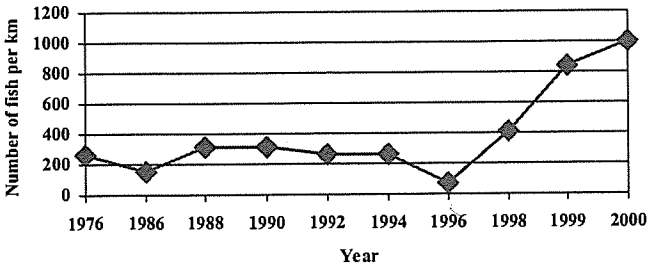


Figure 8.—Mean brook trout density for St. Marys River, 1976-2000.

winter pH values higher than normal. With the limited data available to date, we feel that the increase in population is the result of a combination of factors but that the current record number of trout would not be present without the limestone mitigation effort.

The aquatic invertebrate populations, as measured by the Shannon diversity index, has been our most reliable indicator of stream decline over the history of our studies of the St. Marys River. It is interesting to note that the index rebounded to 1976 levels within only 3 months of treatment (Figure 1). We have collected the data for 2000 (15 months after treatment) but the data is not yet available.

CONCLUSION

The use of limestone sand has proven to be an effective and cost efficient method of treating stream acidification. Our work on the St. Marys River demonstrates that this technique works well for wilderness areas as well in terms of minimal impact to wilderness values and costs. Our review of wilderness regulations and guidelines suggest that such actions are appropriate to wilderness values and can be an important management tool in regions of the country impact by acid deposition.

LITERATURE CITED

Bugas, P. E., L. O. Mohn & J. W. Kauffman. 1999. Impacts of acid deposition on fish populations in St. Marys River, Augusta County, Virginia. Banisteria No. 13: 191-200.

Carle, F. L. 1976. An evaluation of the removal method for estimating bentic populations anddiversity. M.S. Thesis, Virginia Tech, Blacksburg, VA. 170 pp.

Downey, D.M. 1994. Mitigation of acid degradation of Coles Run and Mills Creek Lakes. Report to the Environmental Protection Agency, Clean Lakes Grant Program, James Madison University, Harrisonburg, VA. 199 pp.

Downey, D.M. E.D. Lancaster, C.L. Stoner, J. Wagman and C. French. 1991. Limestone mitigation of trout streams in the George Washington National Forest, A Report Prepared for the George Washington National Forest, Harrisonburg, VA.

Downey, D.M., J.D. Armstrong, K.H. Bennett, C.R. French, and T.W. Graul. 1994. Impact of Watershed Defoliation by Gypsy Moths: water chemistry changes in low ANC Headwater Streams, James Madison University, Harrisonburg, VA.

Downey, D.M. 1997a. Response to Liming of an Acidic trout stream, A Report Prepared for the George Washington and Jefferson National Forests, Roanoke, VA.

Downey, D.M. 1997b. Letter to VDGIF, October 13, 1997.

Downey, D. M., C. R. French and M. Odom, 1994. Low cost limestone treatment of acid sensitive trout streams in the Appalachian Mountains of Virginia. Water, Air and Soil Pollution, 77: 49-77.

Flebbe, P. 1997. Personal communication. Coldwater Fisheries Research Unit, U. S. Forest Service, Virginia Tech, Blacksburg, VA.

Herlihy, A. T., P. R. Kaufmann, M. R. Church, P. J. Wigington, Jr., J. R. Webb, & M. J. Sale. The effects of acidic deposition on streams in the Appalachian Mountian and Piedmont region of the mid-Atlantic United States. Water Resources Reseach 29: 2687-2703.

Hudy, M., D. M. Downey & D. W. Bowman. 2000. Successful restoration of an acidified native brook trout stream through mitigation with limestone sand. North American Journal of Fisheries Management 20: 453-466.

Kauffman, J. W., L. O. Mohn, & P. E. Bugas, Jr. 1999. Effects of acidification on benthic fauna in St. Marys River, Augusta County, Virginia. Banisteria, No. 13: 183-190.

Menendez, R., J.L. Clayton and P.E. Zurbuch. 1996. Restoration Ecology, 4(3):220-233.

Mohn, L. O., & P. E. Bugas, Jr. 1980. Virginia trout stream and environmental inventory. Final Federal Aid Report F-32, Department of Game and Inland Fisheries, Richmond, VA. 70 pp.

Olem, H. 1991. Liming Acidic Surface Waters. Lewis Publishers, Chelsea, Michigan.

Simmons, K.R. and P.G. Cieslewcz. 1996. Restoration Ecology, 4(3): 264-272.

Stose, G. W., H. D. Miser, F. J. Katz, & D. F. Hewett. 1919. Manganese deposits of the west foot of the Blue Ridge, Virginia. Virginia Geological Survey, Bulletin No. XVII, Charlottesville, VA. 111 pp.

Surber, E. W. 1951. Bottom fauna and temperature conditions in relation to trout management in St. Mary's River, Augusta County, Virginia. Virginia Journal of Science 2: 190-202.

U. S. Environmental Protection Agency. 1998. National Atmospheric Deposition Program. http://nadp.sws.uiuc.edu/isopleths/maps1996/fldh.gif.

Webb, J. R. 1987. Virginia trout stream sensitivity study, 1987: Summary report to the Virginia Department of Game and Inland Fisheries, University of Virginia, Charlottesville, VA. 4 pp.

Webb, J. R., F. A. Deviney, J. N. Galloway, C. A. Rinehart, P. A. Thompson, & S. Wilson. 1994. The acid-based status of native brook trout streams in the mountains of Virginia, a regional assessment based on the Virginia trout stream sensitivity study. Report to the Virginia Department of Game and Inland Fisheries. 75 pp.

Werner, H. J. 1966. Geology of the Vesuvius quadrangle, Virginia. Virginia Division of Mineral Resources, Charlottesville, VA. 53 pp.

Multiple Electrofishing Removals for Eliminating Rainbow Trout in a Small Southern Appalachian Stream

Matt A. Kulp[1], Stephen E. Moore[2], and John M. Hammonds[2]

Abstract—We evaluated multiple electrofishing removals of rainbow trout *Oncorhynchus mykiss* as a management tool for the restoration of native brook trout *Salvelinus fontinalis* in a small southern Appalachian stream. We compared the results of this study to those of three streams previously restored using multiple and annual removal efforts. Four removals successfully eliminated rainbow trout reproduction and five removals were required to successfully eliminate rainbow trout from Mannis Branch. Adults dominated the initial removal on multiple removal streams while YOY dominated subsequent removal efforts. As multiple removal efforts proceeded, YOY densities decreased and mean total lengths of YOY increased improving recruitment to the gear. Adults dominated the catch throughout annual removal streams and reproduction was not eliminated for 4-6 years. Eliminating reproduction was key to restoration success in both techniques. Multiple removals exhibited no negative population level effects on blacknose dace in either multiple removal stream or on rainbow trout populations in the control areas. Based upon these results, a minimum of three removals conducted per summer should eliminate reproduction and significantly reduce the number of years required to successfully restore a small southern Appalachian stream.

INTRODUCTION

Historically, fishery managers have introduced nonnative fish to accomplish a variety of management goals. These goals include the diversification of sport fishing opportunities, additions to the forage base, and biological control. In many cases, nonnative fishes offered managers an attractive opportunity for providing new game fish that seemed to solve or quickly reverse problems that environmental mismanagement had created (Courtenay and Stauffer 1984). Unfortunately, this "quick fix" was often implemented with little regard for information about the long-term consequences. These actions have resulted in the establishment of nonnative fish populations that cannot be eliminated and have had disastrous impacts on many native fish communities (Courtenay and Stauffer 1984).

[1] *Fishery Biologist (corresponding author), National Park Service, Gatlinburg, Tennessee*

[2] *Fishery Biologist, National Park Service, Gatlinburg, Tennessee*

The National Park Service (NPS) is unique among land management agencies in that it is mandated to protect and preserve "naturally functioning ecosystems" (NPS Management Policies 1988). Population control of nonnative fishes has become an important objective of the NPS in some national parks (Moore et al. 1986, Stevens and Rosenlund 1986). Reclamation efforts in aquatic systems present a dilemma for managers because of difficulties in locating and capturing nonnative species without negatively impacting native species (Moore et al. 1986). Traditionally, salmonid restoration techniques in national parks have utilized chemical or mechanical methods for eliminating nonnative fishes (Stevens and Rosenlund 1986). Western parks typically utilize chemical renovation techniques (antimycin-A), which have been relatively successful (Stevens and Rosenlund 1986; Rosenlund 1992). Chemical renovation has not been readily accepted in eastern parks primarily due to potential impacts to diverse non-game fish populations, public misconceptions, and previous flawed restoration attempts (Lennon and Parker 1959).

The decline of native brook trout *Salvelinus fontinalis* in Great Smoky Mountains National Park (GRSM) is well documented (Powers 1929; King 1937; Kelley et al. 1980; Larson and Moore 1985). Since the mid-1970s, Park managers have attempted to reclaim carefully selected stream segments for native brook trout using backpack electrofishing techniques (Kulp and Moore 2000). Studies by Moore et al. (1983), West et al. (1990), Moore and Larson (1989), and Habera et al. (1992) have documented the successes and failures of efforts involving annual removals of rainbow trout in GRSM. Carter (1990) removed non-native rainbow trout twice in one summer and determined this method may be more effective than single annual removals for significantly reducing the number of non-native salmonids (Kulp and Moore 2000).

Brook trout distribution surveys in the 1990's identified several GRSM streams suitable for reclamation efforts. Mannis Branch was identified as an ideal candidate for reclamation by electrofishing because of its small size, presence of a downstream barrier, historical presence of brook trout, and accessibility. The objectives of our study were to (1) evaluate multiple electrofishing removals within a year as a tool for the elimination of non-native salmonids, (2) to determine if multiple removals within a year negatively impact non-target species, and (3) to compare the results of multiple removals to those of historic annual removals.

STUDY AREA

We selected two study streams typical of montane, soft water streams throughout GRSM. Mannis Branch is a second order tributary of the East Prong of the Little River, a tributary to the Little Tennessee River system. The lower end of the treatment area began at the top of a waterfall (~10 m high) and was 858 m in length. The upper end of the treatment area was marked by a 3-m bedrock cascade that inhibits upstream migration of salmonids. Rainbow trout *Onchorhyncus mykiss* and blacknose dace *Rhinichthys atratulus* were found in the treatment area. No fish were located above the upper cascade. The 858-m treatment area was partitioned into eight 100-m sampling sites and one 58-m site, prior to the first removal.

Blanket Creek is a second-order tributary to East Prong of Little River located 0.8 km upstream of Mannis Branch and is open to fish migration from East Prong of Little River. Blanket Creek was used as a control stream for Mannis Branch because of its proximity, similar physical and chemical characteristics, and similar fish fauna. Three 100m sampling sites were randomly selected in Blanket Creek to serve as control sites.

For comparison purposes, we compared the results of Mannis Branch to those of three GRSM streams previously restored using backpack electrofishing. One stream (Leconte Creek) was restored using multiple removals and two streams (Silers and Lost Bottom Creek) were restored using annual removals. Physical and chemical stream parameters of the three streams used for comparison were very similar to those of Mannis Branch and Blanket Creek. Stream pH ranged from 6.2-6.7, conductivity 9-15 MS/cm, stream width 3.1-5.5m, and stream discharges 2.5-9.5 ft^3/sec.

METHODS

Rainbow Trout Removal

Four rainbow trout removals were conducted on Mannis Branch between June 1, 1996 and August 30, 1996. Two additional removals were conducted on Mannis Branch in May and October 1997. Blanket Creek was sampled within one week of each removal of Mannis Branch using the same methods (no sampling was done on Blanket Creek during removal 4). Before each removal, block nets were set at the upper and lower site boundaries to prevent fish movement. Three-pass depletion estimates were conducted on all sites of both streams during each removal. Sampling protocols followed those recommended by the Southern Division AFS Trout Committee (1992). Backpack electrofishing units similar to those used by Habera et al. (1996) were used during this study at a setting of 600 V AC and an output was 0.22-0.32 A. Electrofishing passes were conducted upstream between site boundaries. Each electrofishing crew contained three people of similar experience and consisted of one person electrofishing, followed by one person with a dip net, and a person with a bucket.

Total length (TL) (nearest 1)(mm) and weight (nearest 0.1)(g) was recorded for each fish after every pass. Rainbow trout and blacknose dace were held in cages outside the section being sampled until sampling was completed. Rainbow trout from Mannis Branch were released into Little River at the end of each removal effort. Blacknose dace were returned to the sections from which they were collected. All fish were returned to the sections from which they were collected in Blanket Creek.

Following removal 4 in October 1996, native southern Appalachian strain brook trout were collected from Indian Camp Creek (50 fish) and Greenbrier Creek (55 fish) in GRSM. These fish were adipose clipped, loaded into 5-gallon buckets mounted on backpack frames, and transported to a Tennessee Wildlife Resources Agency (TWRA) hatchery truck. All fish were released alive into the treatment area. Mannis Branch was sampled in May and October 1998 using the methods described above to evaluate the status of the brook trout population.

Sampling methods of the three streams used for comparison purposes were similar to those used in Mannis Branch. However, Leconte Creek was restored using multiple electrofishing removals over two summers similar to Mannis Branch, whereas Silers Creek and Lost Bottom Creek were restored using annual removals. A sub-dominant population of brook trout already existed in Silers Creek and Lost Bottom Creek prior to treatment, however no brook trout were present in Leconte Creek prior to treatment.

Population estimates and 95% confidence intervals (95% CI's) were generated by site for each removal using the Microfish 3.0 software (Van Deventer and Platts 1989) which utilizes the Burnham maximum-likelihood population estimate formula (Van Deventer and Platts 1983). Simple time series comparisons of population data were used to compare short- and long-term level effects on non-target population density (# fish/100m^2) and biomass (kg/ha).

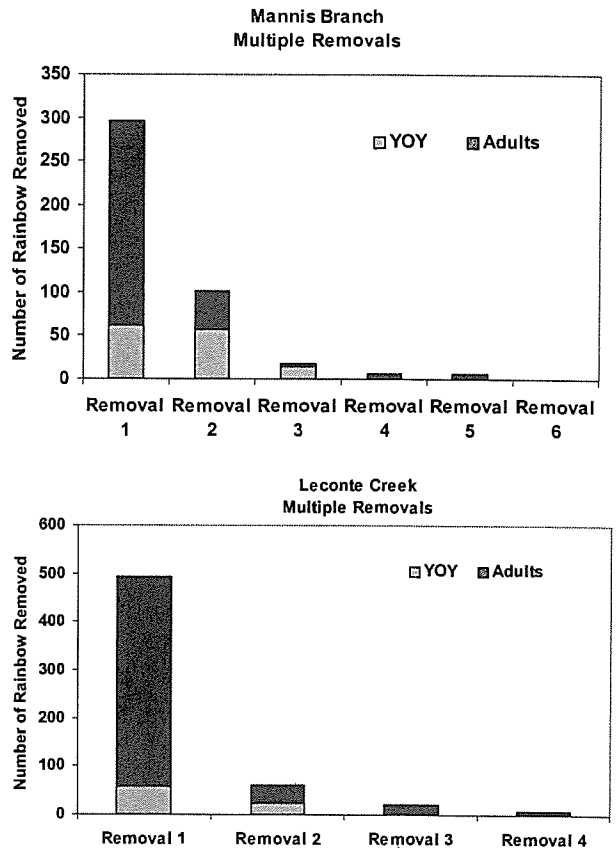


Figure 1.—Rainbow trout removal patterns on Mannis Branch and Leconte Creek following multiple electrofishing removals in Great Smoky Mountains National Park.

RESULTS

Rainbow Trout Removal

A data logger error occurred after completion of the first removal effort that eliminated population data for sites 1, 2, and 5 on Mannis Branch. Therefore, a complete set of data only existed for sites 3, 4, 6, 7, 8, and 9. We chose to discuss only data from these six sites for removal patterns and applicability of population estimates.

A total of 428 rainbow trout were removed from the six treatment sites on Mannis Branch during the six removals. Of these, 139 (32%) were age 0 (<90mm) and 289 (68%) were adults (>91mm). Adult trout (79%) dominated the first removal effort while age 0 trout made up only a small portion (21%) of the catch (Figure 1). Subsequent removals collected greater numbers of age 0 while adults were scarce. The number of age 0 trout collected was nearly the same in the first two removals and dominated removal 3 indicating the initial difficulty of collecting the age 0 fish. During the first removal, age 0 rainbow trout ranged from 28 to 48 mm. By removal 2, age 0 rainbow trout ranged from 47 to 80 mm and may have been more effectively sampled by electrofishing. The sizes of rainbow trout collected in 1997 (removal 5) indicate they were age 0 fish that were missed in 1996.

Two removals eliminated 93% of the rainbow trout from Mannis Branch while three removals eliminated 97%. Rainbow trout reproduction was eliminated in the treatment area following the first summer of removals. All rainbow trout were eliminated from the treatment area after the fifth effort.

The multiple cohorts of brook trout that were reintroduced in 1996 subsequently spawned producing good numbers of YOY. Population monitoring efforts from 1997-2000 indicate the brook trout reintroduction efforts were successful. Brook trout den-

sities surpassed those of pre-treatment levels of rainbow trout by 100% in 1998, 2 years after reintroduction, and continue to surpass rainbow trout by 24% in 2000.

The initial two removals of Leconte Creek were dominated by adults (88% and 59%) and no YOY were collected the following summer after removal 2. Two removals collected 95% of the rainbow trout while three removals collected 99%.

The first removal on Lost Bottom and Silers Creek was dominated by adults, as were most subsequent removals (Figure 2). Reproduction continued for 3-6 years following initial removals on Silers and Lost Bottom Creek. Complete restoration took 5-7 years in the annual removal streams, whereas complete restoration took 1 year in the multiple removal streams.

Mean total length of YOY rainbow trout increased from 38 to 72mm during the multiple removals on Mannis Branch and increased from 61 to 71mm on Leconte Creek (Figure 3). Mean total length varied between 38 to 62mm each year in annual removal streams and was dependent upon the month the removal was conducted. Mean total length of adults changed little in either multiple or annual removal efforts (Figure 3).

Multiple removals on Mannis Branch and Leconte Creek initially took 26 and 32 hr/100m and decreased to 5 and 8 hr/100m by removal 4 (Figure 4). Annual removals on Silers and Lost Bottom Creek ranged from 5-8 hr/100m and 15-25 hr/100m throughout the 4-8 year treatment period. The Mannis Branch and Leconte Creek restorations took 682 and 1,809 hours to treat 858 m (79 hr/100 m) and 2,700m (67 hr/100m) of stream over a one-year period. The Silers and Lost Bottom Creek project took 320 and 6,715 hours to treat 900m and 3,800m (177 hr/100m) of stream over a four and eight-year period.

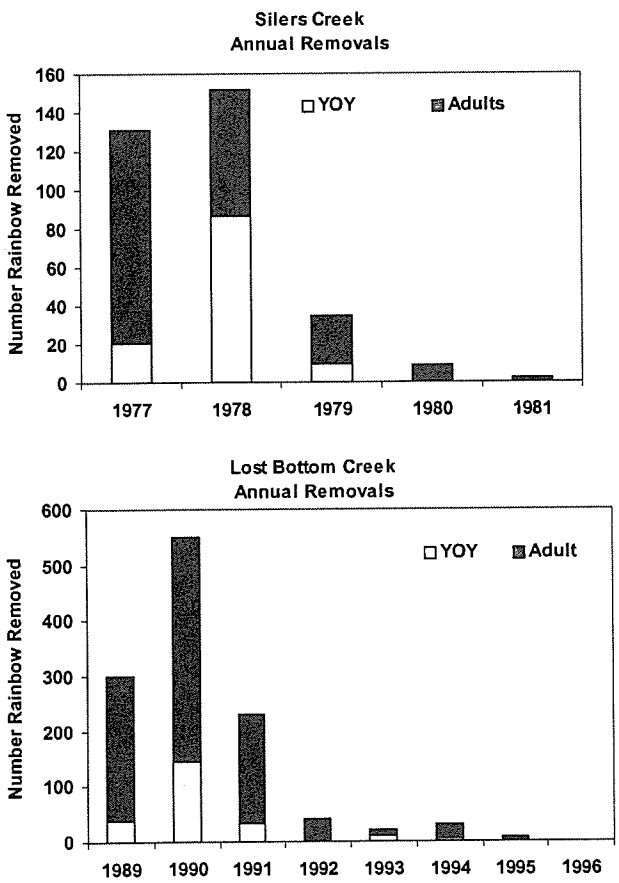


Figure 2.—Rainbow trout removal patterns on Lost Bottom and Silers Creek following annual electrofishing removals in Great Smoky Mountains National Park.

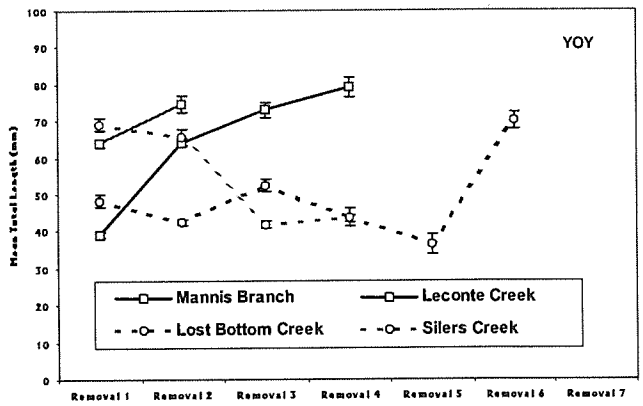


Figure 3.—Mean total length at capture for young-of-year (YOY) rainbow trout during multiple and annual electrofishing removal efforts in Great Smoky Mountains National Park. Error bars represent standard error (SE). Solid lines represent multiple removal streams and dashed lines represent annual removal streams.

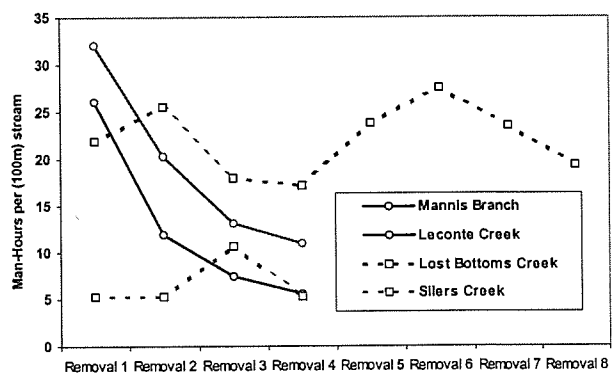


Figure 4.—Total man-hour expenditures per 100m of stream treated during multiple and annual electrofishing removal efforts in Great Smoky Mountains National Park. Solid lines represent multiple removal streams and dashed lines represent annual removal streams.

Effects of Multiple Removals on Dace and Trout Populations

Due to the low number of blacknose dace (<3 per site) in Blanket Creek, comparisons among Mannis and Blanket Creek by removal were not performed. Therefore, we focused only on blacknose dace population changes within Mannis Branch and Leconte Creek. Despite improper handling procedures on Mannis Branch during the July 1996 sample, which resulted in acute blacknose dace mortality, both short- and long-term time series densities showed no population level change during the course of the treatment (Figure 5). Blacknose dace biomass on Leconte Creek also indicates no short-term declines in either treatment or control sites (Figure 5). Brown and rainbow trout time series densities in Blanket Creek also indicate no short- or long-term population level declines following multiple removals (Figure 6). Rainbow trout densities indicate no short-term declines on Leconte Creek following multiple removals.

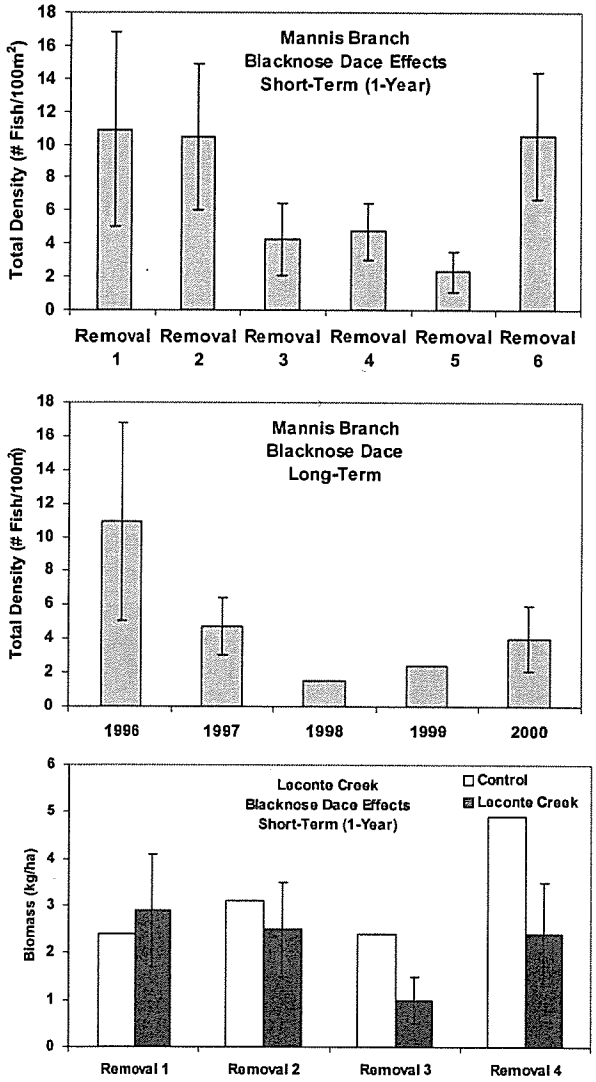


Figure 5.—Short- and long-term trends in blacknose dace populations on Mannis Branch and Leconte Creek following multiple electrofishing removal efforts in Great Smoky Mountains National Park. Bars represent standard error (SE).

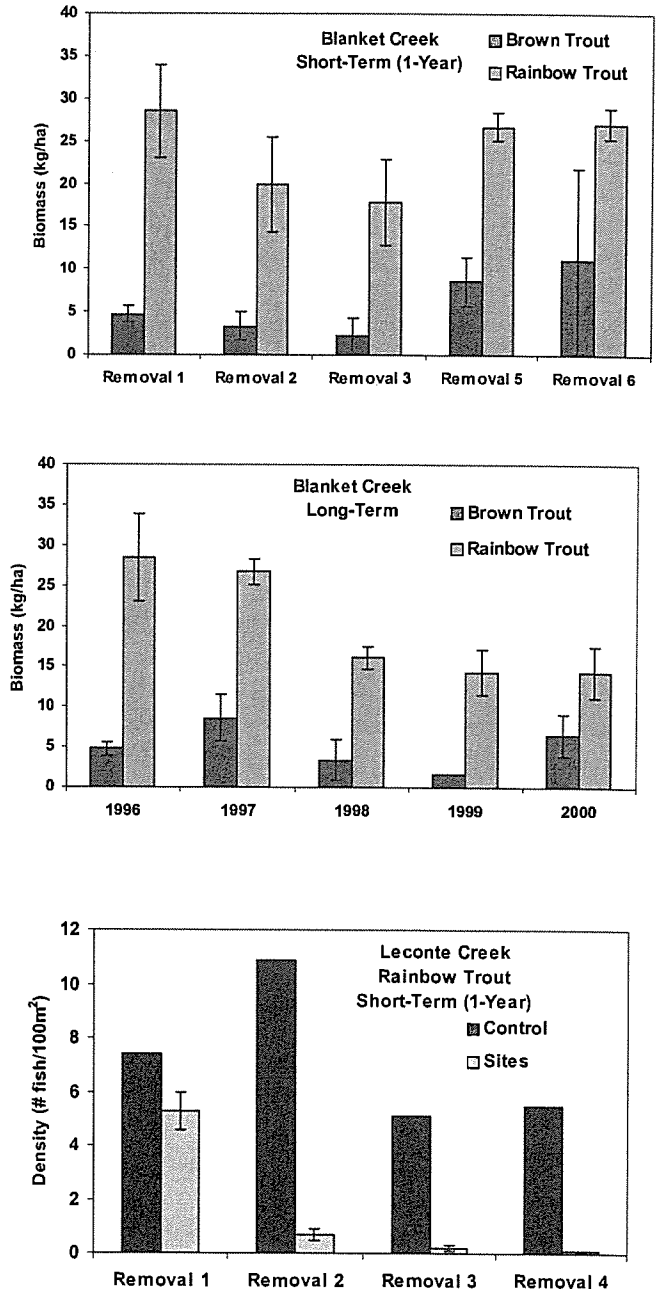


Figure 6.—Short- and long-term trends in blacknose dace populations on Blanket Creek and Leconte Creek following multiple electrofishing removal efforts in Great Smoky Mountains National Park. Bars represent standard error (SE).

DISCUSSION

Mannis Branch and Leconte Creek offered a unique opportunity to evaluate multiple electrofishing removals in relatively short segments of a southern Appalachian stream in Great Smoky Mountains National Park. Multiple removals proved to be an effective tool to eliminate rainbow trout over a one-year period in both streams. Initial removals focused upon the adults, allowing age 0 trout to grow throughout the summer and become more susceptible to the gear. Multiple removals eliminated the possibility of rainbow trout reproduction the following spring by reducing them to <0.4 fish/100m^2 throughout the treatment areas. Although the initial removal was timed to begin approximately two months after rainbow trout emergence, YOY were still difficult to sample in June because of their small size (28-48 mm). Future restoration efforts should consider timing the first removal well after emergence, especially in high elevation areas or in western areas where growth is much slower, to ensure thorough removal of age 0 fish.

The value of multiple removals in one summer becomes apparent when compared to the results of annual removal efforts in other Park streams. Removal patterns indicate that even though the number of rainbow trout declined each year in Silers and Lost Bottom Creek, a significant number of older fish remained and reproduced between years for 3-6 years. Rainbow trout were not eradicated from Lost Bottom Creek until reproduction was eliminated in 1995 seven years after the project was implemented. Successful restoration of two smaller GRSM streams (Moore and Larson 1989) required 3-4 years of annual removals to eliminate reproduction. Once reproduction was eliminated, the complete extirpation of rainbow trout followed within 1-2 years. Similar to the results of previous GRSM studies (Moore and Larson 1986; Moore et al. 1986), Thompson and Rahel (1996) concluded that 42-83% of age 0 brook trout were removed during initial restoration efforts in several Wyoming streams. These studies indicate that initial removals did reduce the numbers of non-native salmonids, but did not meet the objective of eliminating them.

Several factors determine the efficiency of removal efforts, such as stream cover and habitat complexity (Grant and Noakes 1987; Peterson and Cederholm 1984; Thompson and Rahel 1996), deep water (Riley and Fausch 1992), and size of the fish (Reynolds 1989). Size selectivity is an inherent problem of electrofishing surveys (Junge and Liborsvarsky 1965; Thompson and Rahel 1996) and has been a major hindrance to previous restoration efforts in GRSM (Carter 1990; Moore et al. 1981). One benefit of multiple removal efforts is that the effects of size selectivity on restoration success are ameliorated due to increased YOY growth rates due to lower densities.

Transplanting multiple cohorts into the stream and allowing adults to spawn was an effective and relatively inexpensive means of re-establishment given limited funding and reasonable accessibility. This technique has been used successfully in other areas of east Tennessee (Holloway 1945; Lennon 1967; Wilkins 1961) and in Wisconsin with brown trout (R. Hunt, Wisconsin DNR, personal communication).

Fisheries managers are typically limited in what they can accomplish within a given year. Most restoration projects are planned for one removal per year simply due to manpower and time limitations. However, data from Mannis Branch and Leconte Creek indicate that by planning a more intensive initial effort, you may shorten overall time expenditures. By eliminating reproduction in Mannis Branch and Leconte Creek, the projects were completed in two field seasons. However, in Silers and Lost Bottom Creek, the fish reproduced annually during the first 3-6 years prolonging the eradication of rainbow trout.

Effects of electrofishing and handling stress on non-game fish were initially two major concerns of multiple removal restoration efforts. These concerns arose from: (1) numerous publications which identified significant injuries to salmonids due to electrofishing (Sharber and Carothers 1988; Hollender and Carline 1994; Meyer and Miller 1990), and (2) possible effects on non-target species (Barrett and Grossman 1988). Data from Mannis Branch and Leconte Creek showed no population level declines in blacknose dace populations, despite using AC electrofishing and six, three-pass depletion efforts over an 18-month period. Our field observations were similar to Barrett and Grossman (1988) which indicated that handling stress could be the most important contributor to mortality in non-game species in low conductivity streams such as Mannis Branch. The blacknose dace declines observed on Mannis Branch in the August 1996 sample (removal 3) were attributed to handling stress incurred during the July 1996 sample (removal 2) when dace were

held in buckets for an extended period of time while trout were processed. Improved blacknose dace handling procedures in August limited the amount of acute mortality. Despite the acute mortality observed in Mannis Branch in August 1996, reproduction and recruitment enabled population densities to rebound to pre-removal densities by October 1997. Blacknose dace populations in Leconte Creek did not exhibit any effects from the multiple electrofishing removals. In fact, severe drought in 1998 and 1999 resulted in 21% declines of blacknose dace populations. The population trends in Mannis Branch and Leconte Creek mirrored Parkwide trends. These data indicate that intensive multiple electrofishing efforts using 600 volt AC had no effect on population density.

The brown and rainbow trout populations in Blanket Creek exhibited no population level changes even after five sampling exposures in an 18-month period. Habera et al. (1996) found that short-term rainbow trout mortality due to electrofishing is relatively minimal (<9%) in similar streams in the southern Appalachians and has no population level impact. Similarly on a population scale, brook trout populations in Lost Bottom Creek (GRSM Fishery Management Report 1995) increased annually for 5-6 years until they reached carrying capacity, even though 3.4 km of the stream was intensively electrofished annually for eight consecutive years. Therefore, we conclude that multiple electrofishing removals had no significant negative population level effect on brown or rainbow trout in Blanket Creek.

MANAGEMENT RECOMMENDATIONS

Based upon the Mannis Branch and Leconte Creek data, a minimum of three, three-pass removals per summer are recommended. Initial removals should be conducted at least 2 months after emergence to maximize capture probability of age 0 fish, with a second and third removal several weeks or a month afterwards. Removals beyond October would be visually hindered by leaf fall and should be avoided. High elevation and western areas will need to adjust the timing of removals accordingly to account for emergence and leaf fall. Additional removals should be completed the second field season based upon the subsequent catch to ensure no reproduction occurred and complete the project.

ACKNOWLDEGEMENTS

Funding for this project was provided by the National Park Foundation (NPF), Canon USA, National Fish and Wildlife Foundation (NFWF), and Trout Unlimited. We thank Tennessee Wildlife Resources Agency (TWRA) staff and the Little River and Great Smoky Mountain Chapters of Trout Unlimited for their financial support and the numerous hours of volunteer labor donated to all aspects of this project. Special thanks are given to the many fishery technicians who assisted with field sampling over the course of the study.

LITERATURE CITATIONS

Barrett, J. C., and G. D. Grossman. 1988. Effects of direct current electrofishing on the mottled sculpin. North American Journal of Fisheries Management 8:112-116.

Carter, B. D. 1990. Implications of biannual removal of rainbow trout on brook trout management in Great Smoky Mountains National Park. Master's Thesis. Tennessee Technological University, Cookeville.

Courtenay, W. R. and J. R. Stauffer. 1984. Distribution, Biology, and Management of Exotic Fishes. The Johns Hopkins University Press. Baltimore, Maryland.

Grant, J. W. A., and D. L. G Noakes. 1987. Escape behavior and use of cover by young-of-year brook trout, Salvelinus fontinalis. Canadian Journal of Fisheries and Aquatic Sciences 45:1390-1396.

GRSM Fishery Management Report. 1995. Internal Report, Great Smoky Mountains National Park. Gatlinburg, Tennessee. Unpublished.

Habera, J. W., R. J. Strange, and S. E. Moore. 1992. Stream morphology affects trout capture efficiency of an AC backpack electrofisher. Journal of the Tennessee Academy of Science 67:55-58.

Habera, J. W., R. J. Strange, B. D. Carter, S. E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192-200.

Hollender, B. A., and R. F. Carline. 1994. Injury to wild brook trout by backpack electrofishing. North American Journal of Fisheries Management 14:643-649.

Holloway, A. D. 1945. Report on the fisheries of the Great Smoky Mountains National Park. Internal report to the U.S. Department of the interior National Park Service, Gatlinburg, Tennessee, USA.

Junge, C. O., and J. Lobosvarsky. 1965. Effects of size selectivity on population estimates on successive removals with electrical fishing gear. Zoologicke Listy 14:171-178.

Kelley, G. A., J. S. Griffith, and R. D. Jones. 1980. Changes in the distribution of trout in Great Smoky Mountains National Park, 1900-1977, US Fish and Wildlife Service technical Paper 102. 10pp.

King, W. 1937. Notes on the distribution of native, speckled, and rainbow trout in the streams at Great Smoky Mountains National Park. Journal of the Tennessee Academy of Science. 12:351-356.

Kulp, M.A. and S.E. Moore. 2000. Multiple electrofishing removals for eliminating rainbow trout in a small southern Appalachian stream. North American Journal of Fisheries Management 20(1) 259-266.

Larson, G. L., and S. E. Moore. 1985. Encroachment of rainbow trout in the southern Appalachian mountains. Transactions of the American Fisheries Society 114:195-203.

Lennon, R. E. and P. D. Parker. 1959. Reclamation of Indian Creek and Abrams Creek in Great Smoky Mountains National Park. U.S. Fish and Wildlife Service. Special Scientific Report. - Fisheries 306. 22pp.

Lennon, R. E. 1967. Brook trout of Great Smoky Mountains National Park. U.S. department of the Interior Fish and Wildlife Service Technical Paper 15, Washington, D.C., USA.

Meyer, C., and D. Miller. 1990. Spinal injury and mortality in rainbow and brown trout collected by electrofishing. Proceedings of the Annual Conference Western Association of Fish and Wildlife Agencies 70:54-61.

Moore, S. E., B. L. Ridley, and G. L. Larson. 1981. Changes in standing crop of brook trout concurrent with removal of exotic trout species, Great Smoky Mountains National Park. U.S. National Park Service Research/Resource Management Report No. 37. 87pp.

Moore, S. E., B. L. Ridley, and G. L. Larson 1983. Standing crops of brook trout concurrent with removal of rainbow trout from selected streams in Great Smoky Mountains National Park. North American Journal of Fisheries management 3:72-80.

Moore, S. E., and G. L. Larson. 1986. Native brook trout studies in Great Smoky Mountains National Park, 1976-1981. Pages 59-69 in G. Larson and M. Soukup, editors. Conference of Science in the National Parks. Colorado State University, Fort Collins.

Moore, S. E., G. L. Larson, and B. L. Ridley. 1986. Population control of exotic rainbow trout in streams of a natural area Park. Environmental management 10:215-219.

Moore, S. E. and G. L. Larson. 1989. Native brook trout restoration program in Great Smoky Mountains National Park. Proceedings of Wild Trout IV Symposium. September 18-19, 1989. F. Richardson and R.H. Hamre editors.

NPS (National Park Service) Management Policies. 1988. US Department of the Interior National Park Service. Washington D.C. December 1988. 79 pp.

Peterson, N. P., and C. J. Cederholm. 1984. A comparison of the removal and mark-recapture methods of population estimation for juvenile coho salmon in a small stream. North American Journal Fisheries management 4:99-102.

Powers, E. B. 1929. Freshwater studies. 1. The relative temperature, oxygen content, alkali reserve, the carbon dioxide tension and pH of the waters of certain mountain streams at different altitudes in the Smoky Mountain National Park. Ecology 10:97-111.

Reynolds, J. B. 1989. Electrofishing. Pages 147-163 in L.A. Nielsen and D.L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Riley, S. C., and K. D. Fausch. 1992. Underestimation of trout population size by maximum-likelihood removal estimates in small streams. North American Journal of Fisheries Management 12:768-776.

Rosenlund, B 1992. Application of antimycin-a (Fintrol) to alpine lakes and streams in Rocky Mountains National Park and the headwaters of Leadville National Fish Hatchery to establish populations of greenback and Colorado River cutthroat trout. United States Fish and Wildlife Service Report. Colorado Field Office, Golden, Colorado. Pages 1-31.

Sharber, N. G., and S. W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management 14:340-346.

Southern Division American Fisheries Society, Trout Committee. 1992. Standardized sampling guidelines for wadeable trout streams. Unpublished Technical Report. 12 pp.

Stevens, D.R., and B.D. Rosenlund. 1986. Greenback cutthroat trout restoration in Rocky Mountain National Park. Proceedings of the George Wright Society Conference on Science in the National Parks. Pages 104-118.

Thompson, P. D. and F. J. Rahel. 1996. Evaluation of depletion-removal electrofishing of brook trout in small Rocky Mountain streams. North American Journal of Fisheries Management. 16:332-339.

Van Deventer, J. S. and W. S. Platts. 1983. Sampling and estimating fish populations from streams. Transactions of North American Wildlife and Natural Resource Conference 349-354.

Van Deventer, J. S. and W. S. Platts. 1989. Microcomputer software system for generating population statistics from electrofishing data. User guide for Microfish 3.0. General Technical Report INT-254. Ogden, Utah. U.S. Department of Agriculture, U.S. Forest Service, Intermountain Research Station. 29pp.

West, J. L., S. E. Moore, and M. R. Turner. 1990. Evaluation of electrofishing as a management technique for restoring brook trout in Great Smoky Mountains National Park. U.S. National Park Service Research/Resource Management Report SER-90/01 52pp.

Wilkins, L. P. 1961. Efforts to perpetuate endemic strain brook trout. Job completion report, Project F-6-R, Tennessee Wildlife Resources Agency, Nashville, Tennessee, USA.

Developing a Sampling Frame for Watersheds at a Large Regional Scale

Douglas S. Bateman[1], Robert E. Gresswell[2], George Lienkaemper[2], and Troy Guy[2]

Extended Abstract—There is growing consensus that knowledge of the form, function, and historical context of landscapes is essential to research and management of ecosystems at a variety of spatial scales. Recently proposed management plans for state and federal forest lands in western Oregon are directly linked to hypothesized responses of organisms to patterns at large spatial scales. Concomitantly, it is difficult to develop efficient management strategies at an ecosystem scale because little is known about how natural disturbance events and land-use impacts vary across large spatial scales. Current management decisions are based primarily on studies in which data were gathered from representative sites or paired watersheds. This approach, although useful, provides no statistical basis for applying results to areas that were not sampled.

Current research is focused on investigating the relationships between physical stream habitat and the distribution and abundance of salmonids relative to land management in forested watersheds of western Oregon. Despite significant effort, however, it has become increasingly apparent that strong inferences about relationships between physical stream habitat and the distribution and abundance of anadromous salmonids are difficult to attain because these fishes spend some part of their life in the marine environment where they are affected by a much different array of environmental variables, including shifts in ocean currents and commercial harvest. In contrast, salmonids that migrate only in freshwater are dependent on suitable stream habitats throughout their lives and therefore, may be more sensitive to variations in fluvial freshwater habitats. In an attempt to investigate interactions of coastal cutthroat trout *Oncorhynchus clarki clarki* with aquatic habitat at numerous spatial scales, we sought to identify populations that were isolated above natural barriers to anadromous fishes.

To accomplish this goal, the following methodology was developed for creating a sampling frame and producing a non-biased sample from it. The resulting sample is being used to investigate distributional patterns and habitat relationships of isolated populations of coastal cutthroat trout at spatial scales ranging from local (channel units) to regional (western Oregon).

METHODS

Third-order watersheds west of the Cascade Mountain divide were delineated using 30-m digital elevation models at the 1:24,000 map scale and tools from the U.S. Geological Survey (USGS) GIS Weasel application (Viger et al.). With a minimum watershed size of 500 hectares and a maximum size controlled by the distance to the next stream node. A total of 2,780 watersheds were identified in western Oregon.

The locations of barriers to upstream fish movement were delineated using information obtained form the Oregon Department of Fish and Wildlife and interviews with field biologists in numerous state and federal agencies. Because physiographic province and geology were expected to be important explanatory variables, watersheds were subsequently

[1] Department of Forest Sciences, Oregon State University, Corvallis, Oregon, USA, 97331.

[2] U.S. Geological Survey, Forest and Range Ecosystem Science Center, and Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA, 97331

apportioned to one of three ecoregions (i.e., Coast Range, Klamath, and Cascade), and then into one of two erosion-potential classes based on igneous (lower erosion potential) or sedimentary (higher erosion potential) rock types.

RESULTS AND DISCUSSION

By linking the three GIS data layers (watersheds, migration barriers, and ecoregion/erosion potential), a total of 285 third-order watersheds were identified that supported isolated populations of cutthroat trout and were located above barriers to anadromous salmonids. Proportional stratification was used to randomly select 60 basins from the six physiographic/geologic categories for habitat evaluation and population assessment. The resulting sample reflects the distribution of watersheds by ecoregion and erosion potential that will theoretically provide a realistic depiction of the gradient of geology, topography, vegetation, climate, ownership, and disturbance history.

Field verification of basins (n = 30) found 27% with errors in barrier, species, or distribution data. Most errors were found in the Klamath province, and the majority were due to absence of fish. The Coast Range was the only province with fish in all basins.

This simple and explicit geospatial methodology provided relatively inexpensive, precise information that is being used to investigate distributional patterns of coastal cutthroat trout at spatial scales ranging from local (channel units) to regional (western Oregon). In the process, we have assembled what is believed to be the most current and complete database describing distribution of coastal cutthroat trout populations that have been isolated from the influence of anadromous fishes. This database has potential for application to a wide range of evolutionary and conservation issues, including questions about genetic isolation, population persistence, and resilience to natural and anthropogenic disturbance.

ACKNOWLEDGMENTS

This project is part of the Cooperative Forest Ecosystem Research Program, a research consortium that includes the USGS Forest and Rangeland Ecosystem Research Center, the U.S. Bureau of Land Management, Oregon State University, and Oregon Department of Forestry.

LITERATURE CITED

Viger, R. J., S. M. Markstrom, and G. H. Leavesley. The GIS Weasel: an interface for the development of spatial parameters for physical process modeling. U.S. Geological Survey, Box 25046, MS 412, Denver Federal Center, Lakewood, CO 80225.

Patterns of Fish Distribution at the Watershed Scale

Robert E. Gresswell[1], Douglas S. Bateman[2], and Mark A. Ricca[3]

Extended Abstract—Changes in aquatic habitats resulting from land management activities may be especially relevant for coastal cutthroat trout (*Oncorhynchus clarki clarki*). During the last century, the abundance and distribution of this subspecies have declined across their entire range. Aquatic habitat degradation, associated with timber harvest, road building, agriculture, and development, has been identified as one of the potential causes of their decline. To date, however, most research concerning coastal cutthroat trout and their relationships to freshwater habitat has been conducted on the anadromous life-history type, and little effort has been expended to describe potamodromous coastal cutthroat trout populations or linkages with their aquatic habitat.

Interest in the effects of spatial scale on the organization of aquatic species is increasing, and it is apparent that a multiscale approach is integral to the interpretation of spatially extensive data. For instance, numerous studies have investigated, or are currently evaluating, the relationships between physical habitat and anadromous salmonids. Concomitantly, determining the effects of land-management activities on aquatic habitat, and ultimately aquatic organisms, is hampered by the complexity of interrelationships among physical, chemical, and biological characteristics of terrestrial, riparian, and aquatic systems, especially at broader spatial scales.

Within the last several decades, however, conceptual innovations have provided the framework and tools for assessing fish/habitat relationships at broader spatial scales. For instance, Frissell et al. (1986) developed a method for classifying stream systems in the context of the watersheds of which they are a part, and this approach is becoming more broadly accepted as a means of expanding understanding of the influence of disturbance and land management at the watershed scale. Concomitantly, methods have been developed to expand estimates of fish abundance and habitat metrics from channel units to the watershed scale (Hankin 1987; Hankin and Reeves 1988). Unfortunately, in practice, this methodological approach to sampling watersheds has been applied to questions concerning fish distribution in individual basins, not among basins as the method was originally intended. The objective of this study was to explore the usefulness of survey sampling methodology for evaluating distribution of coastal cutthroat trout within watersheds.

METHODS

In 1998, four third-order watersheds (with a range of stream gradient and discharge) in the Oregon Coast Range were selected for intensive data collection. All of the watersheds were located above barriers to anadromous salmonids, and coastal cutthroat trout were the only salmonids in the systems. A combined total of approximately 30 km of stream was sampled in Elk Creek (Nestucca River), Stiltner Creek and Racks Creek (Alsea River), and Camp Creek (Umpqua River).

Prior to initial surveys, major stream segments (sensu. Frissell 1986) were identified using existing databases, topographic and geologic maps, aerial

[1] U.S. Geological Survey, Forest and Range EcosystemScience Center, and Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA, 97331

[2] Department of Forest Sciences, Oregon State University, Corvallis, Oregon, USA, 97331

[3] Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA, 97331.

photographs, and field reconnaissance. During field surveys, geomorphic stream reaches were classified in each segment (Montgomery and Buffington 1997), and channel units were delineated in each geomorphic reach (Bisson et al. 1982).

Following channel unit mapping of the study basin, physical variables that describe channel unit size (e.g., length, depth, width, width:depth ratio, area, and volume), substrate size class, channel type, valley segment type, and woody debris were measured for all of the channel units. The relative abundance of fish in all pools and cascades was estimated by one of two methods (depending on stream size and accessibility: 1) single-pass electrofishing, or 2) visual estimation based on individual counts of fish by snorkelers (Thurow 1994).

Relative abundance was used to compare the census protocol to estimates that would be obtained from a survey sample of pools (simple random and systematic sampling procedures). Resampling simulations of 100 simple random samples were performed for each watershed using a sample size (n) chosen so that the confidence interval of the estimated number of fish/channel unit would fall within ± 20% of the mean. Estimates of mean number of fish/channel unit, mean channel unit area, and the correlation coefficient (r) of these two variables were compared for both the census protocol and the channel unit sample. Subsequently, systematic samples were simulated for a relative abundance in every fourth (k=4) channel unit, and patterns of fish distribution observed in the census were compared to those provided by the sampling procedures.

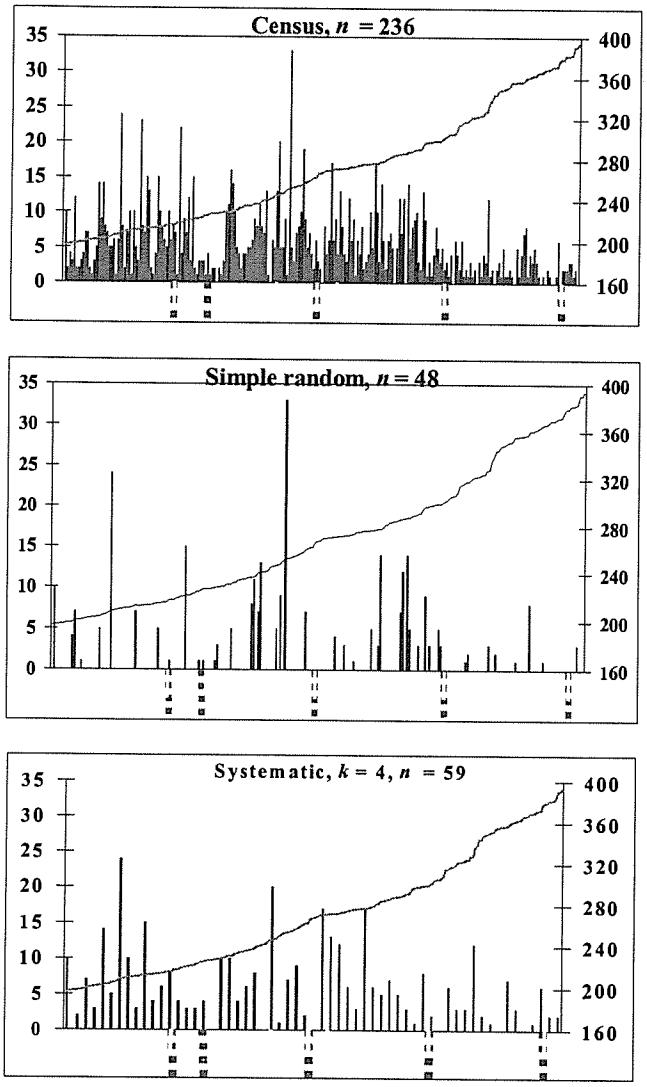
RESULTS AND CONCLUSIONS

Initial analyses suggest that estimates of mean fish abundance/channel unit, mean channel unit area, and the correlation coefficient (r) of these two variables were similar for simple random samples of the channel units (each encompassing approximately 25% of the total number of units in a watershed) and complete census of channel units (Table 1). This result is not surprising because the sampling methodology was originally developed on the basis of well-tested statistical theory (Hankin and Reeves 1988). In contrast, distribution patterns resulting from either simple random or systematic samples appear to lack specificity necessary to decipher longitudinal dispersal of fish in a watershed (Figure 1). If the pattern of distribution is directly linked to habitat characteristics, it may be necessary to census the entire watershed to understand the factors influencing persistence of fish at the watershed scale. This finding has important implications to research that is focused on the effects of disturbance (natural and anthropogenic) on the distribution of fish within, and among, watersheds. We are currently working to include information on additional randomly selected watersheds and to statistically compare the patterns of dispersal that are observed using various levels of sampling effort.

Table 1. Population (from watershed census) and sample (simple random) means of relative abundance of coastal cutthroat trout ($\bar{n}$), mean channel unit area ($\bar{a}$), and correlation coefficient (r) of relative abundance and $\text{Log}_e\ \bar{a}$.

	Watersheds			
Parameter	**Camp Creek**	**Racks Creek**	**Stiltner Creek**	**Elk Creek**
Relative abundance (fish/ unit)				
Census	4.0 (N=507)	2.0 (N=482)	4.0 (N=193)	8.2 (N=213)
Random sample	4.1 (n=114)	2.0 (n=250)	4.0 (n=87)	8.3 (n= 69)
Mean channel unit area (m^2)				
Census	34.7 (N=507)	17.7 (N=482)	36.2 (N=193)	19.8 (N=213)
Random sample	33.8 (n=114)	17.3 (n=250)	36.6 (n=87)	16.3 (n= 69)
Correlation coefficient (r)				
Census	0.51 (N=507)	0.21 (N=482)	0.61 (N=193)	0.57 (N=213)
Random sample	0.51 (n=114)	0.21 (n=250)	0.61 (n=87)	0.57 (n= 69)

Figure 1. Comparison of fish distribution by census of all pools and cascades, a simple random sample of those units, and a systematic sample of those units (*k*=4), for mainstem (third order segments) Camp Creek, Umpqua River, Oregon.



ACKNOWLEDGMENTS

This project is part of the Cooperative Forest Ecosystem Research Program, a research consortium that includes the USGS Forest and Rangeland Ecosystem Research Center, the U.S. Bureau of Land Management, Oregon State University, and Oregon Department of Forestry.

LITERATURE CITATIONS

Bisson, P. A., J. L. Nielsen, R. A. Palmason, and L. E. Grove. 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. Pages 62-73 *in* N. B. Armantrout, editor. Acquisition and utilization of aquatic habitat inventory information. American Fisheries Society, Western Division, Bethesda, Maryland.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10:199-214.

Hankin, D. G. 1986. Sampling designs for estimating the total number of fish in small streams. Research Paper PNW-360, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Hankin, D. G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences 45:834-844.

Montgomery, D. R., and J. B. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geographic Society of America Bulletin 109:596-611.

Thurow, R. F. 1994. Underwater methods for study of salmonids in the Intermountain West. U.S. Forest Service General Technical Report INT-GTR-307, Ogden, Utah.

The Influence of Non-Fish Bearing Streams on the Structure of Fish Bearing Streams in the Coast Range Mountains of Oregon

Christine L. May[1] and Robert E. Gresswell[2]

Extended Abstract—Stream and river ecosystems are intricately connected to the terrestrial ecosystems through which they flow (Bilby and Bisson 1998). First- and second-order streams can represent more than 70% of the cumulative channel length in mountainous drainage basins (Shreve 1969). Because these small streams are so abundant and are tightly coupled with the steep hillslopes, they can form an important link between hillslope and fluvial processes and between terrestrial and aquatic ecosystems. Thus, understanding the role of natural and anthropogenic disturbance in the dynamics of sediment and wood in headwater streams is important for understanding watershed processes and for planning aquatic habitat conservation.

Debris flows are especially important in the Pacific Northwest because they can play a major role in routing wood and sediment stored on hillslopes and in first- through third-order channels, and delivering it to larger rivers (Benda 1990, May 1998). These debris flows deliver sediment, boulders, and wood that can structure the morphology of the receiving channel and are often an important influence on the long-term potential for aquatic habitat development (Benda 1990, Hogan et al. 1995, Reeves et al. 1995). During the interval between debris flows, low-order streams have an indirect affect on fish bearing streams by influencing sediment supply rates, organic inputs, and water quantity and quality.

This study focused on the volume of wood and sediment stored in non-fish bearing, steep mountain streams, and the pattern of stream channel development based on the time since the last debris flow. Basins in the Tyee sandstone lithology of the Oregon Coast Range, that had a minimal history of forest harvesting, were investigated. Dendrochronology was used to establish a minimum time since the last debris flow. Wood and sediment storage volumes, wood recruitment and redistribution processes, and the functional role of wood were compared with the time since disturbance by a debris flow.

INDIRECT AFFECTS

Debris flows scoured small streams to bedrock (Figure 1). Subsequently, these bedrock channels had a high potential for sediment transport because the slopes were continuously steep, and the channels had low roughness and a high hydraulic radius. The presence of large wood fundamentally altered the hydraulics of the channel by introducing a physical obstruction to sediment transport. Once sediment accumulation began, a self-reinforcing cycle of deposition was initiated. Sediment that was stored behind wood in the channel increased the stream bed roughness, decreased the local slope of the channel and reduced the capacity for sediment transport.

Observed volumes of sediment and wood were directly related to the estimated time since the last debris flow, as determined by dendrochronology. For over 50 years following a debris flow, the erosional zone of the channel was predominantly bed-

[1] *Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA, 97331.*

[2] *U.S. Geological Survey, Forest and Range EcosystemScience Center, and Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, USA, 97331*

Figure 1. - Low-order streams can indirectly affect the structure of fish bearing streams by influencing the routing and storage of water, sediment, and wood. A recent debris flow scoured this low-order stream to bedrock.

Figure 2. - Debris flows can directly affect fish bearing streams by functioning as a pulsed disturbance and by redistributing large volumes of sediment and wood. This large wood dam completely blocked the channel and valley floor.

rock with isolated patches of sediment stored behind individual logs. After 100 years, patches of wood and sediment began to coalesce but did not continuously cover the streambed. After 150 years, a highly complex channel structure developed. At this stage the channel had high roughness, variable local slopes, and a broad range of substrate characteristics and bed morphologies. In many cases there was an almost continuous fill of sediment and wood in the valley floor.

DIRECT AFFECTS

The structure and function of debris flow deposits in fish bearing streams varied spatially in a basin and through time. These deposits had the potential to form complex and dynamic channel morphologies and were an important component of habitat development.

Large wood dams (Figure 2) that completely blocked the channel and valley floor and stored a large wedge of sediment upstream were formed in narrow valley floors. These deposits were associated with reach-scale changes in the valley width, valley slope, and channel confinement. In contrast, debris flow fans formed in wider valley floors and were a major controlling factor on channel sinuosity and confinement. These deposits persisted for centuries and were an important factor in trapping recent debris flows before they reached the active channel.

MANAGEMENT IMPLICATIONS

In recent years it has become increasingly apparent that the formation and maintenance of complex aquatic habitat is a manifestation of the physical and biological linkages between streams, riparian zones, and uplands. As a result, watershed management needs to consider processes that occur both proximal and distal to fish bearing streams. Upland forests and headwater streams can influence water quantity, water quality, invertebrate and detritus inputs, and physical habitat characteristics throughout the drainage network.

Small, ephemeral channels often do not directly support fish; however, they may have a strong influence on the rate of sediment and wood delivery to the larger rivers that provide habitat. Small streams have the potential to store large volumes of wood and sediment for decades to centuries, and this material can be episodically delivered to fish bearing streams by debris flows. For example, 11 – 59% of the total wood volume in 11 mid-order basins was recruited directly from debris flows triggered during a large regional flood event in 1996 (May, in press). After the large wood is scoured from the low-order stream and transported to a larger river, recruitment of wood from streamside and upslope forests can replenish the channel in the interval between debris flow events. If these basins are managed on a short timber harvest rotation period and if no streamside buffers are re-

tained, recruitment potential of large wood may be diminished. If this trend continued, future debris flows could be characterized by a lack of large wood stored in low-order channels. When large wood is lacking in a basin, the sediment storage capacity of the channel may be limited and the channel can become a chronic source of sediment to downstream areas instead of an episodic source.

Debris flows are also an important component of the disturbance regime that native biota have evolved with, and are well adapted to. Forest harvest and road construction on steep slopes and along low-order streams may affect natural disturbance regimes by altering the frequency, magnitude, and composition of debris flows (May 1998). By altering these aspects of the natural disturbance regime, land-use practices may have unforeseen and adverse impacts the resilience of aquatic ecosystems.

ACKNOWLEDGMENTS

This project is part of the Cooperative Forest Ecosystem Research Program, a research consortium that includes the USGS Forest and Rangeland Ecosystem Research Center, the U.S. Bureau of Land Management, Oregon State University, and Oregon Department of Forestry.

LITERATURE CITATIONS

Benda, L.E. 1990. The influence of debris flows on channels and valley floors in the Oregon Coast Range. Earth Surface Processes and Landforms 15: 456-466.

Bilby, R.E. and P.A. Bisson. 1998. Function and distribution of large woody debris. Pages 324-346 *in* R.J. Niaman, and R.E. Bilby, editors. River ecology and management: lessons from the Pacific Coastal ecoregion. Springer Publications.

Hogan, D.L., Bird S.A., and M. Hassan. 1995. Spatial and temporal evolution of small coastal gravel-bed streams: the influence of forest management on channel morphology and fish habitats. Pages 365-392 *in* P.C. Klingeman, R.L. Beschta, P.D. Komar, and J.B. Bradley, editors. Gravel-bed rivers in the environment.

May, C.L. 1998. Debris flow characteristics associated with forest practices in the Central Oregon Coast Range. Oregon State University, Corvallis. M.S. Thesis.

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

Shreve, R.L. 1969. Stream lengths and basin areas in topologically random channel networks. Journal of Geology (77): 397-414.

Ecosystem Planning Approach for Reintroducing Bonneville Cutthroat Trout in Nevada[1]

Neal W. Darby[2] and Tod B. Williams[3]

Abstract—Chemical treatments to eradicate nonnative fish would affect all gill-breathing organisms. To minimize impacts on these other aquatic species, an intensive ecosystems based program was implemented. Using established protocols, four streams were surveyed for amphibians, fish, macroinvertebrates, and mollusks to determine organism abundance and diversity for recovery goals after chemical renovation, and the extent of streams requiring treatment. No amphibians were detected. Most fish were non-native salmonids. Mollusks were rare in streams but abundant in springs and seeps. Macroinvertebrates were abundant and diverse. A baseline of mollusk and macroinvertebrate abundance and diversity was established and the extent of streams required for treatment has been minimized based on fish species presence and distribution and mollusk presence.

The BCT reintroduction plan for Great Basin National Park (GRBA) uses an ecosystems approach by using intensive stream surveys for mollusks, macroinvertebrates, amphibians and fish. Survey results could indicate the presence of other sensitive species, such as Great Basin Spring Snails (*Pyrgulopsis* spp.) or the Columbia Spotted Frog (*Rana luteiventris*), and provide baseline data for monitoring stream recovery. Based on these survey results, mitigation measures can be adopted to protect sensitive species and speed recovery to pre-chemical renovation treatment conditions.

Following is an example of survey data collected on three stream systems in GRBA and how it was used to ensure ecosystems planning and protection.

METHODS

Amphibians, fish, macro-invertebrates and mollusks each require a different survey method. Established scientifically based survey protocols for each group were selected.

Amphibians

Look under cover objects within the riparian area 100 meters upstream and downstream from permanent markers.

Fish

Conduct multi-pass electroshocking surveys 100 meters upstream from permanent markers and conduct spot electroshocking for fish.

Macro-invertebrates

Agitate stream bottom and brush objects into kick-nets at 4 points along a transect upstream from a permanent marker.

Mollusks

Agitate stream bottom and brush objects into Surber samplers at 8 points along a transect downstream from a permanent marker.

RESULTS

Amphibians.—No amphibians have been detected. The amphibian survey protocol was modified through adaptive management to correspond with breeding activities in early spring and late summer. Even with this change, no amphibians have been detected.

Fish.—Nonnative rainbow, brook, and brown trout made up the majority of fish sampled in Strawberry

[1] *Presented as a poster at Wild Trout VII.*

[2] *Wildlife/Fisheries Biologist, Great Basin National Park, Baker, NV 89311.*

[3] *Natural Resource Program Manager, Great Basin National Park, Baker, NV 89311.*

Creek and Snake Creek (Table 1). Fish in Mill Creek exhibited strong BCT characteristics and fin clips were obtained for genetic analysis. Last fish observed was at 8,400 feet on Strawberry Creek, 8,200 feet on Mill Creek, and 9,000 feet on Snake Creek.

Macroinvertebrates.—Macroinvertebrate taxa are diverse and abundant indicating moderate to high water quality (Table 2).

Mollusks.—Mollusks were rare in streams but fairly abundant in specific springs and seeps adjacent to streams (Table 3). Quantitative surveys were not conducted on springs or seeps.

CONCLUSIONS

The following summary and conclusions were reached for each stream system:

Strawberry and Snake Creeks

- Sensitive mollusks detected. Headwaters and springs protected from treatment.
- Macroinvertebrate baseline conditions set.
- Fish consist mostly of nonnative salmonids.
- Strawberry Creek chemically renovated in 2000.
- Plan for Chemical renovation of Snake Creek in 2001.

Mill Creek

- No sensitive mollusk or amphibian spp. detected.
- Macroinvertebrate baseline conditions set.
- Fish exhibited strong BCT characteristics.
- Genetic tests confirmed fish as BCT.
- No chemical renovation needed. Monitor.

South Fork Big Wash

- Mollusks found primarily in Springs.
- No fish have been detected.
- No renovation needed. BCT reintroduced.

Table 1.—Average maximum likelihood estimate of fish per mile of stream

	Nonnative salmonids	Cutthroat Trout
Strawberry Creek	942	1 specimen
Mill Creek	1 specimen	418
Snake Creek	2588	0
South Fork Big Wash	0	0

Table 2.—Macroinvertebrate taxa richness and abundance by functional feeding groups. Number of taxa and number of individuals per square meter. Numbers in parentheses are percentages. Unknown or unidentifiable specimens not included in table.

Site	Predators	Shredders	Scrapers	Collectors
	Taxa Richness by Functional Feeding Groups			
Strawberry	5 (19)	3 (12)	4 (15)	11 (42)
Mill	6 (21)	3 (11)	3 (11)	11 (40)
	Abundance by Functional Feeding Groups			
Strawberry	1,083 (7)	404 (3)	1,350 (9)	11,439 (78)
Mill	1,644 (17)	753 (8)	339 (3)	6,615 (68)

South Fork of Big Wash and Snake Creek samples are still being processed at this time.

Table 3.—Number of mollusks collected from each stream system (#/m²).

	Great Basin Spring Snails*	Other Snails	Clams
Strawberry Creek	2 (0.5/m²)	3 (1/ m²)	32 (4.4/ m²)
Snake Creek	1 (0.22/m²)	2 (0.44/m²)	12 (2.7/m²)
Mill Creek	0	0	50 (23.2/m²)
South Fork Big Wash	2 (1.7/m²)	1 (1.4/m²)	0

Multi-partnership Success for Bonneville Cutthroat Trout Conservation in Nevada[1]

Neal W. Darby[2], Chris A. Crookshanks[3], James Whelan[4], and Jennifer Coons[5]

Abstract—Multiple partners, including the Nevada Division of Wildlife, Humboldt National Forest, Ely District of the Bureau of Land Management, Great Basin National Park, Trout Unlimited and private landowners have pulled together to promote Bonneville Cutthroat Trout (BCT) conservation in eastern Nevada. Increased communications, monitoring and management actions accomplished by sharing personnel and equipment have improved knowledge of BCT populations and habitat status. Partners participating went from two prior to 1999 to six. The quality of completed population surveys went from one prior to 1999 to six, providing more precise population estimates and increased response to management concerns. Reintroduction efforts went from relocating 172 fish between 1996-1998 to relocating 254 fish in 1999. Streams actually surveyed as possible reintroduction sites went from four streams over the past 11 years to five additional streams in 1999. This dramatic shift was not a result of changed policies but a result of personal attitudes and desires to promote the conservation of BCT.

INTRODUCTION

Because of the remoteness of Bonneville Cutthroat Trout (BCT) (*Oncorhynchus clarkii utah*) populations in eastern Nevada, monitoring and management actions are difficult to complete in adequate timeframes. This is due to sparse personnel within each agency. The results are difficulties in interpreting trends and results of management actions due to survey time variables between and within populations.

Starting in 1999, we initiated a multi-partnership BCT management team to improve BCT management and information sharing. The team consisted of Nevada Division of Wildlife, Humboldt National Forest, Ely District of the Bureau of Land

Management, Great Basin National Park, Trout Unlimited and private landowners. The goal was to increase the quantity and quality of BCT information collected over a wider area within each field season.

OBJECTIVES/METHODS

Our objective here was to determine if multi-partnership BCT Conservation accomplishments:

1) Increased
2) Decreased
3) or Remained the Same

We reviewed records for BCT population surveys, BCT translocations, and aquatic surveys for potential BCT reintroduction sites, noting number of partners involved and accomplishments to compare with work completed under our multi-partnership work conducted in 1999-2000.

RESULTS

A review of past BCT conservation activity indicated that since the multi-partnership was begun in 1999, more work has been accomplished. Partners went from two to six (Table 1). More population surveys, numbers of fish translocated and streams surveyed were conducted (Figures 1-3). The amount of work done in 2000 was lower than 1999 because most BCT management work was completed in 1999. In fact, most required surveys were completed in 1999, not spaced over several years as was done in the past.

[1] *Presented as a poster at Wild Trout VII.*

[2] *Wildlife/Fisheries Biologist, Great Basin National Park, Baker, NV 89311*

[3] *Fisheries Biologist, Nevada Division of Wildlife, Ely, NV 89301*

[4] *Fisheries Biologist, Fishlake National Forest, Richfield, UT 84701*

[5] *Southern Nevada Chapter President, Trout Unlimited, Henderson, NV 89015*

Table 1.—Partnerships in Bonneville Cutthroat trout conservation.

Bonneville Cutthroat Trout Partnerships Prior 1998	1999-2000
Nevada Division of Wildlife	Nevada Division of Wildlife
Humboldt National Forest*	Humboldt National Forest
Bureau of Land Management*	Bureau of Land Management
	Great Basin National Park
	Trout Unlimited
	Private Landowners

*Participants within their respective jurisdictions only.

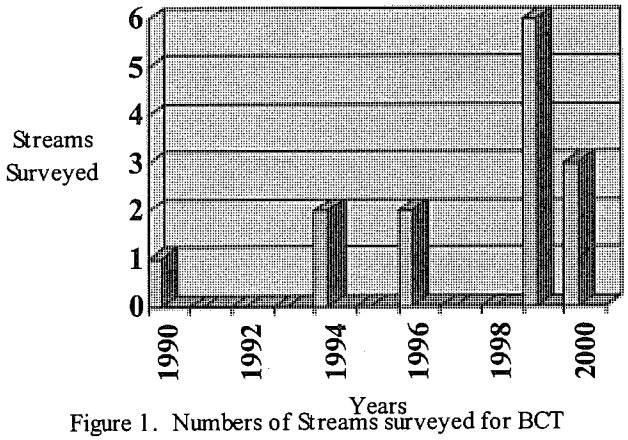


Figure 1. Numbers of Streams surveyed for BCT population estimates

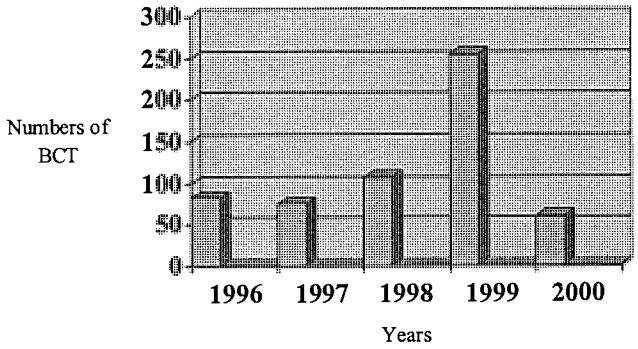


Figure 2. Numbers of BCT translocated.

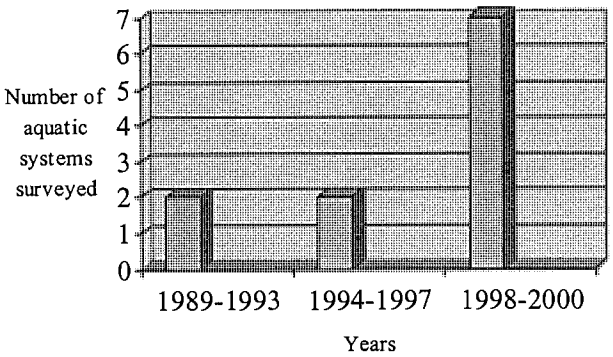


Figure 3. Numbers of Aquatic Surveys completed for assessing Reintroductions of BCT

A review of agency policy or direction towards multi-partnership work, particularly towards BCT, found nothing new since 1998. The only new policy was a Memorandum of Understanding (MOU) between Great Basin National Park and Trout Unlimited to work together and promote the conservation of BCT. However, it set no timelines or specific work to be accomplished. Hence, personal attitudes provided the impetus to establish the multi-partnerships that promote the conservation of BCT.

CONCLUSIONS

This multi-partnership provided the personnel and equipment needed to successfully complete BCT conservation projects. Using multiple personnel from all agencies allowed the completion of population surveys on most BCT occupied streams in a single year. This should lead towards more frequent and complete population surveys to more closely follow trends. Frequent dialog between partners provided information on protocols for aquatic surveys providing consistency and guidance for independent or coordinating surveys. More personnel allowed for greater abilities to translocate more BCT into remote habitats under shorter timeframes.

Overall, work completed should facilitate better management of BCT. An assessment of the quality of information collected is occurring. Multi-partnership work did not precede any shift in policy or agency direction. It preceded personnel changes that complimented attitudes to promote the conservation of BC.

British Columbia's Dean River—Limited Entry: A Management Tool for Maintaining a Quality Angling Experience

Jack Leggett[1]

INTRODUCTION

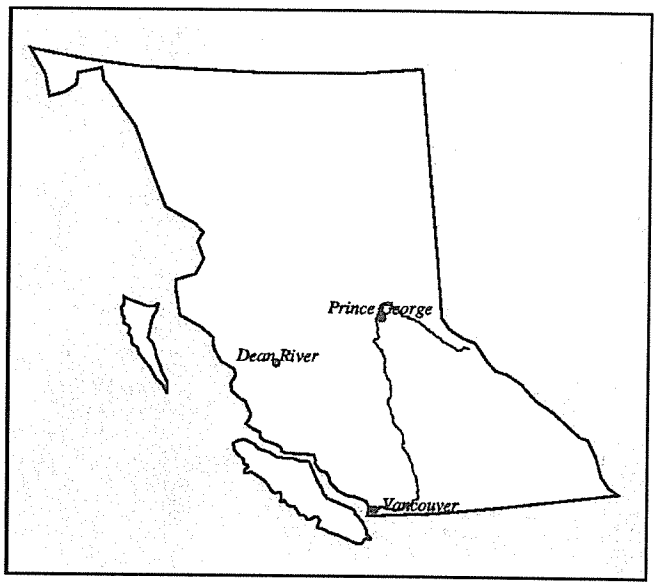
British Columbia is home to a commodity that is becoming increasingly rare on a global scale – opportunities to fish in unspoiled natural surroundings for special stocks of wild fish where angling demand is still manageable.

In the mid 1980's record returns of steelhead created large increases in angler effort, particularly from the commercial oriented users and non-residents. Anglers became concerned that the values they were seeking in a recreational experience were being eroded by competition at prime time and in preferred locations. The province responded by implementing a classified waters system in 1990 and identified 7 Class 1 and 35 Class 2 waters. Most waters were classified for their steelhead attributes and others for their quality rainbow fisheries.

A Class 1 water authorises restrictions on the number of angling days by class of angler (i.e. Guided, non guided, non-residents and residents) with residents being the last group to be restricted. Class 2 waters authorise restrictions on the number of guides and the number of guided days.

The Dean River is renowned as a premier wild summer run steelhead river in B.C. It is a 225 kilometer river system that is located on British Columbia's central coast some 475 kilometers Northwest of Vancouver and 300 kilometers West of Prince George. Access is by aircraft or boat. There is no road access (Map 1).

It is regarded by some anglers as being one of the finest summer-run steelhead rivers in the world and is a popular destination for anglers that enjoy an isolated fishing experience with wilderness and pristine surroundings. The fishery is only open for the period of June 1 to September 30.



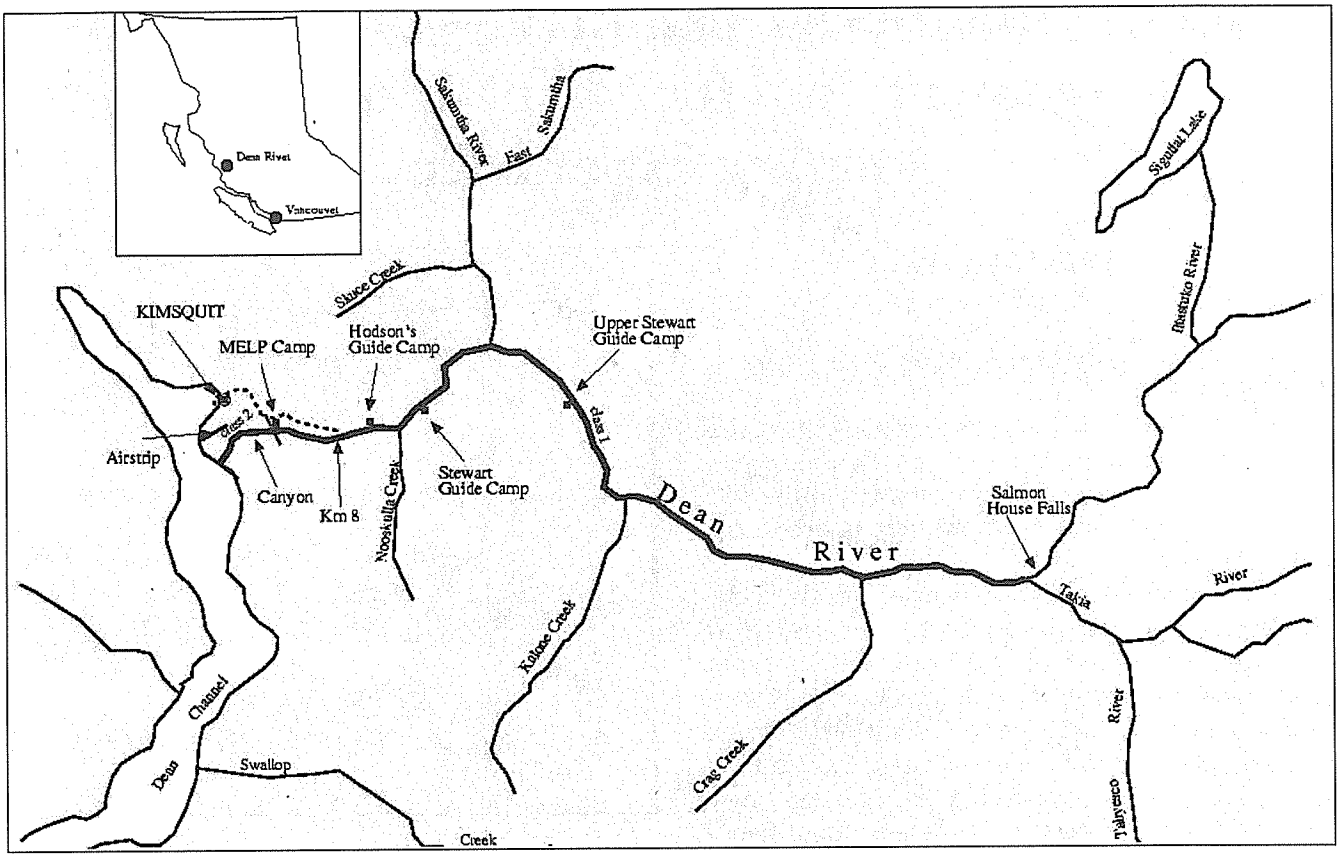
Map 1

In the Dean River Steelhead Management Plan there are both Class 1 and Class 2 waters.

The Class 1 sections (Canyon at 4km to Kalone Creek and Kalone Creek to Crag Creek) a distance of 42 kms there are 3 licensed guides with a total of 1720 guided days (Map 2). Based on a grandfathered 40/60 split this leaves 4300 days available for the unguided angler. In any given day the number of anglers is not to exceed 57 (22 guided – 35 unguided). This number was based on the amount of fishable water over the 42 kms. In the Class 2 section (4 km Canyon to tidewater) there are 320 grand fathered guided days in regulation during the July 1 to August 30 classified period with a maximum of 3 licensed guides for the licenced year (Map 2). The guide days available for this Class 2 section were derived from grand fathering existing guides. In this 4km section there is no restriction on unguided use.

Non-residents of Canada who do not retain the services of a licenced guide must enter a limited entry draw to fish the Class 1 portions of the Dean River. Before days are made available to non-residents the

[1] *British Columbia Ministry of Environmnet, Fisheries Branch, Williams Lake, B.C.*



Map 2

needs of British Columbians and other Canadian residents are first taken into account. Resident needs are based on the previous season use as determined by the River Guardians. Non-residents of Canada who are guided need not enter the draw. Angling days for guided anglers become part of a guides quota. Non guided anglers entering the draw are allocated angler days according to a weekly quota for the period June 1 to September 30 (**table 1**). Summary and overview of Angling Days reserved in the year 2000 draw. Draw applicants may apply as individuals or as a group with a maximum group size of four

TABLE 1.--Overview of angling days reserved in 2000 draw.

Dates Allotted For Draw	Days Available	Days Reserved In Draw	Days Remaining	% of Available Days Used
June 19 to June 25	137	0	137	0%
June 26 to July 2	122	0	122	0%
July 3 to July 9	162	8	154	5%
July 10 to July 16	169	25	144	15%
July 17 to July 23	148	28	120	19%
July 24 to July 30	171	73	98	43%
July 31 to August 6	147	129	18	88%
August 7 to August 13	126	126	0	100%
August 14 to August 20	99	89	10	90%
August 21 to August 27	71	70	1	99%
August 28 to Sept 3	127	126	1	99%
Sept 4 to Sept 10	155	127	28	82%
Sept 11 to Sept 17	174	11	163	6%
Sept 18 to Sept 30	127	32	95	25%
TOTAL	**1935**	**844**	**1091**	**44%**

Table 2.--Dean River Draw Group Summary 1990 – 2000

Description	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
# of Groups Entered in Draw	38	38	34	29	27	51	47	39	43	55	64
# of Anglers in Draw	105	112	94	72	66	152	138	148	149	150	158
Days Accounted for by Draw	710	738	614	559	499	1103	982	973	1110	923	844
# Groups First Choice	34	33	28	29	27	51	37	35	38	38	48
# Groups Second Choice	2	1	1	0	0	0	2	1	2	2	2
# Groups Third Choice	0	1	2	0	0	0	2	3	1	3	1
# Groups Alternate Choice	0	0	0	0	0	0	3	3	2	4	12
# Groups Reduced Days	0	0	0	0	0	0	1	1	0	0	0
Unsuccessful Groups	2	3	3	0	0	0	2	3	0	7	1

(table 2). There is presently no restriction on the number of B.C. resident or non-resident Canadian anglers at this time, as resident use has not reached its weekly allotment.

A non-resident of Canada is allowed only one classified waters licence and may fish only one classified portion (Class 1 or Class 2) of the Dean River for a maximum of 8 consecutive days. Non-residents of Canada accounted for 61% of the effort in 1999. A Fisheries Guardian Program, funded the Habitat Conservation Trust Fund which secures its funding from the surcharge on Hunting and fishing licences, monitors the fishing and regulation compliance on the river.

It is now 10 years since the commencement of the Dean River Limited Entry and public concencus is for it to continue. Anglers seem happy, guides appear happy. A recent note from a Mr. Mike Howard, a Boise Idaho fisherman and fishing in August wrote on his creel card, "The fishing was excellent and we 'broke' off more fish than we landed" What a precious gem B. C. has in the Dean River!

If asked if I am a supporter of limited entry my response would be a resounding "yes". On the Dean River we have been able to maintain a "Quality" angling experience for all classes of anglers in a pristine and uncrowded environment.

Limited Access Fisheries – Management Options for the Future

Mac Minard[1]

Abstract—The confident lodge owner stands to welcome and address his guests for the week. He greets them with a warm Alaskan welcome and moves on to outline the fishing program in store for his eager clients. He explains " Tomorrow we will fish for king salmon. The fishing will be good, the kings are in and we have been averaging a fish an hour. It is going to be crowded there but it is a big river and there is lots of room". The guests begin to wonder where the mystique of the Alaskan wilderness went. Did they really fly all this way to trip over other fishermen and compete with other lodges for the best fishing? The lodge operator sees the disappointment and moves to the next day's plan. "The next day however, we have space on a river where it will only be us for the day. You will be able to enjoy that fishery in an uncrowded unhurried manner with your friends. There are lots of hungry trout, the hatches are good and we will have it to ourselves." We only get if for the day, so I will not be able to get you there again."

CADILLAC TO VOLKSWAGEN

The process under which a pristine fishery deteriorates to what Alaska we call a combat fishery is an interesting process. In all of our states there is some form of public involvement in the regulatory process. This involvement however, is generally constrained to fit within a paradigm that growth in sport fishing participation be addressed by increasingly conservative regulations. This effort is based on the premise that we must be more conservative to ensure that an increasing number of people can have a share of a finite resource. After all, there are only so many fish available to catch and only so many places to go to catch them. This model has in many Alaskan fisheries resulted in a situation where the number of anglers has increased to a point where seasons, bag limits and methods and means restrictions have become ridiculously complex and restrictive. Additionally, and perhaps more importantly, the character of the fishery and the participants have changed. While the public process concerning the restrictive steps is alive and well, what of the public process that set the course from pristine to combat? In most cases it is not a conscious decision in an open public forum. Overwhelmingly, it is the default. Is more always better? I think not.

In the Bristol Bay region of Alaska the recreational fishing industry is estimated to generate some 70 to 90 million dollars per year. The industry does this while harvesting less than two percent of the fish taken within the region. The sport fishery within the region has been described as a high value, low impact, and high quality fishery. The costs of managing this fishery are minimized by the relatively low harvest potential. Studies have shown that guided and non-guided anglers visit the region primarily to fish for salmon and rainbow trout in a pristine wilderness setting. This is a Cadillac. In the 20 or more years I have been associated with the Bristol Bay fisheries changes have occurred that have diminished one or more of the three important elements (salmon, rainbow trout, wilderness) in some fisheries. Crowding, competition for fishing space, frequency of hook-marked fish, reductions in abundance and size composition have all been addressed in the traditional manner, through increasingly complex and conservative regulations. In some fisheries we are now driving a Volkswagen.

In the private sector, no plant manager or company would simply drift from a high value product line to a low value product line without making a conscious decision to do so. And yet, that is exactly what happens when recreational fisheries undergo unlimited growth in participation. Managers and regulators respond to increased effort and harvest potential

[1] *Regional Supervisor, Division of Sport Fish, Fairbanks, Alaska.*

in the age-old traditional manner; by cranking down the bag limit, shortening the season, or just dumping in more catchables. All of these efforts result in increased costs to management and therefore diminish the benefit/cost ration for the fishery. It could be argued that the increased license sales presumably associated with increased effort would carry the costs. What about the social costs. What is the cost of the incremental loss of uncrowded fishing opportunity?

LIMITED ACCESS OR NO ACCESS

In my career I have seen instances where the life history, biology, and vulnerability of a particular stock of fish presents a situation where the manager, and the angling public, are reluctant to allow unlimited participation in a fishery. This situation can be realized on a stock considered to be stable at historical levels, but is just in a particularly vulnerable state, like a prespawning aggregation of rainbow trout. This situation may also present itself in the form of a stock, which for any number of reasons was depressed and is now undergoing a period of recovery. In either case, the usual path is to close the fishery totally since traditional time and area, methods and means, and bag limit restrictions are not sufficient to provide enough protection in an unlimited access situation. In both cases it is a biologically indefensible position to argue that the stock can sustain absolutely no fishing pressure. In fact it may be able to sustain some limited amount and provide a highly unique opportunity to the angler privileged to participate. Managers are fully capable, given the usual tools and informational inputs, to determine some acceptable level of fishing mortality in either case presented. It is a relatively straightforward endeavor to translate that into a measure of effort that can be sustained while still meeting the management objectives for the given fishery. Why then is the fishing public denied the opportunity to participate in a fishery when it can be done in manner consistent with the principles of sustained yield? I would argue that to allow some level of fishing opportunity, albeit in a limited manner, is better than a total closure. Obviously there are considerations of cost of management. The cost of providing a day of limited access fishing opportunity needs to be weighed against the benefits accrued through the realization of that opportunity. This is not a new concept in resource management. On the contrary there are many examples on the wildlife (game) side where there are only so many sheep hunters allowed to participate in a hunt within a given area. This limitation has its basis in both conservation and quality. In Alaska, the Board of Game and the hunting public have recognized the value in providing opportunities to participate in hunts where the participants are essentially guaranteed to not be over run with other hunters. These opportunities are provided not on the basis of maximum sustained yield but on conservative yield principles, where biology and crowding are taken into consideration.

Many other examples of limitations on access can be found, some even in fisheries. The famous waters of Armstrong and Depues spring creeks are managed under a limited access approach. However, in the fisheries arena it tends to be only the privileged few who can afford the cost of participation. Does the fisherman of common means have no interest in such an opportunity. Are the resources managed under the public trust all destined to slide down the slope and ultimately meet with the tragedy of the commons?

A QUESTION OF QUALITY

Mention quality to a group of fishery managers and you can expect to hear the age-old mush about how it varies with the individual and how difficult it is to define and therefore can not be put into clear management objectives. For that reason, I am reluctant to bring the issue of quality to the discussion. Frankly, I do not believe you need to discuss the issue of limited access fisheries in terms of quality to make a compelling argument. Diversity of opportunity and managing within the limits of sustained yield are satisfactory in my opinion. However, in the interest of completeness and to not disappoint the nay sayer, I will address the issue of quality, however, I will do so with a twist.

Quality need not be a nebulous term that we managers puff on our pipes and discuss into no resolution. In the cold science of economics is the answer to how to roll quality into the discussion of limited access fisheries. In fact, it can be rolled into virtually any discussion of angling opportunity. It has been my experience that the discipline of economics and its application to decision making in fishery management is a generation ahead of our current management approach. In Alaskà, allocation of resources between commercial and sport fishermen is an incredibly intense and highly charged topic. Although brave

pioneers have attempted to bring economic theory and decision making to the forefront, they have generally been sent packing by a public and group of regulators not yet willing to formally put it to practice.

IN THE END IT IS PUBLIC PROCESS

Make no mistake, limited access fisheries are not a solution or even a viable option in many cases. It is not the role of an agency to force feed this management option to an unwilling public. However, it is my position that we have a responsibility to consider, to study, to educate, and objectively bring forward to the public arena the potential benefits and costs of such a system. It would be my vision that fisheries to be managed for limited access would have associated with them clear and measurable management objectives. They would be selected based upon criteria developed in a public forum. These criteria would be useful in evaluation of candidate waters so that those most likely to be embraced by the angling public and carry the greatest benefit to a region are selected. In my vision, limited access fisheries would be the exception, not the rule. Access to the fishery would be the privilege of the angler, not an industry owned stock option. They would provide the angler of common means the opportunity to participate in a unique fishing experience.

To accomplish this, managers, researchers, and administrators must leave at the door their own values and begin the collection of information regulators and decision makers need to have to fully evaluate this option. We must look at this as a way to provide diversity in fishing opportunities on a regional basis. Exchange of ideas, methods of deriving management objectives and implementing this concept will be essential to success.

In the end it will be the angling public, along with the public at large, who will decide if this is an acceptable path.

Limited Entry—No Demand Way!

David K. Berry[1]

Changes of the past millennium give reason to doubt the survival of fish resources. Are we ready for the future?

In Alberta, hunters and licensed anglers are registered in an automated licensing system. A drawn system exists for controlled harvest of big game on a quota licence basis, where required. The system is adaptable to fisheries; however, should a limited entry system be used in fisheries management?

Lower Kananaskis Lake in southwestern Alberta sits in the mountains within a high-use provincial park. Bull trout, the primary native species, was reduced to the point of collapse by the 1990s because of angling pressure and habitat alteration. In 1992, the bull trout limit of two over 40-cm (TL) was replaced by catch-and-release only (0-limit) and bait ban. The spawning stream was closed to all fishing.

The bull trout population in Lower Kananaskis already shows signs of recovery. Spawning activity has increased from 60 spawners and 33 redds in 1992 (Stelfox and Egan 1995) to 1152 spawners and 672 redds in 1999 (Mushen and Post 2000). A peak at 1278 spawners and 906 redds occurred in 1998.

Evidence the population is approaching a plateau is suggested by slight reductions in growth and condition, and a possible increase in natural mortality. The slight decline in redd count could reflect saturation of available spawning sites. Anecdotal information from anglers indicates the improved catch rate of large trout is attracting more anglers.

Model development to assess alternate management strategies for bull trout has been based on the Kananaskis research (Post et al 2000). The model predicts maximum sustainable fishing efforts that still maintain a viable population under different regulations. Hooking mortality and non-compliance become crucial factors as angling effort increases. The authors postulate that even under a complete catch-and-release (0-limit) regulation these factors could collapse the bull trout population. However, expanded studies are required to better understand angler-effort dynamics as well as mortality factors.

In 1999, Alberta Environment proposed a pilot study at Seibert Lake for a draw and limited entry licence. Seibert Lake has been managed as a trophy fishery for over twenty-five years. Despite being a relatively remote lake with a limit of only two pike, bait ban and a two-month spring closure, the lake was not adequately sustaining a quality fishery.

The moderate variance of age-class distribution and low densities of age-classes of pike sampled between 1972 and 1994 provided evidence of growth overfishing (Sullivan, pers. comm.). Summer angling pressure increased from 1.3 angler-hours ha^{-1} in 1972 to 2.3 angler-hours ha^{-1} in 1994, and the catch rate dropped from 0.60 to 0.20 pike caught hr^{-1} (0.06 pike kept hr^{-1}).

Anglers and sportfishing organizations, locally and provincially, voiced strong opposition to the concept of limited entry. The pilot study was withdrawn in favour of a minimum-size limit of one pike larger than 100 cm (TL).

Some concern was also expressed concerning the possible evolution of two-tiered fishing rights—private and public. Mechanized resource allocation and limited entry licensing could make privatized access and paid-for-fishing rights an easier step. The waters of Alberta and their fish populations are public resources.

Angler perception of regulations determines how regulations impact fish populations. Most anglers, with the exception of avid flyfishers and walleye enthusiast, view zero limits (catch-and-release) with the negative interpretation "closed." Campgrounds at lakes with zero limits or other severe harvest restriction often experience a reduction in use. Limited entry fisheries could also impose local economic impacts.

Sportfishing licence sales declined from a peak of 352 522 in 1986 to 212 137 in 1999. Fishing pressure also declined from 5.4 million man-days in 1985 to 3.7 million man-days in 1995 (Berry 1997). During the same period, Alberta's human population has increased from 2.3 million to 2.9 million.

In 1995, licensed anglers spent $312 million (CDN) on sportfishing in Alberta, an increase of only $16.9 million from 1985. The loss of 140 000 licensed an-

[1] *Provincial Recreational Fisheries Specialist Fisheries and Wildlife Management Division Alberta Environment (Dave.Berry@gov.ab.ca)*

glers could represent an annual decrease of $188 million to the sportfishing industry and economy.

The average age of our angler population is increasing and first time anglers are few, which is concerning. On average, resident anglers have fished in Alberta 19.6 years. Youth should be encouraged to enter the sport of fishing, not discouraged by limited entry.

Our 'tool box' of open access regulations has not been exhausted. While fishing pressure has been declining, sportfishing regulations have become much more restrictive. The angling public is not requesting limited entry, and the need for drastic control of fishing pressure at this time is questionable. The concept is met with scepticism regarding intent and future application. I submit the current perception of limited entry is "No Demand Way!"

LITERATURE CITATIONS

Berry, D. K. 1997. Sportfishing in Alberta 1995. Alberta Environment, Fisheries and Wildlife Management Division.

Mushens, C. J. and J. R. Post. 2000. Population Dynamics of the Lower Kananaskis Lake Bull Trout: 1999 progress report. Department of Biological Sciences, University of Calgary, Calgary Alberta.

Post, J.R., C. Mushens, A. Paul and M. Sullivan. 2000. Assessment of Alternate Management Strategies for Sustaining Recreational Fisheries: Model Development and Application to Bull Trout, *Salveslinus confluentus*. Manuscript. Division of Ecology, Department of Biological Sciences, University of Calgary, Calgary Alberta.

Stelfox, J.D. and K.L. Egan. 1995 Bull Trout Investigations in the Smith-Dorrien Creek/Lower Kananaskis Lake System. Report prepared by Fisheries Management Division, Alberta Environment and by Golder Associates Limited, Calgary Alberta.

Sullivan, M. Provincial Fisheries Science Specialist, Fisheries and Wildlife Management Division, Alberta Environment. Personal communication.

Limited Entry to Public Trout Water: The Pros and Cons

Gilbert Bergen[1]

Abstract—The Connetquot and Nisequogue rivers flow through state parks lands on New York's Long Island, and are within 100 miles of 30 million people. Historically, these fisheries were controlled by private fishing clubs, but for the past 27 years public angling access to these waters has been available through a system of reservations and fees. Anglers may reserve fishing sessions by phone with fishing sites assigned on a first come first choice basis on the day of the reservation. Angling fees are used to defray the costs of management including hatchery operations and stocking. Because of this system, a quality angling experience has been maintained in a large urban area. Controls on angling access have also helped protect sensitive wetlands, endangered species, and allowed parks to be managed to establish local support and public acceptance of the angling reservation system and fee structure as well as resolving complaints and conflicts between user groups.

INTRODUCTION

The Connetquot River State Park Preserve is located on the south shore of Long Island near the hamlet of Oakdale, New York. Long Island is a drift of eroded continental material deposited by several periods of glacial activity on the North American continent. Long Island is 120 miles long and 16 to 20 miles wide. The south shore is typical of a glacial outwash plain, similar to other such deposits in the Eastern United States. The barrier beach is washed by the Atlantic Ocean, with bays and marshes behind the dunes.

The many streams and small rivers feeding into the bays are fed by rains that fall on the island, and gradually filter out through this great sand sponge. These pure waters were ideal habitat for Brook Trout (*Salvelinus fontinalis*) that sometimes went to the brackish waters to feed.

As early as 1700, the Connetquot was harnesses for use as power for a grist mill by William Niccoll, first proprietor of Islip Grange. The resulting pond formed by the damming of the stream for the mill also provided excellent habitat for trout, and by1820 anglers were coming to Snedecors Tavern for the fishing. After the Civil War, the fishermen found they had trouble getting a room at the Inn, so they did the only logical thing and purchased the property and most of the watershed. On April 6th, 1866, the South Side Sportsmen's Club of Long Island was chartered. This club was made up of wealthy sportsmen who enjoyed fishing and shooting along the Great South Bay of Long Island.

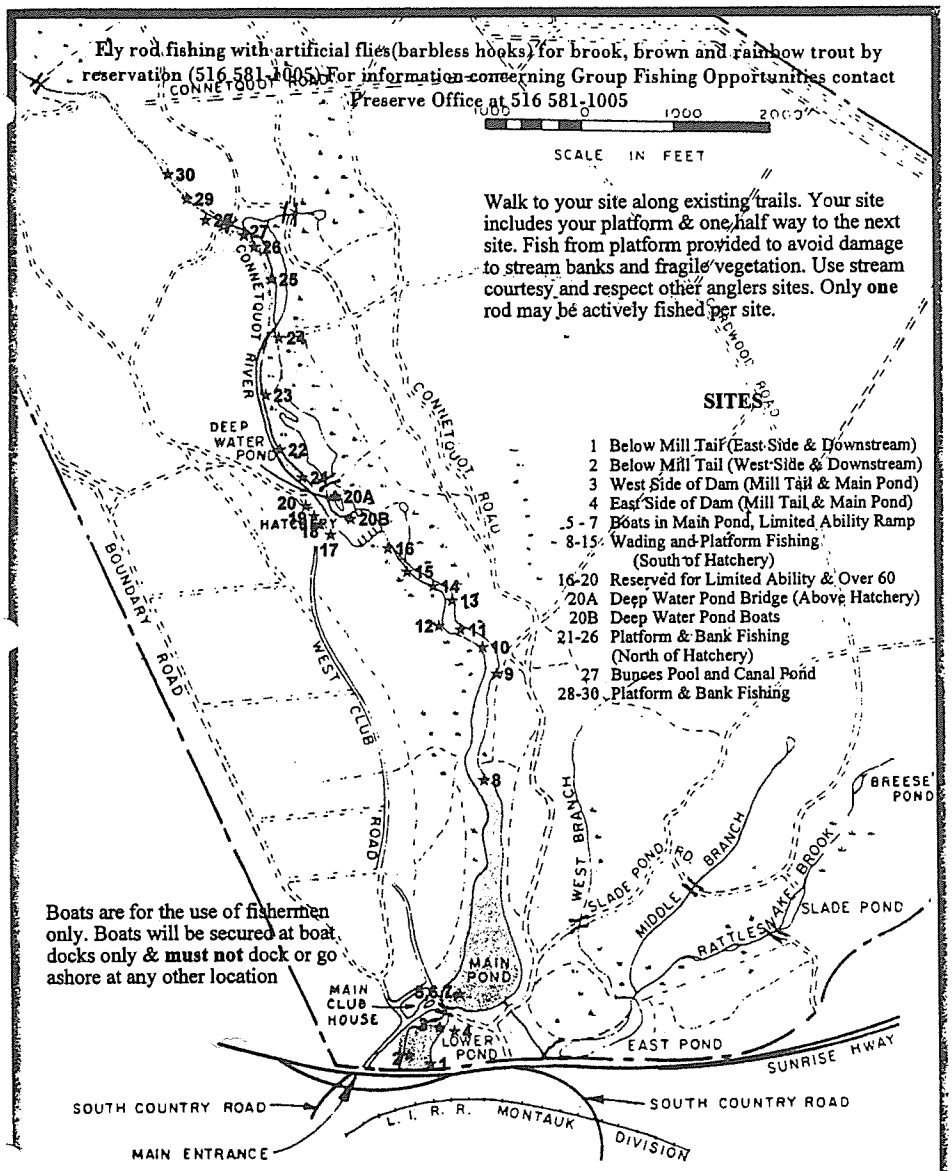
Early conservationists, they improved the area, established a trout hatchery on the property in 1868, and gradually increased their holdings to 3473 acres to protect the watershed. The Club prospered until 1963, when the property was purchased by the State of New York, with a 10 year lease back provision. In August of1973, the Connetquot River State Park Preserve was opened as a limited use facility with various programs for outdoor recreational activities. Programs include Outdoor Education, Environments Interpretation, nature study, bird watching, hiking, bridle paths, cross country skiing, jogging and fly fishing for Brook, Brown and Rainbow trout for a fee. The fee fishing program was decided upon after numerous meetings and consultations with the previous owners, Trout Unlimited, the New York State Department of Environmental Conservation, local fisherman, concerned citizens, the Office of Parks, Recreation and Historic Preservation, local historic societies, conservation organizations and neighboring landowners. Maintaining the historic nature of the property was deemed to be a most important factor in all decisions. The tradition of fly-fishing dating back to the early 1800's was also considered

[1] *Connetquot River State Park Preserve, P.O. Box 505, Oakdale, New York 11769-0505.*

critical to the acceptance of the rules protecting the sensitive freshwater wetlands. In addition, all other user groups voiced their environmental concerns to preserve a bit of Long Island as it used to be in the midst of urban sprawl.

The fee structure was based on a quality fly-fishing experience. Thirty sites were created along the river, with each angler having the use of a site for four hours, and limit of two trout for the session. Those wishing to catch and release fish may do so as long as they do not have two fish in possession. The current fee is $15.00 permit for each session. The number of permits sold per year averages 12,000+ anglers or revenue amounting to $180,000 per year. The preserve also provides trout for Caleb Smith State Park, with a similar fee charged for the 4000 fishermen per season or an additional $60,000. The fees produce almost one quarter million dollars in revenue annually for the State of New York.

The Preserve also provides facilities for the handicapped fishing programs for the disabled, trout for special fishing projects at other state parks and the DEC. The Preserve has functioned in this fashion for the past 27 years. As we leap into the new millennium, let us hope that Connetquot River can serve as a model to protect our natural resources and historic treasures for an ever-increasing population in our nation.



CONNETQUOT RIVER STATE PARK PRESERVE FISHING SITES

Effects of Electrofishing on Survival and Growth of Wild Brown Trout (*Salmo trutta*) from Central Pennsylvania Streams

Robert Jay Weber[1] and Robert Carline[2]

Abstract—The goal of this investigation was to determine electrofishing effects on injury rates, survival, and growth of three wild brown trout populations within a growing season. We first collected a sample of fish by angling and a subsequent sample by electrofishing (400 peak voltage, 3.5 amps DC current). All fish were measured, weighed, fin clipped, X-rayed, a visual implant (VI) tag attached and released. After 5 months, study reaches were electrofished and all fish were measured, weighed, and fin-clips and tag numbers noted. Spinal injuries, determined from x-rays, ranged from 18% to 22% while injuries from angled fish ranged from 0% to 6%. Median lengths (273 – 296 mm) of injured trout were not significantly different ($P>0.05$) than median lengths (270 – 285 mm) of uninjured trout. Minimum survival for the electrofished groups ranged from 49% to 65% while survival for the angled groups ranged from 5% to 42%. Growth of the electrofished group was significantly less ($p > 0.05$) than the angled group in one study water. While some evidence suggests that growth may be reduced by exposure to DC electrofishing, the relatively low injury rates and high survival indicated that sampling with DC electrofishing units would not compromise population abundance and size structure of wild brown trout in moderately alkaline limestone streams.

INTRODUCTION

Electrofishing has been the preferred method for collecting and assessing salmonid fish populations for decades. In Pennsylvania, electrofishing has been used for fisheries management work since at least 1962 (Miller 1962). Basically, fish are stunned by electric current so that they can be readily netted and retained for data collection purposes. Hauck (1949) was the first investigator to document electrofishing effects and reported a 26% 2-5 day mortality on large rainbow trout (1.6 kg – mean weight) using 70-80 volt AC current. Subsequently, he advised caution when using electrofishing as a sampling procedure.

In spite of the apparent warnings, electrofishing has long been considered to be an effective and relatively harmless sampling method. Reynolds (1983) reported that immediate mortality was less than 5% if electrofishing was done properly. Hudy (1985) showed that total mortality in hatchery rainbow and brook trout was less than 2% and concluded that high voltage alternating current should be of little concern for management activities. However, physiological stress and behavior changes have been documented (Schreck et al. 1976; Bouck and Ball 1966). Reductions in growth and condition in salmonids resulting from recent or repeated exposure to electric current has been reported (Gatz et al. 1986; Thompson et al. 1997; and Ainslie et al. 1998).

Although injury rates in salmonids have varied from 2% to 67% (Hudy 1985; Sharber and Carothers 1988; Hollender and Carline 1994; McMichael et al. 1998), most fisheries professionals continue to assume that effects on salmonid fisheries from electrofishing were negligible. These negligible effects have been challenged by researchers who have internally examined fish looking for evidence of electroshocked-induced injury. These injuries result from convulsions of the musculature and include damaged vertebra; spinal compressions,

[1] *Coldwater Technician, PA Fish & Boat Commission, Bellefonte, PA.*

[2] *Leader, Cooperative Fish & Wildlife Research Unit, University Park, PA.*

misalignments and fractures; along with damage to muscle, nerves and other tissues in the form of hemorrhages.

Sharber and Carothers (1988) heightened concerns over electrofishing injury when they reported spinal injury rates of 44-67% in large (>300 mm) rainbow trout electrofished (AC) in high conductivity water (600 umhos/cm). Since then, considerable research has focused on injury rates and possible factors affecting injury rates. The consequences from much of the research on electrofishing injuries has varied from raising awareness of the potential problem to severe limitations on its use. Alaska has voluntarily banned electrofishing as a sampling tool since the late 1980's in streams containing large rainbow trout (Holmes 1990). The Montana Division of Fish, Wildlife and Parks has eliminated use of pulsed DC current above 30 Hz and Idaho is discouraging many federal agency biologist from using electrofishing to sample bull trout (Schill and Beland 1995). Some researchers have suggested that electrofishing should be abandoned or severely limited if electrofishing injuries cannot be adequately reduced (Snyder 1995). These changes in agency policy have concerned many biologists because most research has focused on effects at the sample level and have not addressed the significance of electrofishing injuries at the population level, with a few exceptions (Habera et al. 1996; Kocovsky et al. 1997; McMichael et al. 1998).

Concerns over internal injuries to salmonids due to electrofishing are growing both within the fisheries profession and the general angling public. Without definitive assessment on long-term effects to salmonid populations, the possibility exist that electrofishing will be banned or severely restricted by State and Federal agencies. Alternatives to electrofishing are not as efficient in capturing stream salmonids; thus, it stands to reason that salmonid management and research would be severely hindered without this technique.

STUDY AREA

Spring Creek

Spring Creek is a limestone stream in Centre County, Pennsylvania, arising from a spring located on Tussey Mountain near State College. The stream flows north 36 kilometers through State College and Bellefonte to its confluence with Bald Eagle Creek in Milesburg (Figure 1). Land use within the 370 sq km basin consists of mixed forest, agriculture, industry and residential areas. Spring Creek has four major

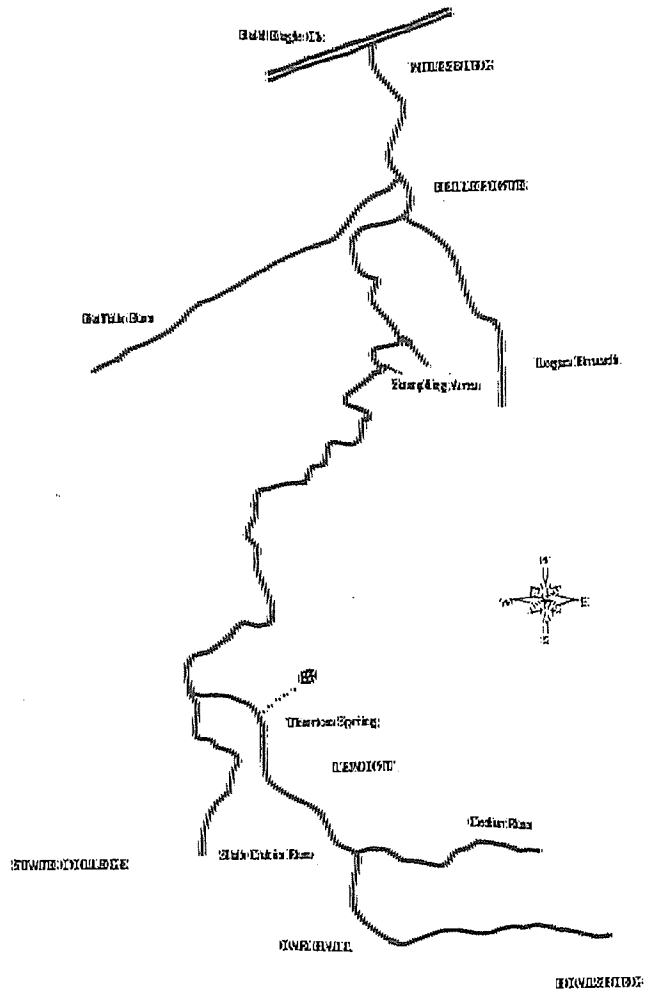


Figure 1. Map of Spring Creek, Centre County, showing study area.

tributaries: Cedar Run, Slab Cabin Run, Logan Branch and Buffalo Run.

Spring Creek has an average width of 5.6 meters in the headwaters to 21.6 meters near the mouth (PFBC, Unpublished Data). The fish community is dominated by brown trout (*Salmo trutta*) and white sucker (*Catostomus commersoni*) that comprise the majority of the biomass (Hollender 1981; Hollender and Wilberding 1987; Beard 1990).

Because of kepone and mirex contamination, Spring Creek has been closed to harvest and stocking has been discontinued since the early 1980s (Hollender et al. 1981). Since 1981 wild brown trout populations have generally been high (Hollender et al. 1981; Hollender and Wilberding 1987), with the biomass generally exceeding the Pennsylvania Fish and Boat Commission's minimum requirement (40 kg/ha) for a Class A wild trout management as outlined in the *Management of Trout Fisheries in Pennsylvania Waters* (Anonymous 1996). Currently the stream is open to

year-round catch and release angling with no lure or gear restrictions, except for Fisherman's Paradise, which is managed under Heritage Trout Angling regulations (Catch and Release, Fly-Fishing Only) and the exhibition area in Bellefonte where no angling is allowed.

Elk Creek

Elk Creek originates in the Bald Eagle State Forest near the Centre/Union County line in Central Pennsylvania. The stream flows south/southwest for 30 kilometers to its confluence with Penns Creek at the town of Coburn (Figure 2). The 243 sq kilometer basin is a mixture of deciduous forest and farmland known as Brush Valley. Elk Creek contains two major tributaries: Phillips Run and Pine Creek.

The fish community is dominated by brown trout and white sucker which comprise the majority of the biomass (Hollender 1986).

The sections of Elk Creek between Livonia and Wolfs Store and from Spring Bank downstream to the mouth were stocked by the Pennsylvania Fish and Boat Commission annually with catchable trout. Stocking was terminated in 1983 and the stream was surveyed only one time since 1983 to assess the brown trout population following cessation of stocking. Brown trout biomass from Spring Bank downstream to the mouth remained high and averaged 78 kg/ha in 1985 (Hollender et al. 1986) qualifying this section for Class A designation by the PFBC. Regulations allowed anglers to harvest up to eight trout (currently five), seven inches or longer, per day. However, recent creel survey data suggest that both angler use and harvest are relatively low on Elk Creek (Weber and Greene 1995).

METHODOLOGY

One site, representing a stream reach, was selected for each study water. A sample of brown trout was taken from each water between May 2 and June 11, 1997 by angling. Angling was only allowed within the study section and anglers were encouraged to concentrate angling near the mid-portion of the study section.

Angling took place for a period of up to nine days or until a sample of 100 brown trout was collected. Sample sizes were based primarily on statistical consultation, angling conditions and what anglers could realistically catch within a reasonable time period. Angled fish were held in instream live cages in Elk Creek and in circular ponds inside a functional hatch

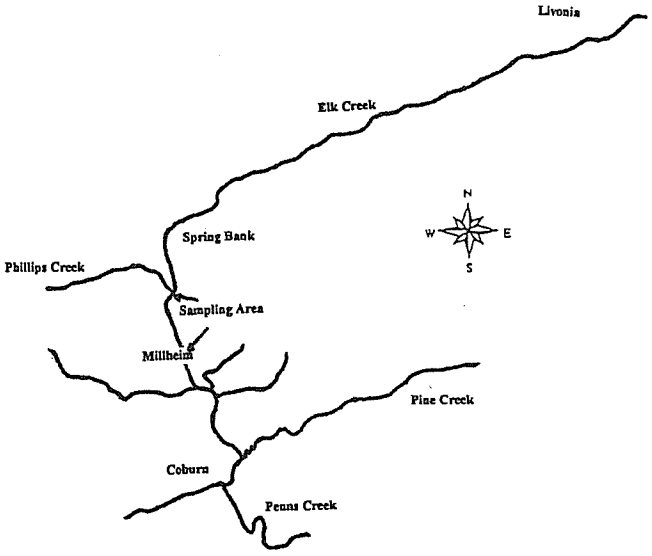


Figure 2. Map of Elk Creek, Centre County, showing study area.

house for Spring Creek. Angled fish were fed fathead minnows if they were held in excess of three days. Immediately after angling ended, a sample of wild brown trout were collected using electrofishing. Electrofishing sample sizes were based on the number of angled fish sampled. We used a towboat T&J electrofishing unit operated at 400 peak volts (3.5 amps), producing a straight DC waveform with a slight ripple (Reynolds, pers comm). Electrofishing conditions were kept similar to actual sampling procedures.

All fish captured by both angling and electrofishing were anesthetized, measured (mm), weighed (g) and tagged using visual implant (VI) tags (Haw et al. 1990). In the event the VI tag was lost, all fish were also given a fin clip. Brown trout captured by angling were given an adipose clip while electrofished brown trout were given a left ventral clip.

All brown trout were then live x-rayed using a Picker portable x-ray machine set at 5mA, 68kV for a 2.5 sec exposure using Kodak Ready Pack II AA film. After processing, all trout were allowed to recover and were released within the study section. X-rays were read by three independent, experienced readers. Discrepancies were solved through re-examination of questionable x-rays and discussion among the readers. Injury type (Misalignment or compression), severity and location were noted and results summarized.

To assess growth and survival over 5 to 6 month period the entire study section was electrofished during the following October. Two passes were made and all fish captured were measured (mm),

weighed (g) and VI tags and fin clips were recorded if present.

Relative survival for both angled and electrofished groups were determined by computing the percentage of each group that was recaptured after five months. We assumed that each group had an equal probability of natural and angling mortality occurring over the study period. Additionally, we assumed that each group would have an equal probability of emigration from the study area and electrofishing efficiency would be the same for both groups.

Growth over the five month period was determined by subtracting the total length from May 1997 samples from recaptures collected during October 1997 sampling. Weight was not used as a measure of growth due to the possibility of weight data being influenced by production of gametes during the October samples. Growth data was summarized and grouped by size (<or> 297 mm (12 inches) and grouped for all brown trout. If possible, non-parametric statistics were used to explain significant differences in growth between shocked and angled groups and within different size groups of brown trout.

RESULTS

Angling and Electrofishing

Angling on Spring Creek occurred between May 6-12, 1997, and was conducted by at least 8 different anglers. All brown trout were caught using flies with the exception of two trout that were caught on live bait. Angled trout were all held in circular tanks within an adjacent hatchery building supplied with a spring water source. Angling captured a total of 97 wild brown trout ranging in size from 211 mm to 473 mm in length (Table 1). The majority of the angled fish were caught in the final three days of sampling. A second sample of 104 brown trout were collected by electrofishing and held in instream live cages (Table 1). Brown trout ranged in size from 168 mm to 445 mm and were all of wild origin. Two mortalities from the electrofished sample occurred during collecting and processing procedures, thus, sample size for the electrofished group was actually 102. Subsequent x-rays showed one of the mortalities had a slight misalignment between vertebra 42 and 48. "Branding or burn" marks were noted on two individual fish in the electrofished sample.

Angling on Elk Creek began on June 2 and terminated on June 11, 1997. Angling was conducted by at least 7 different anglers. All brown trout were caught using artificial lures or flies with most of the trout caught with spinners. A total of 42 wild brown trout were captured ranging in size from 167 mm to 308 mm in length (Table 1). Angling was complicated by high and turbid flows between the third and fifth day of angling. The majority of the fish sampled by angling were caught in the first three days. Fish were held in an instream live cage throughout the 9-day angling period and fed fathead minnows every other day. A second sample collected by electrofishing yielded 77 wild brown trout ranging in size from 166 mm to 366 mm (Table 1). Two mortalities from the electrofishing sample occurred during collecting and processing; thus, the sample size for the electrofished group was 75. Subsequent x-rays showed one of these fish having a slight mis-alignment between vertebra 19 and 20. "Branding or burn" marks ranging from moderate to severe were noted on eight individual fish in the electrofished sample.

Table 1.—Summary of marking efforts and length frequency of brown trout collected by angling and electrofishing between May 2 and June 11, 1997.

Length Group	Spring Creek		Elk Creek	
	# Shock	# Angled	# Shocked	# Angled
125 mm				
150 "	1		2	2
175 "	3		6	3
200 "	5	1	4	1
225 "	8	6	7	14
250 "	19	16	21	11
275 "	29	37	22	10
300 "	20	15	8	1
325 "	10	8	5	
350 "	7	6	2	
375 "				
400 "	1	4		
425 "	1	2		
450 "		2		
Totals	104	97	77	42

X-rays and Injury Assessment

X-rays from Spring Creek showed injury rate to be 18.2% (N = 18) for wild brown trout exposed to electrofishing while brown trout captured by angling had a 6.2% (N = 6) injury rate (Table 2). For the electrofishing group, a mean of 4.5 vertebra were injured while 50.0% of these injuries were judged to be misalignment type injuries (Table 2). Injuries from the angled group affected an average of 7.0 vertebra and were all compression type injuries (Table 2). The mean length of injured fish was 308.1 mm for the electrofished group and 367.7 mm for the angled group (Table 2). Mean length of uninjured fish was 283.5 and 298.3 mm for electrofished and angled groups, respectively.

Table 2.--Summary of x-ray data for brown trout collected between May 2 and June 11, 1997.

	Spring Creek		Elk Creek	
	Electrofished	Angled	Electrofished	Angled
Number Examined	104	97	75	42
Number Readable	99	97	73	39
Number Injured	18	6	16	0
Percent Injured	18.2	6.2	22%	0
Mean # Vert. Injured	4.5	7	2.8	NA
% Compression	50	100	25%	NA
% Misalignment	50	0	75%	NA
Mean Length Injured	308.6	367.7	280	NA
Mean Length Uninjured	283.5	298.3	267.5	253.2
Median Length Injured	306	391.5	273.5	NA
Median Length Uninjured	285	288	271.5	259

Injury rates from Elk Creek were 22% (N = 16) to brown trout exposed to electrofishing while angling showed no injuries on the x-rays (Table 2). For the electrofishing group, a mean of 2.8 vertebra were injured while 75% of these injuries were judged to be misalignment type injuries (Table 2). The mean length of injured brown trout was 269.7 mm for the electrofished group while mean length of uninjured brown trout was 266.2 mm (Table 2). Differences between size of injured trout verses uninjured trout from the electrofished group was tested by comparing median lengths using a Mann-Whitney U test. There was no significant difference between the median size of injured and uninjured brown trout from the electrofishing group in either of the study waters.

The majority of electrofishing injuries (76%) from both waters were located between vertebra 21 and vertebra 35 (Fig. 3) or within the anterior and posterior insertion of the dorsal fin. Injuries on angled fish were few, however, they seemed to be located more toward the anterior and posterior sections of the vertebra.

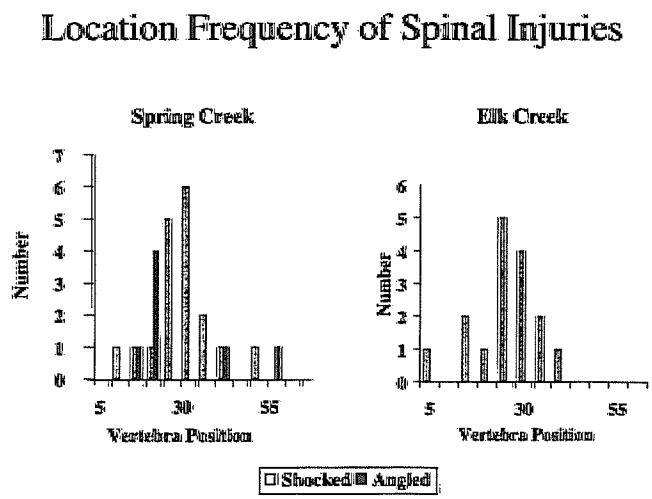


Figure 3.—Location frequency of Spinal Injuries for brown trout from Spring Creek and Elk Creek.

Recapture Effort and Survival

Spring Creek was electrofished on October 2, 1997 to recapture wild brown trout collected the previous May. Two passes were conducted and a total of 1,122 wild brown trout were collected within the study reach. We recaptured 66 wild brown trout with adipose clips from the 102 in the initial electrofishing group and 41 with left pelvic clips from the 97 in the initial angled group (Table 3). This corresponds to minimum (in-hand) survival rates of 65% for the electrofished group and 42% for the angled group following 5 months in the wild (Table 3). The majority of the recaptures were collected in the middle area of the study stretch corresponding to the release area the previous May indicating there was probably minimal movement out of the study area by trout from our initial samples.

Table 3.—Number of brown trout caught from electrofished and angled groups during recapture effort on October 3, 1997.

Water	Total # Caught	#Recaps Shock (AD)	Minimum Survival (%)	#Recaps Angling (LV)	Minimum Survival (%)
Spring Creek (2 passes)	1122	66	65%	41	42%
Elk Creek (2 Passes)	319	37	49%	2	5%

Recapture efforts on Elk Creek were conducted on October 8, 1997. A total of 318 wild brown trout were collected in two passes of the study area. We recaptured 37 wild brown trout with adipose clips from the 75 in the initial electrofishing group and 2 with left pelvic clips from the 40 in the initial angling group (Table 3). Minimum 5-month survival estimates were 49% and 5% for the electrofished and angled groups, respectively (Table 3). Most of the recaptures were collected from the middle to upper areas of the study reach which may indicate some upstream movement had occurred.

Growth

On Spring Creek, 38 out of the 66 recaptured trout from the electrofishing group and 26 out of the 41 recaptures from the angled group retained their VI tag and were able to be included in growth analysis. For trout less than 297 mm (12 inches), the 5 month mean growth was 29 mm for the electrofishing group and 37 mm for the angled group (Table 4). For brown trout greater than 297 mm, growth was 28 mm for the electrofished group and 34 mm for the angled group (Table 4).

There was no apparent difference in growth rates between the size groups, thus, the data was combined. Mean 5-month growth for all brown trout was 29 mm for the electrofished group and 36 mm for the angled group (Table 4). Analysis of median growth from all trout using a Mann Whitney U test (Siegal 1956) determined the growth of the electrofished group was significantly less than growth of the angled group (Table 4). Due to the lack of data on angled fish from Elk Creek growth summaries and growth comparisons could not be conducted on these waters.

Table 4.—Five month growth (mm) of brown trout collected by Electrofishing and angling from Spring Creek during 1997.

< 297 mm	Shocked	Angled
Mean	29	37
St Dev	12	12
C.I.	4.7	5.5
Median	29	36
N	25	18
> 297 mm		
Mean	28	34
St Dev	12	9
C.I.	6.5	6.2
Median	33	33.5
N	13	8
All Trout		
Mean	29	36
St Dev	12	11
C.I.	3.8	3.5
Median	30	35.5
N	38	26

DISCUSSION

Angling and Electrofishing

One of the main criteria for success of this study was to obtain samples of trout to be used as controls without the use of electrofishing. Angling was the preferred sampling technique due to the potential of these streams to produce high angler catch rates (Carline et al. 1991; Weber and Greene 1995) over a short time period. However, sampling by angling proved to be quite difficult. Logistically, it was difficult to coordinate large numbers of anglers on any given day; thus, angler effort on certain days was quite low. Low angler effort led to expanding the sampling period needed to obtain angling samples from 2- 3 days to 7-9 days on Spring Creek and Elk Creek. Thus, trout were held in captivity for an extended period of time as opposed to trout collected by electrofishing that were held for less than one day. Additionally, it was difficult for anglers to immediately transfer caught fish to a live cage due to physical distance between the angler and the live cage. As a result many angler caught fish were temporarily held in a live bag maintained by the angler for an unknown period before transfer to an instream live cage took place. This may have led to excessive stress between the time of capture and the time the trout became part of the control group. These factors alone, or in combination with some other unknown mechanism, may have led to poor performance of control groups.

X-ray Analysis

Vertebral injuries on wild brown trout from electrofishing ranged from 18.2% to 22% for this study (Table 2). These injury rates were below reported injury rates from similar studies on wild brown trout (Thompson et al. 1997; Habera et al. 1999). However, if musculature injuries (hemorrhages) were considered in this study, the injury rates would have been greater. Injuries from angling

ranged from 0% to 6.2% similar to other studies that used angled salmonids as a control (Hollender and Carline 1994; Carline, unpublished data). There is apparently a low-level injury rate in salmonids not exposed to electrofishing. The source of which is apparently unknown but may be related to bird predation.

Injuries from electrofishing were predominately misalignment types injuries (50%-93.7%) while the injuries from angled fish were all compression type injuries (Table 2). The injuries from angled fish may have been in the process of healing (Schill and Elle 2000) and subsequently characterized by the x-ray readers as compression injuries. Injury locations were mostly between vertebra 21 and 35 (Fig. 3) or the anterior and posterior insertion of the dorsal fin as similarly reported by Kocovsky et al. (1997) and others.

Although there was no significant difference in the mean length of injured and uninjured brown trout in this study (Table 2), the injured mean size was higher than the uninjured mean in both study waters. This supports data from previous work (McMichael et al. 1998; Hollender and Carline 1994; Reynolds and Koltz 1988; Sharber and Carothers 1988;) that found that electrofishing injury rates were significantly higher in larger salmonids.

Survival

Minimum survival, defined in this study as the percentage of individuals recaptured after a period of time, could not be compared statistically due to failure of the control (angled) groups. However, 5-month survival of wild brown trout exposed to electrofishing (Table 3) was judged to be quite high when considering electrofishing efficiencies, inherent sampling variability and natural mortality rates of wild brown trout.

When conducting a mark-recapture estimate over a two-day period, it is considered a statistically stronger estimate (low confidence interval) as the number of recaptured fish approaches 100% (Ricker 1975). In Pennsylvania, mark-recapture estimates are considered "good" if recaptures of marked fish exceed 50%. Petersen mark-recapture data from several Pennsylvania limestone waters with high (> 40 kg/ha) abundance of wild brown trout showed recapture rates from 51% to 73% (Table 5). In my study our recaptures were 49% for Elk Creek and 65% for Spring Creek, which were similar to recent mark-racapture data collected in PA waters (Table 5). However, my recapture rates were determined with a five month time period between the marking run and the recap run in contrast to the usual 1 or 2 days. These comparisons indicate that the wild brown trout from Spring Creek and Elk Creek demonstrated relatively low immediate, short-term and long-term mortality after exposure to DC electrofishing.

Table 5.—Recapture percentages for wild brown trout > 149 mm from several Pennsylvania streams.

	# Marked First pass	# Recaps 2nd pass	% Recaptured	Year
Monocacy Ck	222	144	65	2000
Bushkill Ck	215	110	51	2000
Fishing Ck - Upper	265	134	51	2000
Fishing Ck - Lower	272	194	71	2000
Spring Creek	828	536	65	2000

Growth

Growth was found to be significantly less for the electrofished group than the angled group in the Spring Creek samples (Table 4). Angling recaptures for Elk Creek were too small (2 trout or less) for statistical analysis of growth. Thus, discussion of growth will center around data collected on Spring Creek.

The energetics of growth have been described by Elliott (1976) in the form of the basic equation: C=F+U+B+R where: C = total energy content of food consumed, F = energy value of faeces, U = energy value of excretory products, B = energy value of body materials (growth and reproduction) and R = energy of metabolism (resting, swimming, digestion, etc). In wild trout it is difficult to increase growth (B) unless energy from food consumed (C) is increased by some manipulation of the brown trout's environment i.e., increase fertility of system or reduce competition for food resources. Growth (B) can also decrease if the available energy from the food consumed (C) does not change while energy required for metabolism is increased. A wild brown trout that suffers a bodily injury would likely require an increase in metabolic energy (R) to heal from an injury. However, the energy gained from food in a wild environment likely will not increase, and may in fact decrease, while the trout is healing from an injury. Thus, growth B would be the most likely component of the

trout's energy budget that would decline after an injury was sustained.

Schill and Elle (2000) have found the most significant evidence of healing of both hemorrhages and spinal injuries in salmonids exposed to DC and pulsed DC electrofishing. If significant healing of injuries and low mortality occurred following exposure to electrofishing in this study, then it is reasonable to expect a reduction in growth based on the energy budget concept in relation to healing of both known (vertebral) and unknown (hemorrhages) injuries that occurred on Spring Creek. It also seems reasonable that this reduction in growth is temporary and should return to a "normal" rate once electrofishing induced injuries have healed. Future research quantifying the effect on growth from healing of electrofishing injuries may provide additional insight on these ideas.

SUMMARY AND CONCLUSIONS

Although more statistical comparisons and analysis could not be accomplished due to failure of control samples, the data presented does provide some insight into growth, survival and population effects of DC electrofishing on wild brown trout. After exposure to DC electrofishing wild brown trout had low mortality over time which likely did not elevate the natural mortality rate of the population. Growth rates of wild brown trout exposed to DC electrofishing were significantly reduced, however, this is probably a response to the healing process of electrofishing injuries and a subsequent reduction of growth energy from the trout's energy budget.

Research similar to this work should be conducted on streams where an AC electrofishing unit would be the preferred sampling device. However, collection of control samples should be given much more thought and background research than given in this study. This would allow much more in-depth analysis of the question of survival and growth following exposure to electrofishing. In addition, future research relating to healing of electrofishing induced injuries and growth rates may be valuable in assessment of how electrofishing effects salmonid populations.

LITERATURE CITED

Ainslie, B. J., J. R. Post, and A. J. Paul. 1998. Effects of pulsed and continuous DC electrofishing on juvenile rainbow trout. North American Journal of Fisheries Management 18:905-918.

Anonymous. 1996. Management of Trout Fisheries in Pennsylvania Waters – Third edition. PFBC Files. 450 Robinson Lane, Bellefonte, PA 16823.

Bouck, G. R., and R. C. Ball. 1966. Influence of Capture Methods on blood characteristics on mortality in rainbow trout (*Salmo gairdneri*). Transactions of the American Fisheries Society, 95:170-176.

Carline, R. F., T. D. Beard, and B. A. Hollender. 1991. Response of wild brown trout to elimination of stocking and to no-harvest regulations. North American Journal Fisheries Management. 11:253-266.

Elliot, J. M. 1976. The energetics of feeding, Metabolism and growth of brown trout (*Salmo trutta*) in relation to body weight, water temperature and ration size. Journal of Animal Ecology. 45:923-948.

Gatz, A. J., J. M. Loar, and G. F. Cada. 1986. Effects of repeated electroshocking on instantaneous growth of trout. North American Journal of Fisheries Management 6:176-182.

Habera, J. W., R. J. Strange, B. D. Carter, and S. E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass AC electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192-200.

Habera, J. W., R. J. Strange, and A. M. Saxton. 1999. AC electrofishing injury of large brown trout in low-conductivity streams. North American Journal of Fisheries Management 19:120-126.

Hauck, F. R. 1949. Some harmful effects of the electric shocker on large rainbow trout. Transactions of the American Fisheries Society 77:61-64.

Haw, F., P. K. Bergman, R. D. Fralick, R. M. Buckley, and H. L. Blankenship. 1990. A visible implanted fish tag. Pages 311-315 *in* N. K. Parker and five coeditors. Fish-marking techniques. American Fisheries Society, Symposium 7, Bethesda, Maryland.

Hollender, B., R. Wilberding, D. Mayers, and D. Spotts.1981. Spring Creek (309C) management report. PFBC files. 450 Robinson Lane, Bellefonte, PA 16823.

Hollender, B. and R. Wilberding. 1986. Elk Creek (306A) management report – sections 04 and 05. PFBC files. 450 Robinson Lane, Bellefonte, PA 16823.

Hollender, B. and R. Wilberding. 1987. Spring Creek (309C) management report. PFBC files. 450 Robinson Lane, Bellefonte, PA 16823.

Hollender, B. A., and R. F. Carline. 1994. Injury to wild brook trout by backpack electrofishing. North American Journal of Fisheries Management 14:643-649.

Holmes, R. D., D. N. McBride, T. Viavant, and J. B. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, least cisco, and northern pike. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Manuscript 9, Anchorage, AL.

Hudy, M. 1985. Rainbow trout and brook trout mortality from High voltage AC electrofishing in a controlled environment. North American Journal of Fisheries Management 5:475-479.

Kocovsky, P. M., C. Gowen, K. D. Fausch, and S. R. Riley. 1997. Spinal injury rates in three wild trout populations in Colorado after eight years of backpack electrofishing. North American Journal of Fisheries Management 17:308-313.

McMichael, G. A., A. L. Fritz, and T. N. Pearsons. 1998. Electrofishing injury to stream salmonids; injury assessment at the sample, reach and stream scales. North American Journal of Fisheries Management 18:894-904.

Miller, J. G. 1962. Electricity in fish management in Pennsylvania. Pennsylvania Angler. October 1962. pages 4-8.

Reynolds, J. B. 1983. Electrofishing. Pages 147 –164 **in**: L. A. Nielsen and D. L. Johnson, editors. Fisheries Techniques. American Fisheries Society, Bethesda, Maryland.

Reynolds, J. B. and L. Koltz. 1988. Electrofishing injury to large rainbow trout. North American Journal of Fisheries Management 8:516-518.

Ricker, W. E. 1975. Computation and interpretation of biological statistics in fish populations. Fisheries Research Board of Canada. Bulletin 191.

Schill, D. J., and K. F. Beland. 1995. Electrofishing Injury Studies. Fisheries 20(6):28-29.

Schill, D. J., and F. S. Elle. 2000. Healing of electro-shock-induced hemorrhages in hatchery rainbow trout. North American Journal of Fisheries Management. 20:730-736.

Schreck, C. B. and four others. 1976. Physiological response of rainbow trout (*Salmo gairdneri*) to electroshock. Journal of the Fisheries Research Board of Canada 33:76-84.

Siegal, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Company. 312 pgs. ISBN 07-057348-4.

Sharber, N. G., and S. W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management 8:117-122.

Snyder, D. E. 1995. Impacts of electrofishing on fish. Fisheries 20(1):26-27.

Thompson, K. G., E. P. Bergersen, R. B. Nehring, and D. C. Bowden. 1997. Long-term effects of electrofishing on growth and body condition of brown trout and rainbow trout. North American Journal of Fisheries Management 17:154-159.

Weber, R. J. and R. T. Greene. 1995. Evaluation to determine angler demand, catch, and yield on wild trout waters in the Penns Creek drainage. Pennsylvania Fish and Boat Commission Files. 450 Robinson Lane, Bellefonte PA. 16823.

Healing of Electroshock-Induced Hemorrhages in Hatchery Rainbow Trout

Daniel J. Schill[1] and F. Steven Elle[2]

Abstract—We monitored healing in electroshock-induced hemorrhages of myomere blood vessels produced by individually exposing hatchery rainbow trout *Oncorhynchus mykiss* to direct current (n=502) and pulsed direct current (n=708). We used voltage gradients and exposure times suspected to produce high injury rates to facilitate observation of their duration in muscle tissue. At 1 d post-exposure, 86.1% of the test fish exposed to direct current (DC) and 81.6% of those exposed to pulsed direct current (PDC) had at least one hemorrhage. Fish exposed to DC averaged 1.86 injuries 1 d post-exposure, and those exposed to PDC averaged 1.45 injuries. Number of hemorrhage injuries per fish began declining by 15 d post-exposure in both groups. The severity of injuries initially increased through 15 d post-exposure and then decreased through the remaining 3-5 weeks of the tests. At the end of the test, injuries induced by DC had declined by 78.0% (36 d post-exposure) and those induced by PDC declined by 92.4% (57 d post-exposure). A total of 1.8% of all fish exposed to DC and 1.1% exposed to PDC died during the study. Our data for hatchery rainbow trout suggest hemorrhage injuries in salmonids caused by electrofishing exposure exist for a relatively short time and do not represent a long-term mortality or health risk to the fish. Because of the ephemeral nature of blood vessel hemorrhages compared to spinal injuries, future studies that examine electrofishing injuries should evaluate hemorrhage and spinal injuries separately and abandon the practice of combining these data.

Authors' Note: This paper appears in its entirety in the August 2000 issue of the North American Journal of Fishery Management, Vol 20, No 3, pp 730-736. The following is an extended abstract. Considerably more detailed information and literature citations can be found in the actual paper.

INTRODUCTION AND METHODS

The objective of this study was to document the quantity and severity of myomere blood vessel hemorrhages in hatchery rainbow trout *Oncorhynchus mykiss* at fixed time intervals after being electroshocked. Our general approach was to expose individual fish to the same electrofishing field, randomly assign them to treatment groups, and necropsy the treatment groups at fixed post-shocking time intervals to quantify healing.

We exposed hatchery rainbow trout to continuous direct current (DC) in 1996 and pulsed direct current (PDC) in 1998. Electrical exposures were conducted at the Nampa Fish Hatchery (Idaho Department of Fish and Game). Fish were placed into the center of the net at the water surface, and the field was immediately activated. Exposure was regulated with a foot switch and stop watch. Each fish was exposed to the electrical current for 5 s. On November 25, 1996 we individually exposed 502 hatchery rainbow to DC current at 375 V and 7.5 A. On March 12, 1998 we individually exposed 708 fish (mean total length = 287 mm, SD 38, n=103) to square wave PDC current at 325 V (peak), 60 Hz (25% duty cycle), and 7.5 A (average). Following exposure, individual fish were removed from the dip net and placed into five or

[1] *Principal Fishery Research Biologist, Idaho Department of Fish and Game, Nampa, Idaho*

[2] *Senior Fishery Technician, Idaho Department of Fish and Game, Nampa, Idaho*

seven holding pens (depending on the year) in an adjacent hatchery raceway. Prior to necropsy, all trout were given an overdose of tricaine methanesulfonate. The left and right sides of specimens were filleted flush with the spinal column using an electric knife and both fillets and the skeleton section were washed to remove any fresh blood. We ranked all observed hemorrhages for each fish on a scale of 0-3 where 0 = no hemorrhage; 1 = wound separate from spine, 2 = wound on spine ≤width of two vertebrae; 3 = wound on spine >width of two vertebrae (Reynolds 1996). To assess the rate of healing, we evaluated total injuries present over time. To compensate for unequal sample sizes resulting from mortalities and differences in original lot sizes, the mean number of injuries per necropsied fish was calculated for each sampling date. Simple linear regression was used to assess the relationship between time (days post-shock) and mean injuries per necropsied fish in a test lot for the DC and PDC trials separately.

RESULTS AND DISCUSSION

In the DC trial, we initially observed high numbers of hemorrhages with a rapid decline in incidence during the 5-week period. Only two control group trout (4.1%) had single hemorrhages, both level 1. In contrast to the low control injury rate, at 1 d post-shock, 86.1% of the fish exposed to DC had visible hemorrhages. By the end of the evaluation, there were marked reductions in all levels of injury in the DC test (Figure 1). The total number of injuries per fish began to decline markedly by 15 d post-exposure. By the completion of the test at 36 d post-exposure, there was a 78.0% reduction in total visible hemorrhages. There was a highly significant ($p=0.003$) negative relationship between injuries per fish in test lots and days-post shock (Figure 1). Time explained 95% of the variation in injuries observed per fish.

At 1 d post shock, 81.6% of the fish exposed to PDC exhibited hemorrhages compared to only 1.9% of the control fish (1 of 53). However, healing occurred more rapidly compared to the DC trial, with a sharp decline in total injuries observed 15 d post-exposure. By 57 d post-exposure, a 92.4% reduction in the total visible hemorrhages per fish occurred. There was a highly significant ($p=0.01$) negative relationship between injuries per fish and days-post shock; time explained 75% of the variation in injuries observed per fish (Figure 1).

To our knowledge, this is the first study that evaluates longevity and healing of electrofishing-induced hemorrhages in trout muscle. The primary purpose of this study was to document how long electrofishing hemorrhages persist in rainbow trout. For the two

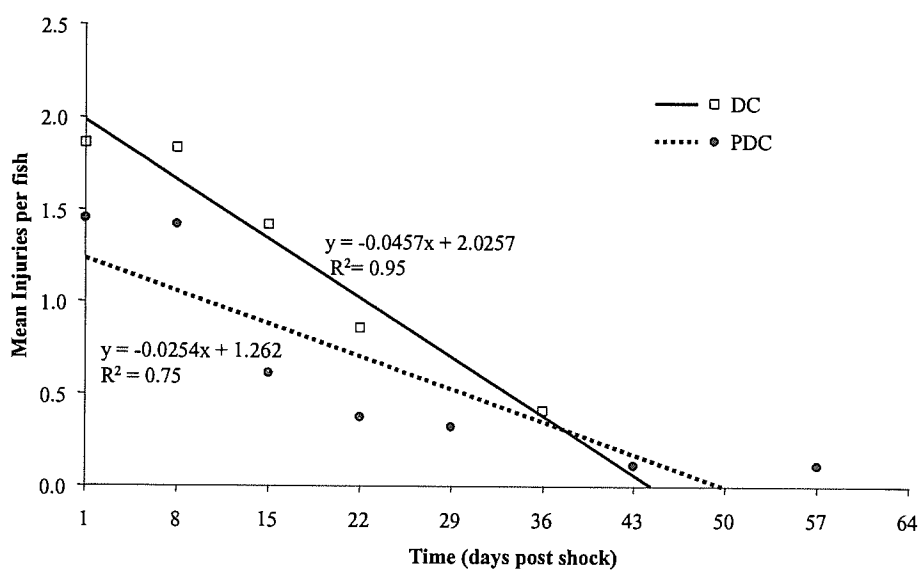


Figure 1.—Simple linear regressions of time (days post-shock) versus injuries observed per necropsied fish in hatchery rainbow trout shocked with direct current (DC) or pulsed direct current (PDC).

waveforms, we observed small (1.6% to 2.1%) declines in total number of injuries per fish by 8 d post-shocking with a much larger decline (23.7% to 57.9%) by 15 d post-shock. Assuming the temporal difference in injuries observed per fish represents healing rate, the majority of injuries healed by 22 d post-shock for both waveforms (Figure 1). We cannot conclusively define the time necessary for the complete healing of all injuries in the study, but our results suggest a likely timeframe of 9-12 weeks.

Hemorrhage injury rates in our tests are higher than rates reported in most field studies (Sharber and Carothers 1988; Holmes et al. 1990; Fredenberg 1992; Hollender and Carline 1994; McMichael 1993). Typically, field conditions result in most fish exposed to increasing electrical stimulus as they enter the electrical field and move towards the electrode. In our study, all fish were instantaneously exposed to high field intensity in a small dip net. The instant exposure to high field intensity may have caused the higher levels of injury (J. Reynolds, Alaska Department Fish and Game, personal communication). To conduct this study it was necessary to induce high levels of hemorrhage injury to facilitate subsequent observations of healing. Thus our overall injury levels should not be considered reflective of field conditions.

If hemorrhage injuries are short term and do not represent a long-term impact to the fish, biologists may need to reevaluate criteria for reporting hemorrhage injuries in the context of electrofishing impacts. Based on a review of several studies (Holmes et al. 1990; Fredenberg 1992; McMichael 1993; Hollender and Carline 1994, etc.), it appears hemorrhage injuries comprise about half of the total injuries being reported. The practice of combining hemorrhage and spinal injury ratings, as has often been done in the past, assumes such injuries have equivalent impacts on growth and survival of the injured fish, an unlikely proposition. Because of their apparent ephemeral nature in hatchery rainbow trout as reported in this study, we suggest hemorrhages be reported and analyzed separately from spinal injuries in future studies.

Effects of Annual Electrofishing with High-Frequency DC on Wild Brown Trout

Robert F. Carline[1]

Abstract—It has been well established that under certain conditions electrofishing can seriously injure trout, but it is not clear how these injuries might influence population statistics that are based on injured and un-injured trout. The objectives of this study were to determine the effects of annual exposure of high-frequency (>800 cps), pulsed DC electrofishing on the occurrence of spinal injuries, growth, size structure, and population density of wild brown trout in a 650-m reach of Spruce Creek, a high-alkalinity stream in central Pennsylvania. This portion of Spruce Creek has been under an artificial-lures-only, no-harvest regulation since 1985. An island divides this reach into two channels, which were designated Section A and B. I compared population statistics of brown trout in a Section A, which had been electrofished annually from 1985 to 1996, to those in Section B, which was electrofished annually from 1985 to 1991 and again in 1996.

INTRODUCTION

In 1996, after two electrofishing passes through both sections, about 100 brown trout from each section were X-rayed in the field and returned to the stream. Frequency of spinal injuries of trout in Section A (43.6%) was not significantly higher than that in Section B (38.0%). About two-thirds of the injured trout in Section A had compression fractures, which involved an average of 7 vertebrae; the remaining trout had abnormal spinal alignments usually involving 2 vertebrae. In Section B, 61% of the injured trout had misalignments and the remainder had compression fractures. To assess background levels of spinal injuries, I captured by angling about 100 wild brown trout from a section of Spruce Creek that had not been electrofished in 20 years. Frequency of spinal injuries in angled trout was 15.5%, and more than 80% of the injured trout had compression fractures.

Throughout the study I measured and weighed large numbers of trout from sections A and B and in 1996 I collected scales to compare growth rates of trout between sections. Median lengths of trout ages 1 to 3 in Section A were greater than those of trout in Section B. Relative weights (an index of fish condition) of trout in Section A and B were similar from 1985 through 1991. In 1996 relative weights of trout in Section B were higher than those in Section A, but these differences were small and only apparent in fish longer than 250 mm. These results indicate that cessation of electrofishing for 5 years in Section B did not negatively influence growth of trout up to age 3, but may have affected older trout.

Among electrofished trout, frequency of spinal injuries increased with fish length ranging from 25% for trout 150 to199 mm long to 62% for trout longer than 300 mm. Two factors may contribute to this phenomenon. Longer fish experience a greater voltage potential from head to tail than do shorter fish; hence, longer fish are more likely to sustain a spinal injury. And, older fish should have a higher probability of having a spinal injury than younger fish, when populations are electrofished on a regular basis, because older fish would have more exposures to electrofishing than younger fish. If annual exposure to electrofishing causes increased mortality, decreased growth, or both in older trout, one might expect a reduction in numbers of large trout. However, size structures of the populations in sections A and B were not different from 1985 to 1991 and again in 1996. Hence, not electrofishing Section B for 5 years did not lead to improvements in the size structure of the population.

[1] *U.S.G.S. Biological Resources Division, Pennsylvania Cooperative Fish and Wildlife Research Unit, Merkle Laboratory, Penn State University, University Park, PA 16802.*

Both sections of Spruce Creek supported a high density of trout throughout the study. From 1985 to 1991, Section A had an average density of 1,312 age-1 and older trout per hectare and a biomass of 170 kg/ha; Section B supported an average density of 1,050 trout/ha at a biomass of 135 kg/ha. In 1996 Section A had a density of 1,298 trout/ha and Section B had 893 trout/ha. Here again, there is no evidence that Section B benefitted from the temporary cessation of electrofishing.

I concluded that despite the high injury rate, there was little or no effect of high-frequency DC electrofishing on most population statistics, though the potential effects on growth should not be dismissed. The use of low frequency DC gear and possibly other wave forms would seem to be the most prudent approach to minimizing detrimental effects on trout using this method of collection.

Impacts of Electrofishing Injury on Idaho Stream Salmonids at the Population Scale

F. Steven Elle and Daniel J. Schill[1]

Abstract—This study assesses the mortality impacts of electrofishing at the population scale based on levels of sampling by Idaho Department Fish and Game (IDFG) and non-IDFG projects during the 1995 and 1996 field seasons. We estimated electrofishing induced population mortality by considering the proportion of stream reach shocked during sampling, the probability of fish exposure to an electric field based on sampling method used, and a hypothesized worst-case (25%) mortality rate for all electroshocked fish. For IDFG mark-recapture estimates the mean mortality from shocking was 1.05% with a range of 0.13-4.02%. For Idaho Department of Fish and Game (IDFG) removal sampling, we estimate a mean population mortality of 0.38% with a range of 0.02-2.91%. For non IDFG sampling mean population mortality averaged 1.11% with a range of 0.05-7.71%. Fifty-one percent of all mortality estimates were less than 0.50%. These low estimates are likely worst-case electrofishing effects because the high assumed mortality value used is not supported by any literature values. We conclude the impacts due to sampling using electrofishing methods does not constitute a meaningful impact to Idaho stream trout at the population level, especially when compared to annual natural mortality levels for most stream salmonids which typically equal 30-60%.

INTRODUCTION

Electrofishing is a widely used and highly effective sampling tool in the management of stream salmonids and other species (Schill and Beland 1995; Reynolds 1996). The use of electrofishing as a sampling tool began in the 1940's and became commonplace in the 1950's and 1960's. Despite the completion of several early injury studies, the technique was considered relatively benign for many years (Reynolds 1996). Recent concern regarding injury of fish collected with electrofishing methods was first raised by Sharber and Carothers (1988), who reported high injury rates for a sample of rainbow trout from the Colorado river. Since this initial effort to quantify injuries, additional studies have documented injury levels of up to 70% for trout sampled using traditional electrofishing methods (Sharber et al. 1994: Fredenberg 1992; Holmes et al. 1990; McMichael 1993; Thompson et at. 1997; Habera et al. 1996). Although short term injury rates from samples of electrofished salmonids often appear to be high, short-term mortality is often low (McMichael 1993; Hudy 1985; Pratt 1955; McCrimmon and Bidgood 1965).

Despite the recent profusion of electrofishing injury studies, few authors have attempted to evaluate long-term survival of injured fish, presumably due to logistical difficulties associated with such efforts. Dalbey et al. (1996) collected wild rainbow trout *Oncorhynchus mykiss* from a stream via electrofishing, rated spinal injuries using x-rays, and released them in a small pond to examine subsequent survival. The authors found no significant difference in survival of injured and uninjured rainbow trout collected with three electrical wave forms 12 months post treatment. Holmes et al. (1990) found no significant difference in angler catch of trout collected by electrofishing and hook and line methods 1 and 2 years previously. Achord (National Marine Fisheries Service, unpublished data) collected wild juvenile chinook *Oncorhynchus tshawytscha* from Salmon River tributaries via DC electrofishing and seining and saw no differences in outmigration survival to Lower Granite Dam a year later based on PIT tag

[1] *Idaho Department of Fish and Game, 1414 East Locust Lane, Nampa, Idaho 83686, USA.*

recoveries. To date, no published study we are aware of has demonstrated a reduction in long-term survival rate from electrofished salmonids compared to a control sample.

Although often called for (Hollender and Carline 1994; Habera et al. 1996; Hudy 1995), few studies have attempted to evaluate the importance of electrofishing injuries at the population scale. Schill and Beland (1995) presented a simple hypothetical example that suggests typical stream electrofishing sampling would be unlikely to negatively affect a population; however no field data were used. McMichael et al. (1998) elaborated on this approach and, using X-rays and necropsies, quantified electrofishing injury rates for samples of chinook salmon and rainbow trout at the sample, reach and population scales. Based on electrofishing *injury* rates ranging from 0.1 to 2.1% at the population scale, the authors concluded that impacts at the population scale were unlikely for either species. Habera et al. (1999) also recently noted that population scale impacts from AC electrofishing in Eastern brown trout *Salmo trutta* streams would not be likely based on their sampling intensity.

Despite the consistent finding of the few studies addressing injuries at the population-scale in salmonids, a more broad-based assessment than those of McMichael et al. (1998) and Habera et al. (1999) would provide additional perspective on risks resulting from electrofishing collection methods. The objectives of this study is to estimate salmonid mortality at the population scale due to electrofishing injury based on actual sampling intensities from a wide variety of Idaho streams.

METHODS

We estimated the probability of electrofishing mortality at the population scale for each sampling effort using the proportion of the stream reach shocked, probability of trout electrical exposure for a given electrofishing application, and an assumed worst case estimate of mortality for fish collected.

One major source of data for this effort was past stream sampling data for salmonids collected by Idaho Department of Fish and Game (IDFG) statewide during 1995 and 1996. IDFG management and research biologists provided a comprehensive list of all streams sampled with electrofishing equipment during both study years. A second source of data for the same two years was derived from collection

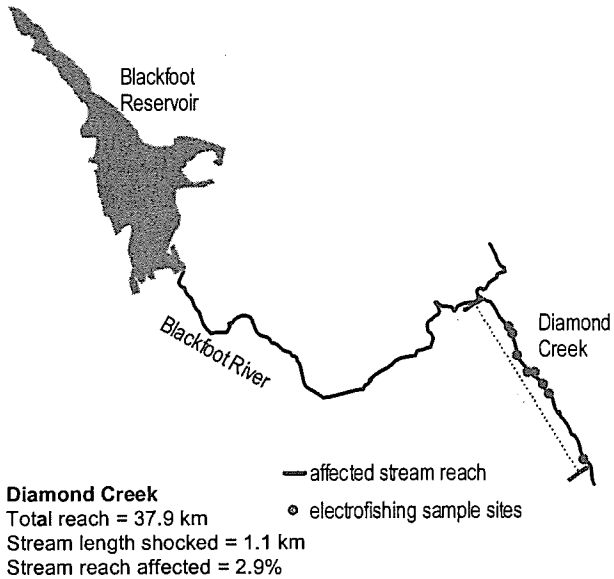


Figure 1.—Example of stream reach used for extrapolation from sample to population scale. Expansion of sections was restricted to equal stream order from which samples were collected as determined by 1:100,000 scale maps.

permit reports required by IDFG for other state and federal agencies, universities, and private consultants to sample Idaho streams. Data summarized from each individual sampling event in both years included a legal description (township, range, section, ¼ section), electrofishing technique used (number of passes if a removal estimate) and the number and length (m) of individual electrofishing sites for each stream.

The proportion of stream reach shocked (P) was calculated by dividing the total length of the sample site (or multiple sites) by the length of the corresponding stream reach. A stream reach, containing a "population" in this study was defined as that portion of a stream reach upstream and downstream of sampling sites that was of the same stream order. This approach was modified only if known migration barriers existed; in those cases population boundaries were adjusted accordingly (Figure 1). A planimeter and 1:100,000 scale BLM land status maps were used to assess stream order and to obtain the length of stream reaches. Actual electrofishing site lengths were included in the sampling data. We assumed electrofishing sample sites were representative of the fish populations at the stream reach scale (McMichael et al.1998). Therefore, the proportion of the habitat sampled was used as a surrogate for the % of trout populations shocked in a given stream reach.

We used 67%, 89%, 96% as the probability of capture or electrical exposure (E) for 1 pass, 2 pass and 3 pass removal sampling. These values represent general capture efficiencies for Idaho streams (Meyers 1999) and are virtually the same as that reported by McMichael et al. (1998). For mark-recapture estimates we used the proportion of fish recaptured as the probability of exposure. This mark-recapture probability was doubled to account for electrical exposure during both the mark and recapture runs (McMichael et al. 1998). Although declines in long-term survival of electrofished salmonids has not been documented relative to control samples, we chose 25% as an estimate of mortality due to electrofishing injury to represent a worst case long-term mortality rate for this study.

The following equation was used to calculate the probability of mortality at the population scale for each sample site or combined sites on a stream reach:

$$M = PE\ (0.25)$$

where M = the estimated mortality resulting for a stream reach;
P = the proportion of the stream reach length shocked during sampling;
E = the probability of trout electrical exposure per site based on the sampling method applied.

RESULTS

IDFG Sampling

IDFG sampled 162 stream reaches during 1995 and 1996 using electrofishing methods, the majority of which were done with two or three pass techniques for population estimation (Table 1). Using the two criteria established above to identify population boundaries, sampling at the reported intensities typically results in a small proportion of available habitat being electrofished. Estimated mean mortality re-

Table 1.--Summary of electrofishing mortality estimates at the population scale for 162 stream reaches sampled by Idaho Department of Fish and Game (IDFG) and 305 stream reaches sampled by non-IDFG agencies during 1995 and 1996.

Sample Effort	No. of sample reaches[1]	Estimated Mortality[2] (%) Mean	Std	Range
IDFG				
Mark-recapture	25	1.05	0.88	0.13-4.02
Removal				
One pass	10	0.45	0.52	0.02-1.73
Two pass	68	0.39	0.45	0.05-2.91
Three pass	59	0.30	0.34	0.04-1.65
Total	**162**	**0.46**	**0.57**	**0.02-4.02**
Non-IDFG Agencies				
One Pass	204	0.95	1.01	0.05-7.71
Two pass	21	0.48	0.24	0.13-1.13
Three pass	80	1.69	1.02	0.15-4.00
Total	**305**	**1.11**	**1.04**	**0.05-7.71**

[1] *Stream defined as the length of stream.*
[2] *Mortality due to electrofishing at the sample level reported as a percentage of the population with a stream reach.*

sulting from electrofishing injury at the reach or population level equaled 0.46% for all samples combined. The range of estimated mortality was 0.02-4.02% for all sections (Table 1).

Mark-recapture sampling had higher associated mortality (mean = 1.05%) compared to one, two, and three pass removal methods (mean = 0.30-0.45%), although estimated mortality associated with all collection methods was low (Table 1). Mark-recapture estimates typically required a longer sample section to produce an estimate, resulting in a higher proportion of the stream reach being sampled. The highest mortality estimate was 4.02% in one mark-recapture estimate. Eighty-two percent of the IDFG samples had estimates of 0.50% or lower (Figure 2). Eighty-eight percent of stream reaches sampled had estimated population mortality impacts <1.0% and only one of all worst-case IDFG estimates exceeded 3%.

NonIDFG Sampling

Non IDFG electrofishing accounted for sampling in 305 Idaho stream reaches during 1995 and 1996. Most non IDFG sampling consisted of one pass electrofishing efforts for species composition (Table 1). Estimated mean mortality at the population scale equaled 1.11% for all sites with a range of 0.05-7.71% (Table 1). Several projects completed intensive sampling associated with research and fish tagging projects which resulted in the higher mortality estimates. Thirty-seven percent of the stream reaches had estimated mortality impacts of 0.50% or less (Figure 3). Fifty-three percent of the population

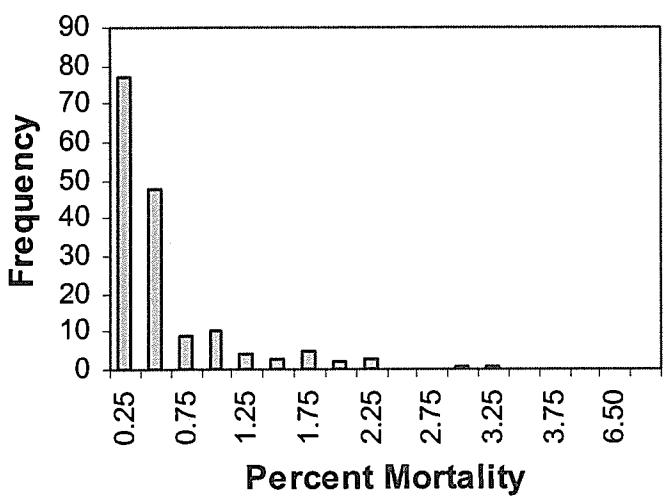


Figure 2.—Distribution of estimated mortality at the population scale by Idaho Department of Fish and Game in 162 stream reaches during 1995 and 1996.

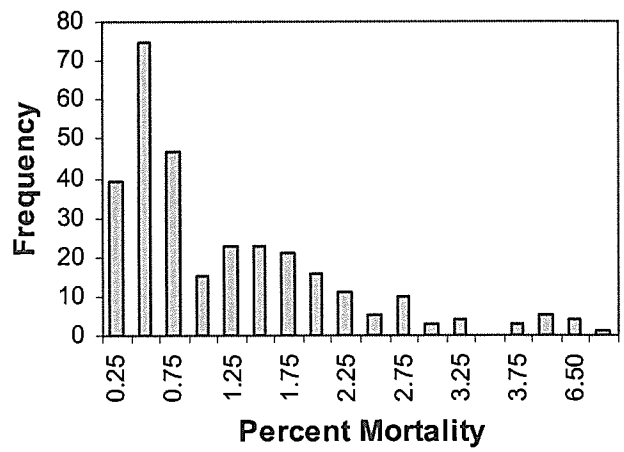


Figure 3.—Distribution of estimated mortality at the population scale by non-IDFG agencies in 305 stream reaches during 1995 and 1996.

mortality estimates were < 1.0% with the maximum mortality impact of 7.71% in a consultant presence/absence sample which extended over the entire stream reach.

DISCUSSION

Based on high injury levels at the sample scale, restrictions on the use of electrofishing collection methods and wave forms have been initiated and called for (Nielsen 1998). Alaska banned electrofishing methods on trophy trout management waters (Holmes et al. 1990) based primarily on fishing guide observations of injured fish (J. Reynolds, University of Alaska, pers communication). Montana has restricted the use of pulsed direct current over 30 Hz (Fredenberg 1992). Snyder (1995) suggested electrofishing methods should not be used when working with sensitive species. Bonar et al. (1997) suggested that electrofishing not be used to collect bull trout in Washington. These suggested or implemented policy shifts were based on injury rates observed in samples of salmonids collected with electrofishing techniques.

However, Habera et al. (1995) cautioned against "dismissing the legitimacy of any sampling gear or technique based on undetermined effects observed in a limited context". A growing number of relatively recent studies have begun to assess electrofishing impacts at the population scale. Schill and Beland (1995) suggested population scale injury and mortality rates in a hypothetical stream sampling situation would likely equal about 2.4% and 1.2%, respectively. McMichael et al. (1998) provided the first

actual field evaluation of electrofishing effect on salmonids at the population scale. These authors estimated that the population *injury rate* (not mortality) for their standard monitoring program ranged between 0.1 to 2.1% in chinook salmon and rainbow/steelhead trout in the Yakima basin. If only a fraction of injured fish in their study would eventually die or experience reduced growth, as suggested by the literature (e.g., Dalbey et al. 1996), the resultant effect on the population would be even lower. Habera et al. (1999) concluded that electrofishing for brown trout could have little population effect on brown trout in a Tennessee stream based on observed injury rates and the proportion of habitat sampled. Carline (this symposium) demonstrated that multiple-year electrofishing of brown trout did not result in detectable population differences compared to a nearby control population. Our results in this study are similar and suggest electrofishing as presently conducted in Idaho would be highly unlikely to impact a salmonid population.

In our study we applied 25% mortality as a worst case scenario to the estimates of injured fish in the electrofishing sample collection. Few long term estimates of mortality related to electrofishing injury are available. Dalbey et al. (1996) found 54-60% survival 335 d post shocking. However, they found no difference in survival between injured and uninjured fish nor between differing electrical waveforms used during collection. Further, they could not separate natural from electrofishing induced mortality. Short term (up to 14 days) mortality reported in electrofishing injury in recent studies ranges from 0-14% (Hollender and Carline 1994; McMichael 1993; Holmes et al. 1990). By applying a worst case estimate for mortality (25%), we believe our estimates of electrofishing related mortality represent the high end of possible impacts to the population.

Several limitations in our study methods should be considered. We used standardized values for trout electrical exposure during multiple pass electrofishing sampling in 1995 and 1996. The values represent a general average for capture efficiencies derived from 2 and 3 pass removal estimates in Idaho (Meyers et al 1999). We did not attempt to adjust capture efficiencies or mortality rates for size or species of fish collected. A final limitation of this study is our assumption (as in McMichael et al. 1998) that sample sections are representative of abundance and densities of the larger population within adjacent reaches of the same stream order. Due to worst case mortality applied, we do not believe these generalizations significantly affect our conclusions.

Although electrofishing impacts at the population scale effects appear unlikely (Schill and Beland 1995; McMichael et al. 1998; Habera et al. 1999; the present study results), injuries to individual fish are important. Public perception regarding injuries of individual fish may override the best studies that document limited impacts on the sample and population scales, thereby resulting in major restrictions in the use of electrofishing methods (Schill and Beland 1995). We strongly support efforts to reduce injury of salmonids due to electrofishing collection and suggest biologists use smooth DC or low frequency pulsed DC when capture efficiencies can still be maintained (Reynolds and Holliman, this symposium).

ACKNOWLEDGEMENTS

We thank the IDFG Regional Fisheries Biologists and Research Biologists for providing statewide summaries of population sampling and calculations of appropriate lengths of streams and rivers at the sample and population scales. Sharon Clark assisted with extracting data from collectors? permit files. Liz Mamer assisted with data entry, data summaries and manuscript preparation. This research was supported by Federal Aid in Sport Fish Restoration funds (project F-73-R-20).

REFERENCES

Beamesderfer, R. C. 1988. MOCPOP: a flexible simulator for analysis of age-structured populations and stock-related functions. Oregon Department of Fish and Wildlife, Fish Division, Information reports Number 88-3, Eugene.

Bonar, S. A., M. Divens, and B. Bolding. 1997. Methods for sampling the distribution and abundance of bull trout/dolly varden. Washington Department of Fish and Wildlife, Report No. RAD97-05, Olympia.

Dalbey, S. R., T. E. Mahon, and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury on long-term growth and survival of rainbow trout. North American Journal of Fisheries Management 16: 560-569.

Elle, F. S. and D. J. Schill. In preparation. Healing response of hatchery rainbow trout to hemorrhage injuries produced by electrofishing methods. North American Journal of Fisheries Management.

Federal Register. 1997. Endangered and threatened species; interim rule governing take of the threatened Southern Oregon/Northern California coast evolution-

arily significant unit (ESU) of coho salmon. 62(138): 38479-38485. Washington, D. C.

Fredenberg, W. 1992. Electrofishing induced spinal injuries by field electrofishing surveys in Montana. Montana Fish, Wildlife and Parks, Helena.

Habera, J. W., R. J. Strange, B. D. Carter, and S. E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass AS electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192-200.

Hollender, B. A. And R. F. Carline. 1994. Injury to wild brook trout by backpack electrofishing. North American Journal of Fisheries Management 14: 643-649.

Holmes, R., D. N. McBride, T. Viavant, and J. B. Reynolds. 1990. Electrofishing-induced mortality and injury to rainbow trout, Arctic, grayling, humpback whitefish, least cisco, and northern pike. Alaska Department of Fish and Game, Division of Sport Fish, Fishery Manuscript 90-3, Anchorage.

Hudy, M. 1995. The truth about electrofishing-revisited once again. Proceedings of the East Coast Trout Culture and Management Workshop II May 31-June 2, 1995. American Fisheries Society.

Kocovsky, P.M., C. Gowan, K. D. Fausch, and S. C. Riley. 1997. Spinal injury rates in three wild trout populations in Colorado after eight years of backpack electrofishing. North American Journal of Fisheries Management 17:308-313.

McCrimmon, H. R., and B. Bidgood. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. Transactions of the American Fisheries Society 94:84-88.

Mc Michael, G. A. 1993. Examination of electrofishing injury and short term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13: 229-233.

McMichael, G. A., A. L. Fritts, T. N. Pearsons. In press. Electrofishing injury to stream salmonids; injury assessment at the sample, reach and stream scales. North American Journal of Fisheries Management.

Nehring, R. B. 1998. Stream Fisheries Investigations: Job No. 1., Electrofishing injury investigations. Final Report. Federal Aid Project F-237R-5. Colorado Division of Wildlife. Fort Collins.

Pratt, V. S. 1955. Fish mortality caused by electrical shockers. Transaction of the American Fisheries Society 84:93-96.

Rieman, B. E., and K. A. Apperson. 1989. Status and analysis of salmonid fisheries: West slope cutthroat trout synopsis and analysis of fishery information. Idaho Department of Fish and Game, Project F-73-R-11, Boise.

Reynolds, J. B. 1996. Electrofishing. Pages 221-253 in B. R. Murray and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Sharber, N. G., and S. W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management 8: 117-122.

Sharber, N. G., S. W. Carothers, J. P. Sharber, J. C. De Vos, Jr., and D. A. House. 1994. Reducing electrofishing-induced injury of rainbow trout. North American Journal of Fisheries Management 14: 340-346.

Schill, D. J. 1991. Wild trout investigations: Statewide data summary. Idaho Department of Fish and Game, Project F-73-R-13, Boise.

Schill, D. J., and K. F. Beland. 1995. Electrofishing injury studies. Fisheries 20(6): 28-29.

Schill, D. J. and R. L. Scarpella. 1997. Barbed hook restrictions in catch-and-release trout fisheries: a social issue. North American Journal of Fisheries Management 17:873-881.

Snyder, D. E. 1995. Impacts of Electrofishing on Fish. Fisheries 20(1): 26-27.

Thompson, K. G., E. P. Bergersen, R. B. Nehring, and D. C. Bowden. 1997. Long term effects of electrofishing on growth and body condition of brown trout and rainbow trout. North American Journal of Fisheries Management 17:154-159.

Thurow, R. 1990. River and streams investigations: Wood River fisheries investigations. Job Completion Report. Idaho Department of Fish and Game, Project F-73-R-12, Boise.

Guidelines for Assessment and Reduction of Electrofishing-Induced Injuries in Trout and Salmon

J.B. Reynolds and F.M. Holliman[1]

Abstract—Over a decade has passed since the revelation that large (>30 cm) rainbow trout *Oncorhynchus mykiss* caught by pulsed DC electrofishing are frequently (~50%) injured. Since then, substantial effort has been expended to understand and reduce electrofishing injuries, especially in salmonids. Injury data on adult fish cannot be extrapolated to juveniles; the latter experience much less risk for injury than the former. Biologists must document electrical waveforms they use with an oscilloscope; this provides "ground truth" relative to injury. Pulsed DC frequency (pulses per second) is the most critical waveform factor relative to injury and should be reduced to 15-30 pps if injury is to be significantly reduced. Pulse duration (i.e., pulse width) and voltage should also be reduced to threshold levels that maintain acceptable catch rates while minimizing fish injury and stress. Although experimental research can provide guidelines, biologists should conduct assessments of their own situations. Injury can be assessed by filleting fish and looking for hemorrhages. A sample of 20 similar-size fish is sufficient to assess injury, including an estimate of proportion injured (p) with adequate confidence limits. Evaluation of sample p must include a perspective of effects at the population level. Effects will be more important on small, threatened stocks than on large, healthy stock.

INTRODUCTION

During the 1950s-1980s, success with electrofishing centered on catch rate and efficiency with little concern for fish injury. Alternating current (AC) was generally regarded as more damaging to fish than continuous direct current (DC), due to the early work on rainbow trout *Oncorhynchus mykiss* by Hauck (1949). As pulsed DC became popular in the 1950s and 1960s, the possibility that it affected fish more like AC than DC was largely ignored by our profession, despite early warnings (McLain and Nielsen 1953). Not until the late 1980s, when Sharber and Carothers (1988) reported that about one of every two large (>30 cm) rainbow trout caught by pulsed DC electrofishing in the Colorado River had internal injuries caused by capture, did we realize that fish captured by electrofishing may be injured even though they appear and act normal when released. Studies during the late 1980s and early 1990s in Alaska (Holmes et al. 1990), Wyoming (Meyer and Miller 1990) and Montana (Fredenberg 1992) generally confirmed the findings in Arizona: large trout are at high risk of internal injury (spinal damage and dorsal muscle hemorrhage) when captured by pulsed DC electrofishing, operating at 50-60 pulses per second (pps or Hz), the most commonly-used waveform of pulsed DC in North America.

Soon after this realization, some western states and federal agencies placed self-imposed restrictions on the use of electrofishing (Schill and Beland 1995), most of which remain in effect today. During the 1990s a growing concern about the electrofishing-injury issue resulted an urgent calls for research (e.g., Snyder 1992) and wider bans on electrofishing in waters containing threatened or endangered stocks of salmonids (Nielsen 1998). Electrofishing turned from a catch-oriented activity to a manager's balancing act: take the chance and use the tool to get the data, or lose the tool by avoiding risk with bans or restrictions; both approaches have been used while all await more information.

[1] *School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, P.O. Box 757220, Fairbanks, AK 99775.*

In this paper, we highlight research findings during the 1990s, what they mean and how they can be used in the management setting. Although we have extensively reviewed the literature, we have relied on pre-1980 literature only where necessary for the purpose of this paper. Our report focuses on pulsed DC because it remains the most common waveform for electrofishing and is at the center of this issue, and on salmonids because of the trout-oriented theme of this conference.

INJURY AND ITS RISK FACTORS

Trauma is a general term (Reynolds 1996) that includes stress (physiological and behavioral changes) and injury (mechanical damage to soft and hard tissues). In restricting this report to injury we do not imply that stress is unimportant. It is well known that electroshocked fish requires hours, even days, to regain normal physiological status (e.g., Mesa and Schreck 1989). We contend that injury occurs during the first 1-2 seconds of exposure to high-intensity electrical fields and that continued exposure primarily serves to increase stress. Stress is probably a larger threat to juvenile salmonids than is injury, at least when electrofishing is the capture method.

Although injuries to gills and internal organs do occur, the incidence of these injuries due to electroschock seems to be infrequent and less explicable; an exception is gill hemorrhaging in coregonids, an event seen by many cold-water biologists. We focus on those injuries more likely to occur in salmonids: external hemorrhages (often called "branding" but actually bruising) and internal spinal damage and muscle hemorrhage that may be present even in the absence of external bruising. Bruises occur when the epithelial capillaries rupture, spreading small quantities of blood into the surrounding surface tissue; they are often well defined because they tend to conform to the shape of the underlying, chevron-shaped myomeres. Dark blotches on the back of a fish may be stress-induced aggregations of chromatophores that will disappear as the fish recovers. Bruises are likely indicators that a fish also has spinal or muscular injuries (e.g., Fredenberg 1992) but their absence does not mean a fish is uninjured internally. Bruises can become sites for bacterial infection after the fish is released.

From the short-term perspective, fish have an amazing capacity to survive severe internal injuries (e.g., ruptured dorsal aorta, separated spine) that would usually prove lethal to birds and mammals. Nevertheless, fish that are released with such injuries logically have a much-reduced prospect of returning to full health and normal function. When induced by electroshock, muscle hemorrhage and spinal damage are caused by severe contractions, simultaneously on both sides of the fish, primarily in the dorsal musculature (Lamarque 1990). Sharber and Black (1999) proposed epilepsy as the underlying cause for all electrofishing-induced injuries in fish, but they offered no proof for their theory. In salmonids, damage to spinal and muscular structures tends to be centered midway between the head and tail (Fredenberg 1992, Ainslie et al. 1998). Spinal damage and muscular hemorrhage are assessed by x-rays and filleting, respectively, and have been classified according to apparent severity for consistency in reporting (Reynolds 1996), but this system has not been well-related to fish well-being (e.g., survival, growth, reproduction). Even though the classification system uses numbers (0, 1, 2, 3) to rank the apparent severity of both types of injuries, these numbers are not ordinal (quantitative) and should only be used as categories. The categorical data for spinal damage and muscle hemorrhage should not be combined.

There are many possible causes related to risk of electrofishing injury for a fish but we suggest that most can be categorized into one of three major risk factors: fish size, electrical waveform and electrical field intensity. All three factors can be considered in the process to assess and, if necessary, reduce electrofishing injury.

Fish Size as a Risk Factor

That electrofishing tends to be size selective, larger fish being more vulnerable to capture, has long been established (Reynolds 1996). Larger fish are also more likely to be injured by electrofishing than smaller ones of the same species (Taylor et al. 1957, McMichael 1993, Hollender and Carline 1994, Dalbey et al. 1996, Thompson et al. 1997, Ainslie et al. 1998). Our unpublished findings from a nation-wide study of electrofishing injury in various cold- and warm-water species (www.shockingnews.org) are in agreement with this size-injury relationship. In general, salmonids less than 15 cm long are much less at risk than those longer than 15 cm, and especially those longer than 30 cm. Data on injury rates (injury incidence) for adult salmonids should not be assumed to apply to juveniles.

Electrical Waveform as a Risk Factor

Pulsed DC waveforms have three characteristics that are related, to varying degrees, to the risk of fish injury: pulse shape, pulse frequency and pulse duration. Manipulation of these characteristics ranges from highly flexible on some electrofishing units to completely fixed on others. Operators can learn about these features by asking the manufacturer for equipment specifications or by using an oscilloscope to view the output at different settings.

Pulse Shape

Although one tends to envision a classical square wave when thinking about pulsed DC, more often than not the actual waveform is something else. Sharber and Carothers (1988) compared the effects of three pulsed DC (60 Hz) waveforms – square, quarter-sine and exponential decay – on injury in large rainbow trout in the Colorado River. They found that the quarter-sine wave was significantly more injurious than the other two types (although the main impact of their paper was the message that *any* 60-Hz pulsed DC waveform can cause high injury rates). Generally, pulse shape is a fixed feature of most equipment and cannot be changed by the operator. In some units, the pulse shape changes with amplitude (voltage), either by design to compensate for increasing power demands, or, more commonly, by consequence of component limitations (e.g., square wave changes to sawtooth shape at higher voltages because the capacitors cannot sustain the peak voltage during each pulse).

Pulse Frequency

Pulse frequency, also called pulse rate, is a key factor affecting risk for injury in salmonids. Sharber et al. (1994) demonstrated a curvilinear relationship between pulse frequency and injury rate in large rainbow trout; frequencies of 60 Hz and higher were more damaging than lower frequencies. This relationship has been confirmed repeatedly (McMichael 1993, Dalbey et al. 1996, Ainslie et al. 1998). The likelihood of tetany (forced muscle contraction) also increases with pulse frequency, lending credence to the idea that tetany tends to induce injury. Pulse frequency can often be manipulated on manufactured equipment, In general, operators should reduce pulse frequency to the range of 15-30 Hz, while trying to maintain acceptable catch rate, if injury rate is to be significantly reduced.

Pulse Duration

Pulse duration is also called pulse width and is measured in milliseconds; 4-8 ms is the typical range for pulsed DC. Pulse duation is related to duty cycle, the percentage of time that pulses are on, relative to total time on and off; for example, if pulse duration is increased while pulse frequency remains constant, duty cycle will also increase. The effect of pulse duration on injury is not clear. At a given peak voltage or amplitude, changing pulse duration will change the average voltage (area under the waveform curve), meaning that the fish is subjected to more electrical energy. It is possible that longer pulse duration (e.g., 6-8 ms) contributes more to added stress than injury, compared to shorter pulse duration (e.g., 2-4 ms).

Electrical Intensity as a Risk Factor

The intensity of an electrical field can be expressed in terms of voltage, current (amperes) or power (watts). The most common expression of intensity is voltage and this feature is almost always changeable on an electrofishing unit. In isolated fish muscle, no contraction occurs below some voltage threshold As voltage increases above the threshold, muscle contraction increases in a stepwise manner until complete contraction occurs; further increases in voltage have no effect (Haskell and Adelman 1955). Although the threshold function serves as a basis for a voltage-injury relationship, the effect of voltage on injury is subject to debate (Reynolds and Kolz 1995, Sharber et al. 1995). As basic as the question is, no studies have yet clearly demonstrated that risk for injury increases with voltage because alternative explanations for increased injury became apparent. Nevertheless, we suggest that the threshold principle of muscle contraction will eventually support the notion that injury can be decreased by reducing field intensity.

ASSESSMENT OF INJURY

Field Procedure

Biologists can inexpensively evaluate electrofishing injury in a target fish population. The target to be sampled is a cohort (or similar sizes) of fish in a population of interest during an electrofishing operation. A sample is defined as 20 fish of a cohort, or of similar size, in a population; generally these are the larger fish in a population because the liklihood of injury, if it occurs, increases with fish size. During a

normal electrofishing operation, collect one or more samples; handle and euthanize the fish with care to avoid additional injury. If possible, collect a control sample by another method (e.g., seine, trap, angling). Record all settings used on the control unit and, if possible, the water temperature, depth and conductivity (as these factors could relate to injury rates). Record the length of each fish in the sample and keep a record of other fish caught during the operation. Estimate the proporton of each species that escaped while sampling, or make a judgement regarding the acceptability of catch effectiveness.

Necropsy Procedure

Keep all fish in each sample together on ice if they are to be transported; they can be frozen for later analysis if necessary. Each fish, fresh or thawed, should be filleted on both sides, cutting or scraping the flesh to the spine. Examine both sides of each fish for hemorrhages, bloody spots on or near the spine with corresponding spots on the fillet. Do not be fooled by blood that appears during filleting; this is easily wiped away, but hemorrhages are not. Find the worst hemorrhage and classify it according to a classifcation system (i.e., 0, 1, 2 or 3) described by Reynolds (1996).

Data Analysis

Calculate the proportion (p) of injured fish in each sample (those with one or more hemorrhages) and estimate the confidence limit of p by assuming that each fish has an equal and independent chance of being injured, using the normal approximation of the binomial distribution, $p +/- z\{[(p \bullet q)/n]^{0.5}\}$, where z is the normal approximation statistic at a given confidence level, q equals 1 - p and n is sample size (e.g., 20). The usual confidence levels of 0.01 or 0.05 may be too high for a sample size of 20; lower confidence will likely be necessary. Also calculate the proportion of fish in each injury class to indicate the injury severity in the sample.

To X-Ray or Not?

The same analysis just described for hemorrhages can also be done for spinal injuries, but requires X-ray analysis. If hemorrhage incidence is low in samples, spinal injury is likely unimportant and X-rays are not needed. However, if hemorrhage injuries are significant, it may be worthwhile to get additional samples for X-ray analysis. Veterinary facilities will often agree to do these, but at a cost. Both dorsal and lateral perspectives are needed when doing this work because spinal injury is directional.

Interpretation

As an arbitrary guide, a sample with 10% or less of fish injured should be considered to mean that injury is not important unless, of course, the fish in question are threatened or endangered. Fish capture and handling by any method intended to release fish alive will cause injury rates in the 1-10% range. Samples injury rates higher than 10% will be regarded as significant or not, depending on the management situation. Schill and Beland (1995) called for research that would put sample-level injury rates into a population-level perspective and a number of researchers responded (Dalbey et al. 1996, Habera et al. 1996, Kocovsky et al. 1997, Thompson et al. 1997, McMichael et al. 1998 and Ainslie et al. 1998). The main outcome of these studies has shown that shocked salmonids tend to survive after release, but may experience reduced growth. However, when these sample-level effects were projected to the population level, the effects were negligible. Socio-political factors may over-ride the fact that population effects are nil: it did not matter to Kenai River fishing guides when Alaskan managers demonstrated no population effects from electrofishing injuries to trophy rainbow trout – any chance that a client would see such an injury was unacceptable (D. McBride, Alaska Department of Fish and Game, Anchorage, personal communication). Nevertheless, biologists must document population effects if at all possible so that the science is there for all to see. It is possible for reproductive success to be reduced in smaller stocks where prespawning females are shocked for egg takes; in these cases the eggs of gravid females have reduced viability, and "green" females returned without being stripped may be too stressed to recover in time to spawn. Thus, electrofishing effects should be carefully evaluated, both in terms of sample effects projected to the population (McMichael et al. 1998) and whole-population ecology.

REDUCTION OF INJURY

Measures to reduce injury need not lead to a significant drop in catch effectiveness. Many biologists fish with more electrical energy than needed. Several guidelines will help to balance catch and injury rates.

First, consider fish response (behavior) during capture and handling. Are they completely immobilized? Do they exhibit signs of tetany (flared opercles,

stiff muscles)? Does recovery (regaining equilibrium) require lengthy periods (5-10 minutes or more)? If answers to these questions are yes, too much energy is being used. We recommend using a simple classification of fish response in the electrical field:

Escape – fish exhibit avoidance by rapidly swimming upright away from the field;

Taxis – fish swim upright, sometimes with jerking motions, toward the anode;

Loss of Equilibrium – fish swim, but without equilibrium, in a disoriented manner; and

Immobilzation – fish exhibit no movement; may be relaxed (narcosis) or stiff (tetany).

Taxis and loss of equilibrium are usually as favorable for fish capture as immobilization and are more likely to reduce stress, injury and death. Fish should be captured before touching energized electrodes and should not be held in the electrical field longer than necessary.

Second, consider the waveform and voltage being used. If pulse frequency can be controlled, try to elicit taxis or loss of equilibrium with frequencies lower than 30 Hz. When threshold frequency is reached, try further reducing energy level by decreasing voltage (and pulse duration if a control is available). In other words, seek the threshold waveform and intensity that gives the minimal capture-prone response.

Third, consider the size of electrodes being used. Commercial manufacturers typically provide cable-style anodes with a 3-6 mm diameter; these create small, intense electrical fields that produce an "all-or-none" effect – the fish feels little or no intensity until it gets close, then it gets all of it. Larger-diameter cables (12-18 mm) or a sphere will produce larger more effective fields with lower intensities near the anode. However, anodes that are too large may overload the power source, especially in more conductive waters, so one must test the limits of the battery or generator under actual conditions before selecting the largest electrodes possible.

Finally, document the effect of reduction measures taken. Was the incidence or severity of injuries reduced? Do the fish recover more quickly? Are catch rates still acceptable? This extra effort will instill confidence through knowledge in those doing the work, and provide guidance for those who will follow. Remember that when the situation changes (e.g., new species, different equipment), the electrofishing ground rules have also changed and a new evaluation will be necessary.

LITERATURE CITED

Ainslie, B.J., J.R. Post and A.J. Paul. 1998. Effects of pulsed and continuous DC electrofishing on juvenile rainbow trout. North American Journal of Fisheries Management 18:905-918.

Dalbey, S.R., T.E. McMahon and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury to long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management 16:560-569.

Fredenberg, W.A. 1992. Evaluation of electrofishing-induced spinal injuries resulting from field electrofishing surveys in Montana. Montana Department of Fish, Wildlife and Parks, Helena.

Habera, J.W., R.J. Strange, B.D. Carter and S.E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass AC electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192-200.

Haskell, D.C. and W.F. Adelman, Jr. 1955. Effects of rapid direct current pulsations on fish. New York Fish and Game Journal 1:64-74.

Hauck, F.R. 1949. Some harmful effects of the electric shocker on large rainbow trout. Transactions of the American Fisheries Society 77:61-64.

Hollender, B.A. and R.F. Carline. 1994. Injury to wild brrok trout by backpack electrofishing. North American Journal of Fisheries Management 14:643-649.

Holmes, R., D.N. McBride, T. Viavant and J.B. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Manuscript 9, Division of Sport Fish, Alaska Department of Fish and Game, Anchorage.

Kocovsky, P.M., C.G. Gowan, K.D. fausch and S.C. Riley. 1997. Spinal injury rates in three wild trout populations in Colorado after eight years of backpack electrofishing. North American Journal of Fisheries Management 17:308-313.

Lamarque, P. 1990. Electrophysiology of fish in electric fields. Pages 4-32 *in* G. Cowx and P. Lamarque, editors. Fishing with electricity: Applications in freshwater fisheries management. Fishing News Books Limited, Oxford, England.

McLain A.L. and W.L. Nielsen. 1953. Directing the movement of fish with electricity. U.S. Fish and Wildlife Service, Special Scientific Report – Fisheries 93:1-24.

McMichael, G.A. 1993. Examination of electrofishing injury and short-term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13:229-233.

McMichael, G.A., A.L. Fritts and T.N. Pearsons. 1998. Electrofishing injury to stream salmonids: injury assessment at the sample, reach, and stream scales. North American Journal of Fisheries Management 18:894-904.

Meyer. C.W. and D.D. Miller. 1990. Spinal injury and mortality in rainbow trout and brown trout collected by electroshocking. Proceedings of the Western Association of Fish and Wildlife agencies 70:54-61.

Mesa, M.G. and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Transactions of the American Fisheries Society 118:644-658.

Nielsen, J.L. 1998. Electrofishing California's endangered fish populations. Fisheries 23:6-12.

Reynolds, J.B. and A.L. Kolz. 1995. Comment: Reducing electrofishing injury to large rainbow trout. North American Journal of Fisheries Management 15:963-964.

Reynolds, J.B. 1996. Electrofishing. Pages 221-253 *in* B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Schill, D.J. and K.F. Beland. 1995. Electrofishing injury studies: A call for population perspective. Fisheries 20(6):28-29.

Sharber, N.G. and S.W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management 8:117-122.

Sharber, N.G., S.W. Carothers J.P. Sharber, J.C. DeVos, Jr. and D.A. House. 1994. Reducing electrofishing-induced injury of rainbow trout. North American Journal of Fisheries Management 14:340-346.

Sharber, N.G., S.W. Carothers J.P. Sharber, J.C. DeVos, Jr. and D.A. House. 1995. Reducing electrofishing injury to large rainbow trout: Response to comment. North American Journal of Fisheries Management 15:965-968.

Sharber, N.G. and J.S. Black. 1999. Epilepsy as a unifying priciple in electrofishing theory: a proposal. Transactions of the american Fisheries Society. 128:666-671.

Snyder, D.E. 1995. Impacts of electrofishing on fish. Fisheries 20(1):26-27.

Thompson, K.G., E.P. Bergersen, R.B. Nehring and D.C. Bowden. 1997. Long-term effects of electrofishing on growth and body condition of brown and rainbow trout. . North American Journal of Fisheries Management17:154-159.

Native and Non-Native: What's the Difference?

Stan Guffey[1]

Abstract—Few, if any, fisheries biologists today would recommend willy-nilly stocking of non-native fishes into wild habitats containing indigenous species. Appropriate fisheries management practices, and legal and management policy mandates have changed as concepts of biological conservation have changed. The predominant concept in biological conservation today is biological diversity, and the overall goal of conservation is the preservation of native biodiversity. Perhaps no where else are the tensions between conservation ideals, law, policy, and public interest more evident than in cold-water fisheries management. In this paper I argue that removal of non-native salmonids and their replacement with native taxa should be a primary focus of wild-lands fisheries management. I further suggest that compelling arguments for this cannot be derived solely from biology. Instead, our educational and public relations efforts should emphasize authenticity. Authenticity of a region' s biota is what distinguishes it from the homogeneous menagerie that much of our North American landscape has become. And authenticity as a source of pride becomes a stimulant to continued conservation efforts in a region. For the wild-lands fisheries biologists then the task is one of focused research into new methods and approaches for removing non-native taxa, and of restoring and maintaining native biological diversity.

"In assenting, however unconsciously, to the destruction of biological diversity, we domesticate ourselves and contract our experience. Wilderness preservation and ecological restoration are, at different scales, homage to undomesticated creatures and communities. They hinge on authenticity and integrity." (Mills 1994)

INTRODUCTION

Intensive manipulation has been a hallmark of cold-water fisheries management for over a century. Components of that manipulation have included eradication of taxa deemed undesirable, stocking with game fishes obtained from a variety of geographical regions, and manipulations of stream habitats to increase carrying capacity and/ or viability and reproduction. In these regards, the concept of restoration is not new in biological fisheries management. However, many of these past activities, particularly involving eradication of native taxa and stocking with non-native taxa or stocks, have fallen into disfavor. Over the last 30 years a new discipline of conservation biology has coalesced around the interrelated themes of indigenous biodiversity, preservation of critical habitats, and restoration of habitats and landscapes with the goal of preventing anthropogenic extinctions. Each of these themes has its suite of questions and problematics not amenable to simple answers or broadly applicable generalizations. In this paper I will explore, in broad outline, some of these problematics and questions. My intent is most decidedly not to hold contemporary fisheries management accountable for practices deemed appropriate under a past management philosophy that no longer holds favor. Instead I suggest that cold-water fisheries management has the opportunity and the obligation to continue at the forefront in modern conservation biology with an emphasis on the restoration of native stream biodiversity: extending Crossman's (1968; cited in Feruson 1990) classification of fisheries management eras, an age of native biodiversity restoration. Of course there are the nagging problems of all of that non-native biodiversity, alive and well and reproducing, from earlier ages of introductions and hatcheries, as well as all those fisheries currently maintained by regular stocking.

[1]*Division of Biology, The University of Tennessee, Knoxville 37996-0001*

The flip side of our contemporary emphasis on native biodiversity is our concern with non-native taxa. If native biodiversity is the ideal, then non-native elements of biodiversity are something less than ideal. Concern for the effects of non-native taxa on native biodiversity has reached a fevered pitch in the United States largely as a result of the rather clear ecological consequences and costs of a number of high profile introduced taxa (Pimentel et al. 1999). There is little disagreement that zebra mussels, purple loosestrife, and melaleuca, to mention a few, are destructive of native ecosystems and biodiversity, and carry high economic costs. The consequences of these introductions, among others, has stimulated a spate of new laws and policies in the United States and elsewhere. Focus of this newly energized concern has been particularly intense with respect to aquatic systems, largely as a consequence of the recent arrival and rapid spread of zebra mussels. However the zebra mussel story involves a very different kind of introduction than that involved in fisheries management introductions, inadvertent rather than purposeful (and in many instances ongoing), and clearly the consequences of the two types of introductions differ dramatically. Such differences necessitate some definitions to account for differences in the geographical source of species, the nature of the introduction, and the observed or perceived consequences of the introduction. A number of definitional schemes have been put forward by professional bodies, working groups, and individual researchers. I will draw primarily on definitions recently deployed by the IUCNs Species Survival Commission (Invasive Species Specialist Group 2000).

Definitions

Native species (indigenous): A species, subspecies, or distinct evolutionary unit occurring within its natural range (past or present) and dispersal potential (i.e. within the range it occupies naturally or could occupy without direct or indirect introduction or care by humans).

Non-native species (alien, exotic, foreign, non-indigenous): A species, subspecies, or distinct evolutionary unit occurring outside of its natural range (past or present) and dispersal potential (i.e. outside the range it occupies naturally or could not occupy without direct or indirect introduction or care by humans).

Non-native invasive species: A non-native species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity.

Introduction: The movement, by human agency, of a species, subspecies, or distinct evolutionary unit outside its natural range (past or present).

Re-introduction: An attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated as a result of direct or indirect human actions.

Natural ecosystem: An ecosystem which has not been perceptibly or significantly altered by humans.

Semi-natural ecosystem: An ecosystem which has been altered by human actions, but which retains significant native elements and characteristics.

Restoration: Actions undertaken to restore ecosystems substantially altered by human actions to a natural or semi-natural condition.

Introductions of cold-water fishes have been almost entirely purposeful, by fisheries biologists or otherwise, but the limited range of habitats conducive to persistence of introduced salmonids does not usually qualify them for consideration as invasive species. However, recent studies have suggested that stocked salmonids have greater potential for spread throughout watersheds or watershed segments than we had previously thought (Young 1995), i.e., some introductions have the potential to become invasives within the receiving watershed. The effects of other stressors on the survival of native taxa or the potential invasibility of non- natives is to some extend a wild card in the inquiry. Although there has been considerable research, the effects of system stressors such as rapid climate change or acidic deposition on the persistence and spread of either native or non-native taxa remains largely conjectural. Potential for persistence and spread along with concern for the effects of introduced species on declining populations of native species has spawned a great deal of research over the past 30 years, and provides the primary justifications for attempts to restore cold water ecosystems.

A TRADITION IN FISHERIES RESOURCE MANAGEMENT

The fisheries management tool kit is diverse, reflecting the diversity of circumstances that must be ameliorated, restored, augmented, or monitored - that is to say, managed, and the diversity of demands placed on managers by stakeholders - policymakers, commercial concerns, and the public. Throughout its

history though, the focus of fisheries management has been almost exclusively utilitarian or anthropocentric. And toward the goal of establishing and maintaining viable stocks for angling, introductions, transfers, and reliance on hatcheries have played a prominent role. Welcomme (1986) identified six categories of reasons for inland stocking of fish: 1). Sport or recreation, 2.) aquaculture, 3.) ecological manipulation, 4.) biological control of unwanted organisms, 5.) ornament, and 6.) a catchall category, nonpurposeful. Of these, sport or recreation (and food) are largely the sole reasons for stocking salmonids.

The general outlines of the history of salmonid stocking are well documented (Nico and Fuller 1999) and need only a cursory treatment here. By the turn of the century destructive land use practices (primarily logging and post-logging slash fires, and in the west, grazing) and over fishing had severely reduced salmonid populations in both the eastern and western United States. Decades before, stocking as a means of augmenting declining fisheries and of establishing new ones had come into wide practice. Transfer of fishes from nearby areas and stocking with non-native species were both employed. However the latter approach was most common because of the ability to rear large numbers of a few selected species in hatcheries, and because of perceptions of the superiority of these introduced species as sport and food fishes. In these efforts brook, lake, rainbow, and brown trout, among others, were stocked into western waters, and rainbow and brown trout were stocked into eastern waters. Fish in both parts of the country were stocked into waters with extant populations of native salmonids, into waters from which native species had been extirpated, and into waters that did not historically have salmonid populations. In this manner, and in conjunction with similar developments in warm-water fisheries, an institutional subculture of reliance upon stocking developed within the discipline of fisheries management, particularly the management of North American salmonids. Consequences of this culture of stocking included the establishment in many areas of fisheries entirely reliant on extensive and regular stocking, and in the past, adoption of restoration practices involving the chemical eradication of non-game native taxa to allow for introductions or the establishment of new hatchery based fisheries.

CONSEQUENCES OF INTRODUCTIONS FOR NATIVE BIODIVERSITY

Generalizations about the effects of introductions are difficult to make, therefore, so too are predictions. This is not surprising given the enormous number of interacting factors involved and the variability of these factors in different places and at different times. Each introduction is essentially unique in terms of pathways to an outcome. However a number of broad generalizations have emerged from the enormous volume of research undertaken over the last three decades. The most broadly applicable generalizations are happy ones from the point of view of maintaining native biodiversity: most introductions do not become established, and most that do become established become integrated into the ecosystem without the loss of native species (Moyle and Light 1996, Li and Moyle 1999). Other generalizations, or empirical rules (Moyle and Light 1996, Li and Moyle 1999) derived from the wealth of research and experience in biological fisheries management have been used to develop guidelines for future potential introductions (Li and Moyle 1999, Pearsons and Hopley 1999). Paramount in all of these sets of guidelines are strong recommendations against introductions into systems with little evidence of human disturbance (natural and semi-natural ecosystems). Instead, introductions should primarily be considered only in systems that have been so altered by human activities that native taxa have been extirpated and the potential for their re-introduction is low (ecosystems that are degraded with respect to native biodiversity). Sound and reasonable guidelines for fisheries management and biodiversity conservation in the 21st century: introductions, hatcheries, stocking, have roles to play, but roles under different rules than in the past.

However, the problems of a century of past introductions that have become established are very much with us. In many instances, such as those involving hybridization with congenerics or with conspecifics from evolutionarily distinct populations (Krueger and May 1991, Behnke 1992, Meffe 1992), the implications for the preservation of native biodiversity are straightforward. The roles of interactions between taxa - competition, interference, and predation, to say nothing of interactions between these processes and habitat variables, are more difficult to explicate.

Our theoretical understanding of species interactions is rich, but not nearly so rich as the complexities of the systems that ecological theory attempts to understand: competition is easy to talk about, but difficult to observe or demonstrate. Where such interactions are demonstrated, or strongly implicated, as a component of endangered native species decline, the management imperative is the same as that involving endangerment through hybridization: to devise means of removing the threat.

However, local, regional, or even global endangerment of native taxa is only part of the picture. Another consequence of introductions, even where they do not contribute to the loss of native taxa, is a decrease in landscape level species heterogeneity (beta diversity), or, conversely, increased biotic homogeneity at landscape levels. This result of introductions is of less immediate concern than the endangerment of taxa (from whatever causes), but the next step in the management of coldwater fisheries must address this component of biological diversity as well.

THE FISHERIES MANAGEMENT RESPONSE TO CONCERNS OVER INTRODUCTIONS AND BIODIVERSITY CONSERV ATION

Biological fisheries management has never been easy, and the difficulty has only increased over time. From its inception the discipline was given the task of restoring, establishing, improving, and maintaining viable fisheries. More often than not, fisheries were to be maintained in the context of multiple use landscapes and of continually deteriorating aquatic environments due to channel modifications, siltation, and pollution. Fisheries biology rose to these challenges spectacularly. Through the application of sound science the discipline has and continues to develop a solid underpinning of methods, data, theories, and models to meet the goal of maintaining viable fisheries in the face of increased demand and continued habitat deterioration. Thirty or forty years ago fisheries biology was shackled with yet another task, introduced as one of the central themes of contemporary conservation biology: the protection and restoration of native biological diversity. As with most changes in the discipline this addition did not replace another part of the management mandate, but was instead an add-on to the mandate. Fisheries biologists got busier and their task became even more difficult and complex.

Before the emergence of the field of conservation biology and even before the promulgation of laws and policies concerning management of native taxa in trouble, fisheries biology was on the task. In meeting the mandate of maintaining viable fisheries, many fisheries biologists had noted and chronicled the decline of certain taxa in their areas of responsibility. More importantly, they began to conduct research into the causes of declines and into management methods to arrest declines. Indeed, it was from the field of fisheries biology that some of the first recognition of the negative effects of introduced species on native taxa emerged. Because fisheries biology is an applied discipline, the gap between research and application is a relatively narrow one, and the time lag between theory coalescence and management application potentially short. Concern for declining populations of native populations and the implication of introduced taxa as possible causative factors in such declines, stimulated a vigorous debate within the fisheries professions over issues of introductions, stocking, and hatcheries. Unlike many debates initiated outside the profession, these discussions generated more light than heat. The insights gained, the principals and guidelines that emerged from these debates found ready, if uneven, application in fisheries management. Much remains do be done in the way of research and policy formulation, but the tradition of the fisheries professions leadership in biological conservation, rather than following perspectives originating outside of the discipline, continues.

The National Park Service's Response

To some extent the response of the National Park Service (NPS) to decline of native fishes and to problems of introduced non-native taxa was independent of developments occurring in the fisheries professions generally. At the very least, interpretations of the Service's legal mandate that began to come together in the 1960s admitted substantially less debate than occurred in the larger world of biological fisheries management. This is surprising given the contradictory nature of the mandate and the flexibility of interpretation the enabling act admits. The Organic Act tasks the National Park Service with seemingly contradictory mandates:"...to conserve the scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations"

(Zaslowsky and Watkins 1994). Enjoyment is of course a type of use, and use will inevitably come into conflict with conservation at some point. As Ronald Foresta (1984) has pointed out, "If use destroys, how can a management policy both accommodate use and preserve the natural area? A mandate which is inherently contradictory must, by logical extension, become a management dilemma...."

The strength of the Organic Act is the same as its weakness: the act is flexible with respect to interpretations of what constitutes unimpaired conservation and enjoyment. All in all, this flexibility has been employed to good advantage to develop clear policies concerning the management of native and non-native taxa in the nation's parks. For most of the history of the parks, policies have stressed the conservation and restoration of native species and discouraged the establishment of non-native species (Wright 1992); at least for most components of the biota. Reflecting prevailing attitudes in fisheries management, coldwater fishes were a notable exception. Stocking, including introductions of non-native taxa were staples of fisheries management in the Parks. Since the early 1970s however, in line with a growing interpretive environment with respect to the management of other components of the Parks' biota, NPS policy has been squarely focused on native species and the preservation and restoration of natural systems. Key elements of NPS fish stocking policy (as summarized by Panek 1997) include: 1. No stocking into waters that are naturally fishless; 2. Stocking of native fishes into natural zones only to restore species or stocks to their historic range; 3. Stocking of native species into development zones; 4. stocking of non-native fishes only highly modified systems such as reservoirs and manipulated rivers, with a preference give to native taxa where possible.

In most respects the Park Service response to the decline of native fishes is the same as the biological fisheries management response generally, with one exception. NPS policies emphasize native biodiversity within the Parks, independent of the global status of the taxa. Endangerment in Park natural habitats is sufficient for concern and action, and if non-native taxa are apart of the cause of endangerment, policies up to and including eradication are permitted (National Park Service 1988). I believe that a consideration of the meaning of native and non-native at the scale of landscape level biodiversity argues for a greater focus on the eradication of non-native taxa in natural habitats generally.

NATIVE OR NON-NATIVE: WHAT'S THE DIFFERENCE? (NEXT STEPS IN THE RESPONSE)

Biological (or legal, or policy) definitions of native and non-native provide us with a common language as to what such things are. Unlike some problems of spatial and temporal delineation in other systems (Houston and Schreiner 1995), there is little uncertainty or disagreement as to what taxa are native in coldwater ecosystems and what taxa are not. However, general agreement on terms and identifications tells us nothing about why we should care. Consideration of biotic diversity at the landscape level provides us with a biological justification for a preference for native taxa over non-native. Independent of hypothesized or demonstrated effects of non-native fishes on the persistence of native taxa, reduction of biotic heterogeneity is an inevitable consequence of the widespread stocking of a small number of domesticated species. However, this reduction in beta diversity is still incomplete as a reason for preferring native taxa, and for taking the next step, the phenomenally difficult task of repairing past mistakes.

The differences between native and non-native are ones of value, integrity, and authenticity, concepts that are not a part of the usual operational lexicon of science. Aldo Leopold (1949) suggested long ago that " A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community .It is not when it tends otherwise." With respect to salmonids, Leopold also suggested that the difference between hatchery trout (or their stream bred descendents) and wild native trout was one of value, by extension the latter have greater value with respect to the integrity of natural communities. Of course words like value and integrity (and beauty) are impossible to define as elements of management policy, they are simply too imprecise to fit into scientifically based management discourse. However I believe that much of the difficulty is removed if we evaluate these pretty words in the context of another, more easily definable: authenticity (Mills 1994). The native taxa of a community or system are authentic, non-native taxa are not. Natural communities are authentic (indeed they are natural) to the extent that their component organisms and biological processes are authentic. Authenticity is what confers value, and integrity, and even beauty.

By extension, the biological justification for an emphasis on native taxa (the beta diversity justifica-

tion), and even more so the authenticity argument, argue for one more step in our management of native and non-native fishes. Development and adoption of guidelines for introductions and stocking are now apart of the biological fisheries management culture. The next step is restoration, and restoration involves eradication, a radical step. Again calling on Leopold, he pointed out that "We have radically modified the biotic stream; we had to." We did what we had to do, but there is no reason why we should continue after that need has been largely met. A goal of coldwater fisheries management generally, not just in National Parks, should be the establishment of authentic natural communities wherever feasible.

Feasibility is the usual out for any proposal, with considerable latitude for interpretation of what is and is not feasible. I suggest that feasibility is something that can be empirically determined. A primary focus of coldwater fisheries research should be the investigation and development of methods for the removal of non-native taxa from communities and systems that still retain substantial natural characteristics. Application of the methods developed should then become a priority of management. This emphasis on native taxa is not a call for a reorientation of biological fisheries management. The elements are already in place, and "traditional" approaches in the human modified landscape (including hatcheries and stocking) remain an important and necessary part of fisheries management. But coldwater fisheries biology also has a wealth of experience in the management of native taxa, and the concept at least of restoration is very much apart of the discipline. In addition, this restoration of natural systems around native taxa will require a considerable public education effort. This is not new to fisheries management professionals either, nor is the inevitability of conflicting perceptions and interests from the stake holding public. All fisheries management actions occur in a climate of support and opposition from interested parties with differing interests. However, biological fisheries management has a powerful tool in the concept of authenticity .I believe that authenticity, along with the connected notions of uniqueness and pride of place, will coincide with the thinking of a substantial and growing proportion of the public. And through these efforts, biological fisheries disciplines will continue as leaders in the larger domain of biodiversity conservation.

LITERATURE CITED

Behnke, R. J.1992. Native trout of western North America. American Fisheries Society, Monograph 6. Bethesda, MD.

Ferguson, M. M. 1990. The genetic impact of introduced fishes on native species. Canadian Journal of Zoology 68: 1053-1057.

Foresta, R. A. 1984. America's National Parks and their keepers. Resources for the Future, Washington, DC.

Invasive Species Specialist Group. 2000. IUCN guidelines for the prevention of biodiversity loss caused by alien invasive species. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland.

Houston, D. B., and E. G. Schreiner.1995. Alien species in National Parks: Drawing lines in space and time. Conservation Biology 9:204-209.

Krueger, C. C., and B. May. 1991. Ecological and genetic of salmonid introductions in North America. Canadian Journal of Fisheries and Aquatic Sciences 48 (Supplement 1); 66-77.

Leopold, A.1949. A sand county almanac. Oxford University Press, NY

Li, H. W., and P. B. Moyle. 1999. Management of introduced fishes. Pp. 345-374 In Kohler, C. C., and W. A. Hubert, eds., Inland fisheries management in North America (second edition). American Fisheries Society, Bethesda, MD.

Meffe, G. K. 1992. Techno-arrogance and halfway technologies: Salmon hatcheries on the Pacific coast of North America. Conservation Biology 6:350-354.

Mills, S. 1994. The wild and the tame. Pp. 43-57 In Burks, D. C., ed., Place of the wild. Island Press, Washington, DC.

Moyle, P. B., and T. Light. 1996. Biological invasions of freshwater: Empirical rules and assembly theory. Biological Conservation 78: 149-162.

National Park Service. 1988. NPS management policies. Washington, DC.

Nico, L. G., and P. L. Fuller. 1999. Spatial and temporal patterns of nonindigenous fish introductions in the United States. Fisheries 24(1): 16-27.

Panek, F. M.1997. Threats, risks, and promises: Challenges for trout management in the twenty-first century. Fisheries 22(6): 24-26.

Pearsons, T. N., and C. W. Hopley. 1999. A practical approach for assessing ecological risks associated with fish stocking programs. Fisheries 24(9): 16-23.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 1999. Environmental and economic costs associated with non-indigenous species in the United States. College of Agricultural and Life Sciences, Cornell University, Ithaca, NY. (http:/ /www.news.cornell.edu/releases/Jan99/species_costs.html)

Welcomme, R. L. 1984. Intentional transfers of inland fish species. Pp. 22-40 In Courtney, W. R., and J. R. Stauffer, eds., Distribution, biology, and management of exotic fishes. The Johns Hopkins University Press, Baltimore, MD.

Wright, G. R. 1992. Wildlife research and management in the National Parks. University of Illinois Press, Chicago.

Young, M. K. 1995. Resident trout and movement: Consequences of a new paradigm. Fish Habitat Relationships Technical Bulletin Number 18, U. S. Forest Service, Washington, DC.

Zaslowsky, D. and T. H. Watkins.1994. These American lands. Island Press, Washington, DC.

Using Partnerships for Attaining Long Term Sustainability of Bull Trout *Salvelinus confluentus* Populations in the Upper Willamette Basin, Oregon

Jeffrey S. Ziller[1] and Greg A. Taylor[2]

Abstract—During the past decade, the Oregon Department of Fish and Wildlife, U.S. Forest Service, Federation of Flyfishers and others formed partnerships with the objective of attaining long term sustainability of bull trout populations in the upper Willamette Basin. Partners increased efforts to determine bull trout distribution, abundance trends, and habitat use. Cooperative projects increased habitat complexity, provided access to spawning and rearing areas and increased public awareness of bull trout and factors potentially limiting population growth. To reduce angler take of bull trout, we modified angling regulations and hatchery trout releases. Our results indicate the number of juvenile and adult bull trout have increased and have expanded their range. We initiated restoration of the bull trout populations in Sweetwater Creek and the Middle Fork Willamette Basin above Hills Creek Reservoir by transferring fry from the McKenzie Basin to potential spawning and rearing sites. Monitoring surveys found spawning age adults in Sweetwater Creek and juvenile bull trout at all release sites in the Middle Fork Willamette Basin. The partners plan to continue cooperative work to evaluate the results of our restoration efforts.

INTRODUCTION

Bull trout *Salvelinus confluentus* are large char, weighing up to 18 kg, which feed almost exclusively on fish (Goetz 1989). Cavendar (1978) separated bull trout as a species different from the Dolly Varden trout *S. malma*. The decline of bull trout populations in much of their range prompted the American Fisheries Society to classify this fish as a "species of concern" in 1989. In 1993, the Oregon Department of Fish and Wildlife (ODFW) listed all of the state's bull trout populations as "sensitive". Buchanan et al. (1997) listed the bull trout population in the mainstem McKenzie as "of special concern", the South Fork McKenzie population as "high risk", and the bull trout above Trail Bridge Reservoir as "high risk". Bull trout in the Middle Fork Willamette were listed as "probably extinct". On June 10, 1998, the US Fish and Wildlife Service (USFWS) listed the Columbia River bull trout population segment (including the Willamette sub-basin) as Threatened under the federal Endangered Species Act.

In Oregon, bull trout were once distributed throughout 12 basins in the Klamath and Columbia river systems. Distribution in the Columbia system included the Clackamas, Santiam, McKenzie and Middle Fork Willamette sub-basins in the Willamette sub-basin west of the Cascade Range (Buchanan et al. 1997). However, it is believed bull trout have been extirpated from west of the Cascades with the exception of the McKenzie sub-basin. Following the construction of Cougar and Trail Bridge reservoirs in 1963, there were three isolated populations: 1) mainstem McKenzie and tributaries from the mouth to Trail Bridge Reservoir, 2) mainstem McKenzie and tributaries above Trail Bridge Reservoir to Tamolitch Falls, and 3) South Fork McKenzie and tributaries above Cougar Reservoir.

[1] *Watershed District Fish Biologist, Oregon Department of Fish and Wildlife, Springfield, OR*

[2] *Fish Biologist, Oregon Department of Fish and Wildlife, Springfield, OR*

During 1989, a group of 45 fisheries professionals from around the Pacific Northwest met near Gearhart Mountain, Oregon to collect and exchange information about bull trout populations (Howell and Buchanan 1992). Collaborative working relationships developed during this workshop were carried back to other bull trout areas, including the upper Willamette Basin.

In the early 1990's, Willamette Basin biologists and other concerned entities commenced intensive investigations of the status of Willamette bull trout. We soon found the job extraordinarily large and consolidated our work with both informal and contractual partnerships. This paper summarizes our methods for monitoring and rehabilitation of bull trout populations and their habitat and presents the results of our efforts to attain long term sustainability of these fish in the upper Willamette Basin.

STUDY AREA

The Willamette Basin is located in northwestern Oregon. The Willamette River drains the approximately 19,380 sq km north to a confluence with the Columbia River near Portland, Oregon. We conducted our work in McKenzie and Middle Fork Willamette sub-basins, comprising approximately 25 percent of the area in the Willamette Basin (Figure 1).

Major streams in these watersheds originate in the Cascade Range at elevations generally above 1,800 m. Stream gradients range from about 4 percent in fourth order tributaries in the mountainous reaches, to less than 1 percent on the valley floor.

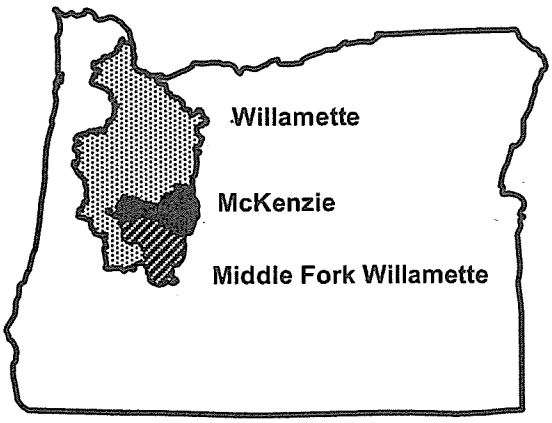


Figure 1.—Location of McKenzie and Middle Fork Willamette sub-basin study and project areas relative to the Willamette Basin, Oregon.

Forested lands dominated by Douglas fir *Pseudotsuga menziesii* and western hemlock *Tsuga heterophylla* are common in the upper reaches of the watersheds where the United States Forest Service, Willamette National Forest (USFS) is the principal landowner. Private forestry, agriculture, and residential development are the primary land uses in the lower portions of the watersheds.

METHODS

Over the past eight years, at least 19 different entities have participated in fieldwork, planning, plan review, and financial aid aspects of bull trout research and management in the basin (Table 1).

In a typical year, our work plan was developed by members of the Upper Willamette Working Group in January or February, reviewed by the entire working group in March, and implemented by various members throughout the year. Our results were reviewed annually by a steering committee comprised of biologists from the USFWS, Bonneville Power Administration (BPA), ODFW, and the US Department of Agriculture Willamette National Forest (WNF). In addition, members of the *Salvelinus confluentus* Curiosity Society (ScCS) and the Oregon Chapter of the American Fisheries Society reviewed major projects.

Table 1.—Partners working to attain long term sustainability of bull trout populations in the Upper Willamette Basin, Oregon during 1992 to 2000.

Partner	Relationship
Bonneville Power Administration	Planning, Review, Financial
Willamette National Forest	Personnel, Planning, Financial
US Fish and Wildlife Service	Planning, Review, Financial
Eugene Water and Electric Board	Planning, Financial
Oregon Department of Transportation	Financial
Oregon State Police	Personnel
Oregon Council Federation of Flyfishers	Personnel, Planning, Review, Financial
McKenzie Flyfishers	Personnel
National Fish and Wildlife Foundation (Bring Back the Natives Program)	Financial
Trout Unlimited	Planning, Financial
Weyerhaeuser Company	Personnel, Review
Bureau of Land Management	Personnel, Review
Native Fish Society	Review
McKenzie Watershed Council	Planning
Saturday Academy (Apprenticeships in Science and Engineering)	Personnel, Financial
Oregon Chapter American Fisheries Society	Review
Salvelinus confluentus Curiosity Society	Personnel, Review
US Army Corps of Engineers	Personnel, Planning
Oregon Department of Fish and Wildlife	Personnel, Planning, Review, Financial

Our work is presented in four major groups of activities: 1) determining population size and life history characteristics, 2) improving spawning and rearing habitat, 3) population restoration and 4) fisheries management actions.

Population Size and Life History

Adult Distribution and Migration Monitoring

We used four methods to monitor upstream migration of adult and sub-adult bull trout: 1) radio telemetry 2) standard pool counts in the upper mainstem McKenzie and the South Fork McKenzie, 3) video cameras at Leaburg Dam (McKenzie RK 63) and on Sweetwater Creek, and 4) passive electronic counting devices on Anderson Creek and Roaring River (Figure 2).

Radio tags were surgically implanted in bull trout greater than 51 cm in length using an ODFW protocol (Bellerud 1998) to track bull trout movement and rearing locations. The radio tags measured 71 mm long and 18 mm wide, weighed 28 grams, and had a service life of approximately 18 months. We monitored movements of radio tagged bull trout weekly by foot, vehicle, or plane using telemetry equipment from Advanced Telemetry System. We recorded the date and river kilometer of each bull trout located.

We conducted standard pool counts in the mainstem and South Fork McKenzie from June through September as an index of abundance. We recorded the number and size of bull trout observed in seven large pools between Olallie Boat Ramp and Paradise Campground, a distance of 15 km. In the South Fork McKenzie, nine pools were counted between Roaring River and approximately 1.6 km upstream from Cougar Reservoir, a distance of 17.6 km. In general, we surveyed bi-weekly using a team of two snorkelers.

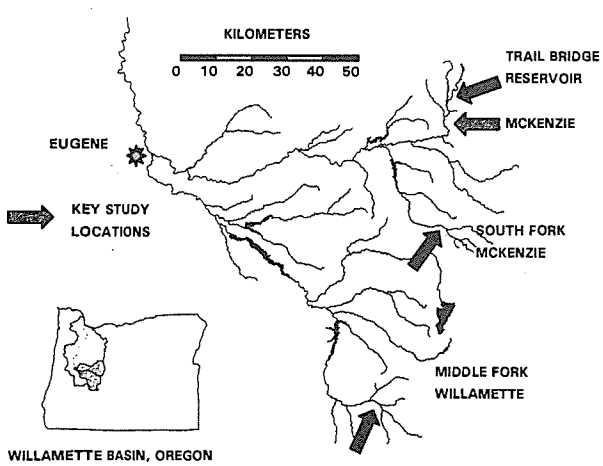


Figure 2.—Location of key study areas for research and management of bull trout populations in the upper Willamette Basin.

We utilized video cameras to count bull trout migrating upstream through the fish ladder on Leaburg Dam and immediately upstream from the Highway 126 culvert on Sweetwater Creek. Video equipment has been in operation at Leaburg Dam since 1970, although, a color camera, installed during 1997, has increased our ability to identify bull trout. Incandescent and fluorescent lighting allows fish to be observed 24 hours per day. Video monitoring on Sweetwater Creek was implemented in 1999 during daylight hours. In 2000, lighting was installed for viewing passage during hours of darkness.

We installed a Vaki River Watcher electronic fish counter in Anderson Creek and Roaring River to determine the number of spawning adult bull trout in each stream. Weirs constructed in both streams guided fish to the counter. The counter emits infrared light beams that are interrupted when a fish swims through the counter, recording a silhouette of the fish. The unit also records the date, time, water temperature, length, and height for each fish passing upstream or downstream. We monitored fish passage during the late summer and early fall when bull trout were expected to ascend these spawning tributaries.

Spawning Surveys

Surveys for bull trout redds in the upper McKenzie Basin were initiated in 1989 (Goetz 1994). From 1989 through 1993, surveys in Anderson Creek were conducted from the mouth upstream approximately 2.6 km. In 1994, we expanded the survey area to include all 3.8 km of Anderson Creek accessible to bull trout. We implemented annual surveys in Roaring River in 1993, the mainstem McKenzie River above Trail Bridge Reservoir in 1994 Olallie Creek in 1995, and Sweetwater Creek in 1998. Surveys were conducted during September and October beginning at the mouth of each stream and progressing upstream to natural barriers for fish. A two-person team conducted each survey with one surveyor walking each side of the stream.

Juvenile Distribution, Migration and Abundance

To determine distribution of juvenile bull trout, we surveyed portions of approximately 400 km of streams in the Middle Fork Basin and about 280 km in the McKenzie Basin. Most of the surveys were con-

ducted from 1992 through 1999 using snorkeling gear or backpack electrofishing equipment.

From 1994 through 2000, we captured juvenile bull trout migrating down Anderson Creek using an E. G. Solutions 1.5 m rotary screw trap. The trap was located immediately downstream of the culvert passing under Highway 126 approximately 0.4 km upstream of the confluence with the mainstem McKenzie. The trap generally operated four days each week beginning in early February until the first week of June. During two years, we operated the trap into November to estimate the number of juvenile bull trout migrating out of Anderson Creek through the summer and fall months. We recorded the number, species, and length of all juvenile bull trout (age 1+) and a proportion of the fry (age 0+) captured.

In 1999, we installed a 1.5 m screw trap in Olallie Creek, about 50 m above Highway 126. We operated this trap in the same manner as the trap in Anderson Creek. We also used screw traps to sample for bull trout in Lost Creek and the South Fork McKenzie River both above and below Cougar Reservoir. These trapping efforts were generally conducted for only a few months.

We estimated the abundance of juvenile bull trout in 2.6 km of Anderson Creek using a modified Hankin and Reeves (1988) protocol. We divided habitat units based on water velocity. For each habitat unit identified, we recorded length, width, and maximum depth measurements. We randomly selected 1/2 of the habitat units for snorkel sampling. A team of five divers night-snorkeled the sample units during August 1999. Divers performed a single pass on all sample units and recorded the number of age 0+ and age 1+ juvenile bull trout, and dive time within each unit. For calibrated units, divers performed four repeat passes within the unit.

Habitat Improvement

Large wood placements

WNF biologists placed large wood into Anderson Creek, Buck Side Channel (on the upper mainstem McKenzie), South Fork McKenzie below and above Cougar Reservoir, and in Roaring River (Table 2). The objectives for the large wood placement included: providing additional cover, nutrient capture, and prey items to increase production of bull trout. Projects in the South Fork McKenzie and Roaring River were intended to capture bedload, subsequently providing spawning gravel for bull trout. These projects were generally designed to increase the amount of large wood in the stream to approximately 70 pieces per km. Projects initiated after 1993 placed large wood with a helicopter to reduce impacts to endemic instream habitat and riparian areas.

Table 2.—Amount of large wood placed into the upper McKenzie River Basin by the Willamette National Forest during 1991 through 1998 for increasing bull trout production.

Year	Location	Pieces	Distance (km)	Approximate Cost
1991	Anderson Creek	14	0.1	$4,300
1993	Buck Side Channel	31	0.4	$7,800
1995	S Fk McKenzie (below Cougar Reservoir)	40	1.5	$14,000
1996	S Fk McKenzie (above Cougar Reservoir)	191	4.0	$65,000
1998	S Fk McKenzie (above Cougar Reservoir)	160	3.2	$57,600
1998	Roaring River	40	0.8	$14,400

Impassable Culvert Replacements

Culverts installed in 1962, when Highway 126 was reconstructed, blocked fish from ascending Sweetwater and Olallie creeks. Sweetwater Creek and Olallie creeks contained approximately 2.4 km and 3.2 km of potential bull trout spawning and rearing habitat, respectively. In November 1992, a cooperative project on Sweetwater Creek placed a second culvert, pre-fit with fish passage weirs, under Highway 126. The culvert was designed to discourage brook trout from ascending. In August 1995, a similar cooperative project restored fish passage on Olallie Creek.

Population Restoration

Cooperative work to restore bull trout to spawning and rearing habitat, made available by installation of fish passage under Highway 126, involved five steps: 1) writing a risk analysis, 2) developing a work plan, 3) implementing bull trout fry capture in Anderson Creek, 4) transporting fry to selected rearing locations, and 5) monitoring results. A portion of the bull trout fry captured in the screw trap at Anderson Creek were transferred into Sweetwater Creek from 1993 through 1999 and into Olallie Creek in 1995 and 1996.

A plan to restore a bull trout population in the upper Middle Fork Willamette was completed and approved by the Willamette Basin Bull Trout Working Group (ODFW 1997). Bull trout fry from Anderson Creek were released into Middle Fork Willamette

River tributaries beginning in 1997 and will continue through 2003.

We monitored the survival and growth of transferred bull trout by observing fish at release sites with snorkel equipment, and capturing individual fish at night with aquarium nets. We monitored downstream migration at one major release site by operating a fyke net with an attached live box. The fyke trap was in operation from the date of release in the spring through the summer.

Fisheries Management Actions

We implemented more restrictive angling regulations (Table 3), changed hatchery reared rainbow trout releases (Table 4), and educated anglers about bull trout identification and status to reduce the take of bull trout by anglers in the upper Willamette Basin.

We placed posters in important angling areas that included a picture of a bull trout, essential identification attributes, information on the status of bull trout, and telephone numbers to report any bull trout caught. In addition, officers from the Oregon State Police set up an action plan to increase their contacts with anglers in areas frequented by bull trout.

Table 3.—Angling regulations approved by the Oregon Fish and Wildlife Commission to reduce take of bull trout in the upper Willamette Basin.

Year	Location	Action
1991	Willamette Basin	Taking bull trout prohibited
1992	McKenzie River (Mainstem and South Fork)	All wild trout must be released
1994	McKenzie River (RK 105 to 133)	Artificial flies and lures only
1997	S Fk McKenzie	Artificial flies and lures only
1997	Trail Bridge Reservoir	All wild trout must be released
1997	Middle Fork Willamette (above Hills Creek Reservoir)	All wild trout must be released Artificial flies and lures only
2001	Most McKenzie River Tributaries and Trail Bridge Reservoir	All wild trout must be released Artificial flies and lures only

Table 4.—Changes in hatchery reared rainbow trout management implemented by the Oregon Department of Fish and Wildlife to reduce take of bull trout in the upper Willamette Basin.

Year	Location	Action
1988	McKenzie River (RK 0 to 24)	Rainbow trout stocking discontinued
1992	McKenzie River	Only adipose fin marked trout may be taken
1994	McKenzie River (RK 105 to 133)	Rainbow trout stocking discontinued
1997	S Fk McKenzie	Rainbow trout stocking discontinued
1997	Trail Bridge Reservoir	Only adipose fin marked trout may be taken
1997	Middle Fork Willamette (above Hills Creek Reservoir)	Only adipose fin marked trout may be taken

RESULTS

Mainstem McKenzie Population

Between 1994 and 1996, the average number of fry captured in Anderson Creek using a 5 ft. rotary screw trap 1994-96 was 1,893. This number increased to 7,283 between 1997 and 2000 (Table 5). The estimated capture if the trap ran continuously ranged from 5,308 in 1994 to 23,153 in 1998. Estimated trap efficiency for bull trout fry was approximately 60%.

During our work estimating the population of juvenile bull trout in Anderson Creek, we observed 106 juvenile bull trout (age 1 to 2+) in 60 habitat units, an average of 1.8 bull trout per unit. The observed density of juvenile bull trout was highest in pockets and lowest in fast water units (Table 6).

During 1994 through 1999, the maximum daily counts of bull trout in mainstem McKenzie River standard pools ranged from 15 to 36 fish. We discontinued these counts after 1999 because these data were highly variable and inconsistent with redd counts in the basin.

Table 5.—Number of bull trout fry and juveniles captured in the downstream migrant trap in Anderson Creek, 1994-2000.

Date	Number of fry (age 0+)		Number τ 1+	
	Captured	Estimated Capture[a]	Captured	Estimated Capture[a]
1994	1,808	5,308	129	403
1995	1,877	5,995	261	785
1996	1,995	5,700	179	550
1997	6,540	21,592	64	215
1998	7,902	23,153	151	453
1999	7,406	21,693	100	263
2000	6,097	17,713	190	553

[a] *Estimated number of bull trout captured if the trap ran continuously and captured fish at a 60 % rate of efficiency.*

Table 6.—The number and density of bull trout greater than or equal to age 1+ observed by divers in three habitat units in Anderson Creek, 1999.

Unit Type	Bull trout greater than or equal to age 1+	
	Number	Density (/100 m^2)
Fast	66	0.8
Slow	10	1.2
Pocket	30	9.7

The number of bull trout counted at the fish ladder at Leaburg Dam increased from one fish in 1995 to 28 fish in 1999 (Figure 3). Counts for 2000 are incomplete and, although we expect additional bull trout to migrate upstream this year, it is unlikely the annual total will surpass the 1999 count. Regardless, the number of bull trout residing in the lower McKenzie River appears to be increasing. The known range in the mainstem McKenzie was extended when an adult bull trout was captured with a seine at the mouth of the McKenzie River during March 1999.

Bull trout monitored with radio telemetry equipment, began to move upstream from the over-wintering sites in late spring and early summer. They continued moving upstream throughout the summer and entered Anderson Creek in late August or early September. They remained in Anderson Creek for approximately one month and then quickly returned to over-wintering sites lower in the river. Several bull trout returned to the same over-winter sites each year.

The electronic fish counter in Anderson Creek recorded 249 bull trout passing upstream and 214 downstream. Bull trout migrated at a higher rate during day light up (69%) and downstream (61%). Peak migration of bull trout through the fish counter during 1999 occurred during the middle of September. Bull trout ranged in size from 18-81 cm.

We found bull trout in 170 km of streams in the McKenzie Basin (Table 7). Bull trout spawning occurred in only 5.8 km of the total, in Anderson and Olallie creeks.

Spawning surveys in Anderson Creek have averaged 80 redds per year since 1995 (Table 8). Spawning timing was similar from 1995-99 and generally peaked on third week of September. Bull trout commenced spawning in Olallie Creek within one month of the installation of the fish passage culvert. From 1995 through 2000, redd counts on Olallie Creek ranged from six to ten (Table 8).

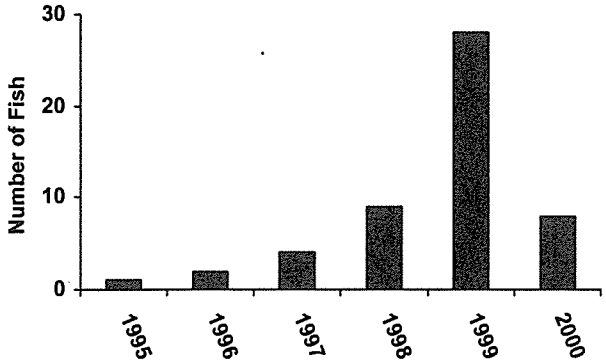


Figure 3.—Number of bull trout counted at Leaburg Dam on the McKenzie River during 1995 through September 2000.

Table 7.—Streams and lakes containing bull trout in the McKenzie River Basin, Oregon during 2000.

Population	Stream	km (ha)
McKenzie	McKenzie River)	133.0
	Horse Creek	17.7
	Separation Creek	3.1
	Deer Creek	3.5
	Blue River	2.7
	South Fk McKenzie (below Cougar Reservoir)	7.1
	Olallie Creek	3.2
	Anderson Creek	2.6
SF McKenzie	Cougar Reservoir	(518)
	South Fork McKenzie River	24.3
	Roaring River	5.0
Trail Bridge	Trail Bridge Reservoir	(23)
	McKenzie River above Trail Bridge	1.1
	Sweetwater Creek	2.4

Table 8.—The number of bull trout redds observed in Anderson and Olallie creeks 1989 - 2000.

	Number of Redds Observed			
	Anderson			
Year	Index Area (RK 1.3)	Total (RK 2.6)	Olallie	Total
1989	7			
1990	9			
1991	7			
1992	13			
1993	15			
1994	22	30		
1995	30	77	10	87
1996	26	82	8	90
1997	18	85	9	94
1998	29	79	7	86
1999	47	77	6	83
2000	44	83	9	92

South Fork McKenzie Population

During 1995 through 1999, the maximum daily counts of bull trout in mainstem McKenzie River standard pools ranged from 15 to 17 fish. As cited for the mainstem McKenzie, we discontinued these counts after 1999 because the counts were highly variable and inconsistent with redd counts in the South Fork McKenzie Basin.

Four bull trout with radio transmitters were tracked in the South Fork McKenzie Basin during 1999. One bull trout moved below Cougar Dam in the middle of January and, because there is no upstream fish passage, was unable to return above the dam. The remaining three tagged fish resided in the Cougar Reservoir until the end of April. These fish entered the South Fork in early May. Two fish entered

Roaring River in late August and early September and reentered the reservoir by the middle of October.

The electronic fish counter in Roaring River recorded 41 fish passing upstream and 39 passing downstream. Most bull trout migrated upstream (66%) at night, while most downstream passage (71%) occurred during daylight hours. In 1999, most bull trout migrated (83%) into Roaring River during the first two weeks of September. Downstream migration peaked in late September and early October and was complete by early October. The average length of fish passing upstream was 42 cm and ranged from 21-58 cm.

Distribution surveys for the South Fork McKenzie River population found approximately 24 km of stream inhabited by bull trout (Table 7). Bull trout spawning occurred only in Roaring River, 5 km of the total. Spawning surveys conducted on Roaring River have shown a sharp increase in bull trout redds over the past four years (Figure 4). In 1999, the estimated number of bull trout per redd was 3.2 in Roaring River.

Trail Bridge Reservoir Population

Our distribution surveys for the Trail Bridge Reservoir population found a total of only 3.5 km of the mainstem McKenzie River and Sweetwater Creek inhabited by bull trout (Table 7). Juvenile bull trout found in Sweetwater Creek originated from releases of fry transported from Anderson Creek during 1993 through 1999 (Table 9). Prior to 2000, bull trout were thought to spawn only in 1 km of the McKenzie River immediately above Trail Bridge Reservoir. Juveniles probably migrate downstream into Trail Bridge Reservoir to rear to maturity. Counts of bull trout redds for this population are complicated by spring chinook salmon *Oncorhynchus tshawytscha* that spawn at the same location and time. Brook trout *S. fontinalis* spawn several weeks later in the same area. Our estimates of the number of bull trout redds has ranged from zero to 12.

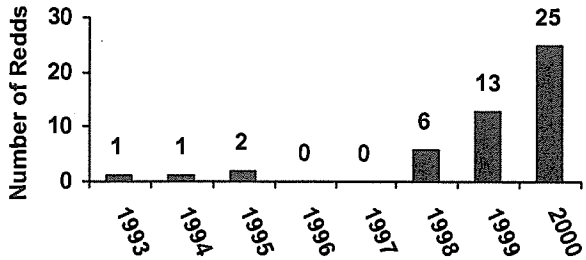


Figure 4.—Number of bull trout redds observed in Roaring River, South Fork McKenzie Basin, from 1993 through 2000

Table 9.—Number of bull trout fry transferred from Anderson Creek to Sweetwater Creek, Olallie Creek, and the Middle Fork Willamette, 1993-99.

	Number of fry transferred		
Year	Sweetwater Cr.	Olallie Cr.	MF Willamette
1993	308	0	0
1994	507	245	0
1995	589	313	0
1996	894	0	0
1997	1,193	112	178
1998	1,889	0	1,497
1999	997	0	1,978
2000	0	0	2,788
Totals:	6,377	670	6,441

Surveys for bull trout redds on Sweetwater Creek are not compromised by other spawning fish and no redds were found from 1995 through 1999. In 2000, video-monitoring equipment recorded 11 adult bull trout entering Sweetwater Creek during September and subsequent spawning surveys found two bull trout redds.

Middle Fork Willamette Population

Although large portions of five years of fieldwork were invested into efforts to find bull trout in the Middle Fork Willamette Basin, none were found. In 1997, we implemented a plan to restore a bull trout population to the Middle Fork Willamette (ODFW 1997). Between 1997 and 2000 a total of 6,439 bull trout fry from Anderson Creek, approximately 25 to 35 mm in length, were released into seven sites in the Middle Fork Willamette Basin (Table 9).

Monitoring of bull trout reintroduced to the Middle Fork Willamette above Hills Creek Reservoir revealed juvenile in all release locations that received more than 50 fish. On 21 June 2000, we conducted a census Iko Springs (a key release site) and observed 67 juvenile bull trout in three age classes. The fyke trap was fished for 1,441 hours and no fish were recovered. During July 2000, eight bull trout were found in a survey conducted by snorkeling on the Middle Fork Willamette River in the vicinity of Iko Springs (RK 116). These fish probably migrated from Iko Springs during the spring.

During early June 2000, a sub-adult bull trout was captured by an angler in the Middle Fork Willamette River below Hills Creek Dam (RK 66). The origin of this fish is unknown, although it is possible it was one of the 178 fry released into Middle Fork Willamette River tributaries in 1997.

DISCUSSION

Collaborative efforts by at least 19 partner agencies, private and public organizations, and many individuals have produced a tremendous amount of work towards restoring bull trout populations in the upper Willamette Basin. These efforts appear to be having a positive effect on the three McKenzie Basin bull trout populations and may eventually restore a self-sustaining bull trout population to the Middle Fork Willamette Basin.

Surveys conducted in tributaries of the mainstem McKenzie River (Anderson and Olallie Creek) have yielded consistent redd counts, since more than doubling in 1995, which indicates this population has a stable number of spawning adults. We calculated a ratio of 3.7 bull trout per redd in Anderson Creek in 1999. This ratio is similar to those reported for streams in the Metolius Basin (Ratliff et al 1996). The density of redds in Anderson Creek (29.6/km) is among the highest reported in the state (Buchanan et al. 1997). The stable redd counts and high density may indicate spawning habitat is fully utilized and increased production in Anderson Creek is not possible.

The number of emergent bull trout fry captured in Anderson Creek has been consistent since a significant increase in 1997. The increases in fry production correlates with an increase in redd counts, with the exception of 1996. In 1996, we believe a February flood impacted the number of emergent fry. On the positive side, WNF surveys found that embeddedness of substrate in Anderson Creek decreased following the flood and this may have been responsible for an increase in spawning success in 1997 through 1999.

Olallie Creek is the only other known spawning tributary for bull trout in the mainstem McKenzie Population. The restoration of fish passage to waters above Highway 126 has yielded an average of eight redds per year and considerable juvenile bull trout production. Progeny from the first spawning in 1995 will be maturing in 2000 and 2001. Provided juvenile survival was good in 1995, a significant increase in the number of redds may be observed during the next few years.

During 1999 and 2000, redd counts in the South Fork McKenzie Basin increased to the highest level observed. We believe changes in fish management practices are a major cause for this increase. Anglers are restricted to using artificial flies and lures and must release all trout unharmed. Similar angling regulations imposed on the Metolius River helped restore that bull trout population (Ratliff et al 1996). These regulations greatly reduce the take of bull trout by anglers who are unable to identify species. In addition, we discontinued releasing hatchery-reared rainbow trout into the South Fork McKenzie in 1997. Since that time, we have observed a sharp decrease in the number of anglers using this river.

After the restoration of fish passage on Sweetwater Creek, we successfully transferred bull trout into this high quality rearing habitat. We are encouraged to find adult bull trout ascending the stream to spawn. Because brook trout spawn in the mainstem McKenzie above Trail Bridge Reservoir and may hybridize with bull trout spawning there, Sweetwater Creek may only spawning habitat suitable for sustaining this population.

Our confidence in efforts to restore a bull trout population in the Middle Fork Willamette Basin is strengthened by the preliminary success on Sweetwater Creek. Monitoring of juvenile bull trout released into the Middle Fork Basin has documented similar life history characteristics to those of their natal stream. Bull trout in the mainstem McKenzie population exhibit a strong downriver migratory characteristic that provides them opportunity to rear to adults in larger waters. Because of the large amount of lacustrine habitat in Hills Creek Reservoir downriver from our release sites, we expect this reservoir will be very important for sustaining a population in the Middle Fork Basin.

The future for partners working on bull trout in the Willamette Basin includes participating in development of a recovery plan, increasing spawning and early juvenile rearing habitat, continuing to monitor population trends and continuing to our efforts to restore a Middle Fork Willamette population. The fundamental purpose of our efforts is to facilitate the removal of bull trout from the federal Endangered Species List. We believe the collaborative effort presented in this document can provide a means to achieve recovery goals for bull trout.

ACKNOWLEDGEMENTS

We thank the many people who have collaborated with us on these efforts to increase upper Willamette Basin bull trout populations; especially U.S. Forest Service biologists David Bickford, James Capurso, and Doug Larson, ODFW biologist Mark Wade, Greg Pitts and Andrew Reasoner. The Bonneville Power Administration and Willamette National Forest sponsored major portions of this study.

LITERATURE CITED

Buchanan, D.V., M.L. Hanson, and R.M. Hooton. 1997. Status of Oregon's Bull Trout. Oregon Department of Fish and Wildlife, Portland. 168pp

Bellerud, B. 1998. ODFW Northeast Oregon Bull Trout Study Radio Tagging Procedures. Oregon Department of Fish and Wildlife. Unpublished report. La Grande District, La Grande

Cavendar, T.M. 1978. Taxonomy and distribution of the bull trout, *Salvelinus confluentus*, (Suckley) from the American Northwest. California Fish and Game 64(3): 139-174.

Goetz, F.A. 1989. Biology of the bull trout, *Salvelinus confluentus*, a literature review. U.S. Department of Agriculture, Forest Service, Willamette National Forest, Eugene, Oregon.

Goetz, F.A. 1994. Distribution and Juvenile Ecology of Bull Trout (*Salvelinus confluentus*) in the Cascade Mountains. M.S. Thesis: Oregon State University, Corvallis.

Hankin, D.G., and G.H. Reeves. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45:834-844.

Oregon Department of Fish and Wildlife. 1997. Rehabilitation of the Middle Fork Willamette Bull Trout Population; Risk Analysis and Monitoring Plan. Unpublished report Springfield Field Office, Springfield.

Ratliff, D.E. S.L. Thiesfeld, W.G. Weber, A.M. Stuart, M.D. Riehle and D.V. Buchanan. 1996. Distribution, life history, abundance, harvest, habitat and limiting factors of bull trout in the Metolius River and Lake Billy Chinook, Oregon, 1983-1994. Information Report, Oregon Department of Fish and Wildlife, Portland.

Conservation Agreements: Balancing the Interest of Anglers and ESA in Utah

Yvette Converse[1], Bryce Nielson[2], Chad Crosby[3], Dale Hepworth[4], and Charlie Thompson[5]

In the west, most are wary of restoring native cutthroat trout where it could lead to removing popular nonnatives and limitations on angling. Yet, ESA mandates that the long-term persistence of native trout is ensured. Conflicting views have created opposition to native trout restoration efforts. In Utah, the Conservation Agreement (CA) program enhances native trout angling opportunities while ensuring long-term species persistence. The Bear Lake project has increased native trout abundance and condition, while maintaining fisheries for other popular sportfish. In the Uinta Mountains, an aggressive wildbrood and captive rearing project provides native trout for stocking into historic range while promoting high-elevation lake angling. In 1999, 55 lakes were stocked with 60,000 two-inch fish. In the Boulder Mountains, a multi-year project will use a local native trout brood source to replace stunted brook trout in several mountain lakes. Yet without local support, restoration projects can extend over decades with limited success for restoration and angling. In the Deep Creek Mountains, restoration activities were met with illegal introductions and sabotage during the 80s. Now, the local community is working with management agencies. In 1999, local residents established a culture pond which successfully yielded 85 mature native trout for nearby stream re-introductions.

[1]US Fish and Wildlife Service, Lincoln Plaza, 145 East 1300 South State Street, Suite 404, Salt Lake City, UT 84115

[2]Utah Division of Wildlife Resources, Bear Lake Station, PO Box 231, Garden City, UT 84028

[3]Utah Division of Wildlife Resources, Northeastern Region, 152 East 100 North Vernal, UT 84078

[4]Utah Division of Wildlife Resources, Southern Region, 1470 North Airport Rd., Cedar City, UT 84720

[5]Utah Division of Wildlife Resources, Central Region, 1115 North Main Street, Springville, UT 84663

Protection of Native Cutthroat Trout Using a Removal Program for a Non-Native Predator: Lake Trout Reduction in Yellowstone Lake

Daniel Mahony[1] and James R. Ruzycki[2]

For the past five years, Yellowstone National Park fishery biologists have conducted a vigorous removal program to control the abundance of non-native predatory lake trout in Yellowstone Lake. Bioenergetic analyses suggest that, at current predation rates, 1000 mature lake trout eat approximately 50,000 cutthroat trout annually. Without some reduction in lake trout abundance, long-term effects could include collapse of the cutthroat population, trophic implications for aquatic and terrestrial predators that utilize cutthroat trout as a food source, and restriction or closure of a multimillion-dollar recreational fishery.

Our consistently increased gill netting effort yielded timely information about lake trout life history characteristics in Yellowstone Lake. Determination of three distinct age and size distributions has enabled National Park Service to focus netting spatially and seasonally on vulnerable portions of the lake trout population. Our current netting program emphasizes capture of adult fish at spawning grounds and targeting juvenile lake trout in deepwater. Equally important, refinements in netting techniques and timing decreased the incidental catch of Yellowstone cutthroat trout.

Although elimination of lake trout from Yellowstone Lake is probably not feasible, trends in indices such as decreased mean length of adult spawning lake trout suggest that the National Park Service may yet meet its goal of reducing lake trout abundance to a level that affects cutthroat trout only minimally.

[1]National Park Service Aquatic Resources Center, Box 168, Yellowstone National Park, Wyoming 82190

[2]Oregon Department of Fish and Wildlife, Fish Research and Development, N.E. Region 211 Inlow Hall, Eastern Oregon College, 1 University Avenue, LaGrande, Oregon 97850

Whirling Disease, Water Flows and Spawning Habitat Destruction on the Madison River

Randy J. Cain[1]

[1](406/646-0059), P.O. Box 1450, West Yellowstone, MT 59758

Water flows during egg laying and incubation create a significant relationship with recruitment of yearling rainbow trout in the upper Madison River from 1976-1997.

On the upper Madison river in Montana in the years 1976-1997 data from water flows were regressed against yearling rainbow trout populations. The regression with significance (P=0.000) suggest that 62% of the annual variance in yearling rainbow populations can be determined by the water flow (figure 4). Using the same data with a different regression with significance (P=0.001) suggests that 61% of the annual variance in yearling rainbow trout populations can be determined by the mean water flow during the peak rainbow spawning month of April and the highest peak flow during rainbow trout egg incubation (figure 4.3).

Extremely fast rising waters and high water can devastate prime spawning areas by eroding them away. In addition numerous year classes of rainbow trout can be lost when these conditions occur year after year during the time frame in which eggs have been placed in a redd and prior to emergence of the fry. Conversely it may take another high water year or three as it did here on the Madison to partially restore some of the lost spawning habitat.

Equally important to spawning rainbow trout is that spawning areas have adequate flows during spawning for access to quality habitat and incubation until swim-up.

Locating major spawning areas and evaluating the habitat along with gathering baseline data on recruitment populations can be invaluable when assessing the health and forecasting populations of a fishery. The Madison river is a good case being that Montana Fish Wildlife and Parks would have known a spawning area that accounted for 50% of the rainbow trout redds in the upper Madison river was destroyed in 1993 (figures 1,2,3). Mechanical enhancement to the spawning area and working to get better water flow management would have significantly shortened the recovery time for rainbow trout population in the Madison river.

Montana Fish Wildlife and Parks preliminary 1999 yearling rainbow population correlated to the 1998 water flow year is well above mean pre-whirling disease populations. Because of the water flow levels the regression analysis also predicted this age class to be a good population. The regression has predicted the 2000 year class to be even stronger than the 1999 year class.

At Raynolds bridge, immediately below the huge spawning area, mean whirling disease infection rates of wild yoy rainbow trout grab samples since 1994 have been 32%. Of the graded lots, less than 50% are 2.5 or higher.

Water flows and quality spawning habitat are the most significant factors affecting year classes of wild rainbow trout in Montana's Madison river.

Trout Stream Mitigation for Highway Construction Impacts

Mickey Clemmons

In 1997, the North Carolina Wildlife Resources Commission (WRC) and the North Carolina Department of Transportation (DOT) entered into a unique agreement to mitigate the loss of 13,000 feet of trout stream due to the Interstate 26 construction project between Asheville, N.C. and the Tennessee state line. The U.S. Army Corps of Engineers required DOT to mitigate this loss by performing offsite stream restoration at a 2:1 ratio, totaling 26,000 linear feet. The interagency agreement calls for mitigation sites to be acquired through purchase or conservation easements from private landowners. Mitigation will be carried out within Madison County, NC, which suffered all of the stream loss. DOT is paying $50 per linear foot to the WRC to carry out mitigation activities, additionally they are responsible for acquisition of mitigation sites and the first 5 years of maintenance. WRC is responsible for preparing site restoration plans, contracting and overseeing plan construction and long-term maintenance. Mitigation activities may include restoration of stream dimension, pattern and profile, enhancement of fisheries habitat, fencing of livestock to protect riparian zones or natural bank stabilization. The primary objective is to improve water quality and fisheries habitat in the county. Mitigation of stream loss due to major DOT projects by this method provides a local fund for stream restoration (broadly defined). Mitigation takes place close to the impacts, thereby compensating that segment of the public that is most affected by the DOT project.

The Status of Native Cutthroat Trout Subspecies Under the Endangered Species Act

Jessica Gourley[1], Yvette Converse[2], and Janet Mizzi[3]

[1]US Fish and Wildlife Service, Lincoln Plaza, 145 East 1300 South State Street, Suite 404, Salt Lake City, UT 84115, phone: 801-524-5001 x139, fax: 801-524-5021, email: jess_gourley@fws.gov

[2]US Fish and Wildlife Service, Lincoln Plaza, 145 East 1300 South State Street, Suite 404, Salt Lake City, UT 84115, phone: 801-524-5001 x135

[3]US Fish and Wildlife Service, 134 Union Boulevard, Lakewood, CO 80228, phone: 303-236-7862 x280

From the federally threatened Greenback and Lahontan cutthroat trout to the recently petitioned Westslope, Bonneville, Yellowstone and Colorado River cutthroat trout, the Endangered Species Act (ESA) plays a role in the management of these species and affects both government and private undertakings. Listing under ESA affords different levels of protection and requires compliance with certain regulatory authority. Species requiring protection may be designated as either "endangered " meaning the species is likely to become extinct throughout all or a significant portion of its range or "threatened" meaning a species is likely to become endangered in the forseeable future. Alternatively, a species may be found to be 'not warranted' for listing under ESA. Using cutthroat trout subspecies as examples, we describe the process of listing a species under ESA. We also describe the status and time-line of each inland cutthroat trout subspecies undergoing this process. Furthermore, we provide an explanation of the Sections of ESA, such as Section 7 and Section 9, and the regulatory authority associated with each section. This presentation is designed to shed light on this complicated, far-reaching piece of environmental legislation and how listing of cutthroat trout might affect the angling public, land management and other industry.

Spatial and Temporal Variation in Habitat Use of Coastal Cutthroat Trout Above Barriers to Anadromy

Steven R. Hendricks[1] and Robert E. Gresswell[2]

[1]Department of Fisheries and Wildlife, 104 Nash Hall, Oregon State University, Corvallis, OR 97331, 541-758-7762, steve_hendricks@usgs.gov;

[2]Cooperative Forest Ecosystem Research Program, USGS-FRESC and Department of Fisheries and Wildlife, OSU, Corvallis, OR

In an effort to broaden the knowledge of coastal cutthroat trout *Oncorhynchus clarki clarki* distribution patterns and habitat requirements above natural barriers to anadromy, we are monitoring movement of marked coastal cutthroat trout throughout Camp Creek, a small third order watershed in the Umpqua River Basin. Since June 1999, approximately 3500 cutthroat trout have been captured and marked with either a Passive Integrated Transponder (PIT) tag or fin clips to facilitate determination of original capture location. PIT tags were implanted in 752 individuals, and the remainder received unique fin clips. Radio tags were implanted in 35 individuals in January and February to monitor movement during high winter flows. A rotary screw trap was installed immediately below the barrier, a four-meter waterfall, in late February in order to estimate magnitude and timing of emigration out of the basin.

Rapid Temperature Flux Can Permanently Mark Fish Otoliths in Tailwaters

Mark A. King[1], Scott M. Smith[2], and Colin W. Krause[3]

[1]*Virginia Commonwealth University, Dept. of Biology, 816 Park Ave., Richmond, VA 23284, (804)828-1562, Fax (804)828-0503, mking@saturn.vcu.edu.*

[2]*Virginia Department of Game and Inland Fisheries, 1132 Thomas Jefferson Rd., Forest, VA 24551, (804)525-7522.*

[3]*Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, 149 Cheatham Hall, Blacksburg, VA 24061-0321, (540)231-5320.*

Tailwaters in the USA provide valuable coldwater fisheries on impounded warmwater streams, often for trophy sized trout. The high recreational value of the Smith River, Virginia, fishery has long been recognized but declines in numbers of trophy brown trout, *Salmo trutta*, have been documented. We observed that otoliths of young-of-year and juvenile trout from various capture stations downstream of a reservoir exhibit a repeating pattern of five opaque (optically dense) daily increments isolated by two wide translucent zones, separated by a single faint opaque band. Through the use of a benchmark week in May of 1999 in which power generation was disrupted from the typical five days on, two days off cycle, we were able to calibrate the otolith increment pattern relative to the discharge flux chronology. The otolith increments accurately reflected the weekly repeating pattern of daily discharge on the river. A strong daily temperature change was noted from instream temperature records. The temperature flux was believed to produce the equivalent of thermal marking on the otoliths. While thermal otolith marking is a valuable tool used extensively for salmonid populations to study the effectiveness of hatchery supplementation to a fishery, thermal marks on naturally spawned fish have not been reported. Species from other fish families, including the cyprinids, centrarchids and percids were also sampled and their otoliths were examined for pattern recognition, which was apparent for some, but not all, species. We then compared otolith increment patterns for Smith River brown trout to those of a nearby stream, the Dan River, which has a more uniform thermal regimen and found no pattern on otoliths. Dan River trout growth was greater, especially for younger ages, than that exhibited by Smith River trout. Our otolith and growth studies combined with flow and temperature data will be applied towards a goal of improving trout habitat by deriving more suitable flow recommendations in this section of the Smith River.

Distribution of *Myxobolus Cerebralis* in Yellowstone Cutthroat Trout from the Yellowstone Lake Basin

Daniel Mahony[1] and Crystal Hudson[2]

[1]*National Park Service Aquatic Resources Center, Box 168, Yellowstone National Park, Wyoming 82190, Phone: 307-344-2280; FAX: 307-344-23, e-mail: dan_mahony@nps.gov*

[2]*Director, Bozeman Fish Health Center, U.S. Fish and Wildlife Service, 920 Technology Blvd. Suite G, Bozeman, Montana 59718, Phone: 406-582-8656; FAX: 406-587-3998, e-mail: crystal_hudson@fws.gov*

Since whirling disease was detected in rainbow trout near Yellowstone Park in 1994, park fishery biologists have been testing resident fish for the presence

of *Myxobolus cerebralis*. Juvenile rainbow trout, Yellowstone cutthroat trout, brown trout, and mountain whitefish captured during electrofishing surveys were examined for the presence of cranial spores. Whirling disease was not detected in salmonids sampled in the park between 1995 and 1998, except that several cutthroat trout captured in Yellowstone Lake in a September 1998 gill netting survey contained the parasite.

Initial results suggested that *M.cerebralis* infected approximately 10-25% of two to six year old cutthroat trout in the lake. Because Yellowstone cutthroat trout and rainbow trout appear to have similar susceptibility to whirling disease, and some whirling-disease-infected rainbow trout populations in Montana and Colorado have significantly declined, this potential level of infection prompted increased concern about the long-term abundance of the Yellowstone Lake cutthroat trout.

Subsequent examination of cutthroat trout incidentally captured during a NPS lake trout removal program indicated that mild infection of older cutthroat trout is widespread. In contrast, sentinel fry exposed to standard test conditions rarely tested positive for presence of the parasite. The current low level infection rates suggest that the parasite has only recently been introduced into the basin or that young Yellowstone cutthroat trout become parasitized in the fall as summer water temperatures decline to an optimum range for emergence of the infective stage of the parasite.

Barging Hatchery Steelhead Smolts Down Columbia River Does Not Interfere with Performance in Sea Water

Juhani Pirhonen and Carl B. Schreck

Oregon Cooperative Fish and Wildlife Research Unit, Department of Fisheries and Wildlife, Oregon State University, 104 Nash Hall, Corvallis, 97331 Oregon

Salmonid smolts from the Snake River must pass 8 dams on their migration out of the Columbia River system. Because of the significant mortality associated with the dams fish are collected at upstream dams and barged through the remaining dams for release below the last dam (Bonneville Dam). Fish which are not barged and migrate in-river take about two weeks longer than those that are barged. We tested the hypothesis that accelerating migration by barging altered the subsequent performance in sea water (SW). Specifically, we examined if there were differences in smolting status at the entrance to SW between barged and run-of-the-river (ROR) fish. As steelhead trout of the Snake River system are on the Endangered Species list, we did this experiment using hatchery raised fish instead of wild fish.

Fourty eight barged and 48 ROR steelhead were collected at Bonneville Dam as the barge from the Snake River passed that point and from the smolt collection facility at the dam, respectively, on May 2, 2000. They were transposted by truck to the Hatfield Marine Science Center in Newport, Oregon, and divided into four tanks, two for each treatment. After two and a half days in fresh water the water was changed to full strength flow through SW.. Fish were sampled after 1, 7 and 14 days in SW. To estimate feeding, before sampling the fish were fed in excess with a special dry diet containing small X-ray dense lead glass beads (Ballotini). The fish were sampled for weight, length, muscle water

and plasma sodium and potassium. After sampling the fish were X-rayed and the amount of food eaten was calculated based on the number of beads detected in each fish.

We found only slight differences between the two groups: after 1 day in SW ROR fish eat more than barged fish, but later no differences were observed. In general, feed intake was surprisingly good (about 0.4 % of body weight / feeding; two rations were offered each day) when taking into account transport and drastic change in the environment. Hypo-osmoregulatory capacity was already well developed in both groups based on the low plasma sodium values after 24 h in SW (163 mmol l^{-1}). There was a trend for increasing condition factors in the course of time in both groups. Condition factors were significantly higher in barged fish than in ROR fish after 1 and 2 weeks in SW. Taken together, accelerating migration by barging does not seem to be harmful for steelhead in terms of performance in SW.

Effects of a Catastrophic Flood and Debris Flow on Density and Growth of Brook Trout (*Salvelinus Fontinalis*) in the Staunton River, Shenandoah National Park, Virginia

Craig Roghair[1] and C. Andrew Dolloff[2]

[1]*Department of Fisheries & Wildlife, Virginia Tech, Blacksburg, VA 24061-0321* croghair@vt.edu

[2]*US Forest Service Southern Research Station, Department of Fisheries & Wildlife, Virginia Tech, Blacksburg, VA 24061-0321 (540) 231-4864, (540) 231-7580 FAX* adoll@vt.edu

In June 1995, the Staunton River experienced a massive flood which was accompanied by a catastrophic debris flow along the lower 1.9km of the stream. In the debris flow affected area the stream bed was scoured and new substrate materials were deposited, trees were removed from the riparian area, and all fish were eliminated. We conducted basinwide biannual fish surveys from 1993-1999 and a post-event mark-recapture study to examine the effects of the debris flow on density and growth of brook trout. The debris flow affected area of the stream was completely recolonized by YOY and age 1+ brook trout within 2.5 years. In the stream as a whole, YOY density exceeded pre-debris flow levels within 1 year, and 1+ density exceeded pre-debris flow levels within 2.5 years. Brook trout density was similar in the debris flow affected and unaffected areas by 1999. Between 1996 and 1998 brook trout in the debris flow affected area displayed significantly greater average length-at-age and individual growth than brook trout in the unaffected area of the stream. Growth was not significantly different between the affected and unaffected areas in 1999, and there was a general decrease in fish growth between 1996 and 1999. A strong negative relationship (r^2=0.91) was found between density and growth over the period. While extreme natural events such as floods and debris flows can decimate local populations, brook trout rapidly recolonize devastated areas from nearby source populations.

Fintrol Concentrate

Nick and Mary Romeo

Aquabiotics Corporation, PO Box 10576, Bainbridge Is, WA 98110

WHAT IS FINTROL?

Fintrol is one of 2 EPA-approved fish pesticides. It has been used since 1963. It is absorbed through the gills of fish and interferes with their respiration by inhibiting an enzyme system needed for oxygen consumption. It is undetected by fish, acting like carbon monoxide poisoning in humans. Sensitivity to Fintrol varies widely among fish species. Therefore, according to dosage, it may be used either for complete kill of all fish, or selective kill of some species, while not affecting others. Sensitivity also varies by size. Fintrol may be also used to remove smaller, stunted fish, while keeping the larger ones. Fintrol's active ingredient, Antimycin A, is an antibiotic discovered at the University of Wisconsin in 1945.

ADVANTAGES OF FINTROL

- EPA Registered for Aquatic Use
- Environmentally sound
- Does not contain petroleum derivatives or carcinogenic synergists
- Much lower toxicity and dosage than Rotenone
- Rapidly biodegrades—may restock in 1 week or less
- Quickly neutralized with 1ppm potassium permanganate
- Does not affect water quality
- Flora and Fauna essentially unaffected
- Does not repel fish
- Fish won't hide from it
- Can treat part of a large lake
- Good for stream applications
- Light-weight; can be packed into remote areas
- Kills fish eggs too
- At full dosage (5ppb), removes all scale fish
- At partial dosage, selectively kills some species, while leaving other species;
- Selectively kills smaller fish, while leaving adults
- Can kill small brim & leave bass
- Can kill shad, brim, perch, carp and minnows and leave catfish

CURRENT USES OF FINTROL

- State and Federal agencies use it to save endangered native species of fish in streams and lakes.
- Currently it is used to save more than 15 species.
- Fishing lakes use it to kill undesirable fish.
- Small bluegill, sunfish & minnows can be removed, while keeping bass and adult bluegill
- Fish farmers use it to remove trash fish
- Eliminate cormorant-attracting shad
- Decrease competition for food and oxygen
- Reduce stress on remaining fish
- Increase yields
- Shrimp and crawfish farmers use it to control predatory fish.

APPLICATION

One unit of Fintrol is packed in a can containing 2 bottles: (1) a ½ pint bottle of diluent containing surfactant and detergent that will be added to (2) a pint bottle, ½ full of 20% Fintrol concentrate. The resulting 10% concentrate is then mixed with at least 5 gallons of water before application.

Fintrol's performance is affected by species to be eradicated, water temperature, pH, correct acre-feet calculations, chemicals or pollution in the water, incomplete mixing, and cold spots in warm, springfed ponds. In general, to kill all scalefish, one unit treats 7.5 acre-feet at 5 parts per billion when the pH is less than 8.0 and the temperature is greater than 60 degrees F.

Effects of Episodic Stream Acidification on Wild Brook Trout Distribution in Stone Run, Pennsylvania, USA

W. E. Sharpe, S. J. Dolte, and B. R. Swistock[1]

[1]Professor of Forest Hydrology, former Graduate Assistant, and Extension Associate, respectively, School of Forest Resources and the Environmental Resources Research Institute, The Pennsylvania State University, University Park, Pennsylvania 16802.

Episodic stream acidification is a significant problem in the Appalachian Mountains of the eastern U.S. with more than 1,000 km of affected streams in Pennsylvania alone. Episodic acidification has been reported to disrupt spawning, alter distribution and extirpate native fishes in the region. We attempted to survey the wild brook trout (Salvelinus fontinalis) population of Stone Run before and after a period of episodic acidification to determine the effects of episodic acidification at the watershed level. We electro-fished 4,800 meters of stream and major tributaries and fin clipped 2,475 brook trout in the fall of 1995. The next spring we attempted to recover these fish to determine their distribution in Stone Run after a period of severe episodic acidification. Significant changes in distribution were noted, along with a drastic reduction in recruitment of young-of-the-year fish and a sharp reduction in fish captured. Streams like Stone Run that are subject to episodic acidification maintain wild brook trout, but trout numbers and distribution may fluctuate greatly in response to unfavorable water chemistry during episodes.

The Use of Major Histocompatibility Complex Genes of Rainbow Trout and Brown Trout in Population Analysis

Benny P. Shum*, Laura L. Flodin*, Mark A. Adkison†, Ronald P. Hedrick†, R. Barry Nehring¶, and Peter R. Parham*

**Stanford University School of Medicine, Department of Structural Biology, Fairchild Center, 299 Campus Drive West, Stanford, CA 94305-5126. Tel: (650) 723-7456, Fax: (650) 723-8464, email: bshum@cmgm.stanford.edu*

† Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California at Davis

¶ Colorado Division of Wildlife, Department of Natural Resources

In mammals, the Major Histocompatibility Complex (MHC) class I and class II genes are central to adaptive immunity. With most animals studied, these genes are highly polymorphic, which we would like to employ as markers for examining the diversity of wild trout populations. Although other genetic makers exist, MHC genes provide added information on the fish immune system. In this initial study, we included hatchery-raised rainbow trout (*Oncorhynchus mykiss*) maintained at the University of California at Davis, and wild rainbow trout and brown trout (*Salmo trutta*) collected from the Colorado River and the Big Thompson River in Colorado. Indeed, the MHC class I and class II (DAB beta-chain) sequences are polymorphic among trout with no identical sequence shared between the two species. No identical class II DAB allele is found between the California and the Colorado samples examined thus

far, with few shared alleles between the Colorado River and Big Thompson River brown trout populations. Due to the smaller size and the relatively simpler evolutionary history of the DAB gene, it could be a practical and useful system for the examination of trout populations. MHC gene allotypes will also be used to correlate with susceptibility to Whirling Disease.

Acidic Deposition and the Status of Virginia's Wild Trout Resource: Revisited

J.R. Webb[1], F.A. Deviney[2], Jr., B.J. Cosby[3], A.J. Bulger[4], and J.N. Galloway[5]

[1]Department of Environmental Sciences, University of Virginia, Charlottesville, Va. 22903, Phone: 804-924-7817, Fax: 804-982-2300, Email: rwebb@virginia.edu

[2]Department of Environmental Sciences, University of Virginia, Charlottesville, Va. 22903, Phone: 804-924-7817

[3]Department of Environmental Sciences, University of Virginia, Charlottesville, Va. 22903, Phone: 804-924-7787

[4]Department of Environmental Sciences, University of Virginia, Charlottesville, Va. 22903, Phone: 804-924-0531

[5]Department of Environmental Sciences, University of Virginia, Charlottesville, Va. 22903, Phone: 804-924-0561

VTSSS 2000 is part of an effort to insure that change in the acid-base chemistry of surface waters following enactment of the Clean Air Act Amendments of 1990 will be effectively evaluated for acid-sensitive watersheds. VTSSS, the Virginia Trout Stream Sensitivity Study, was initiated in the spring of 1987 when the solute composition of 344 Virginia brook trout streams was determined. The results of this sampling survey were reported at Wild Trout IV. For the first time, a baseline was established against which to measure the future effects of acidic deposition on this biologically defined class of streams. Since the 1987 survey, a geographically distributed subset of 60 streams has been sampled on a quarterly basis. In addition, a small number of streams has been sampled on a weekly schedule and even more frequently during high-runoff. VTSSS 2000, to be conducted during the last week of April, will be a repeat of the 1987 survey that initiated the program. Taken together, the data from VTSSS 2000 and the subset of more intensively studied streams will provide a basis for examining long-term changes related to acidic deposition, while accounting for the effects of season, flow, and other sources of short-term variation.

Profitable Stream Positions Differ for Brook Trout and Cutthroat Trout

Peggy Wilzbach and Kenneth W. Cummins

California Cooperative Fishery Research Unit, Humboldt State University, Arcata CA 95521; VOX: 707-826-5645; FAX:707-826-3269; paw7002@axe.humboldt.edu

Fausch (1984) proposed that potential profit of positions maintained by stream salmonids could be estimated as the energy available from drift minus metabolic costs of swimming. We tested this model by comparing specific growth rates of fish with a ranking of habitats by potential profit, as defined by Fausch. Focal positions of resident brook trout (*Salvelinus fontinalis*) were determined by underwater observation in an experimentally enclosed section of the West Fork Clark's Fork of the Yellowstone River (Park Co., MT), and associated drift densities and velocities were measured to develop a habitat ranking. Residents were removed and replaced with an equal number of brook

trout. Introduced fish occupied the same set of positions, and comparison of specific growth rates showed general but not complete correspondence with prior habitat rankings. Brook trout were then replaced with equal numbers of cutthroat trout (*Oncorhynchus clarki clarki*) from Soda Butte Creek. Cutthroat trout occupied a different set of focal positions, in faster velocities and closer to cover. Larger individuals maintained distinct resting spots in cover and only rarely left to feed. Differential habitat use between the two species suggests that competition for limiting spatial resources where the fishes co-occur may materialize only at high densities.

Threats and Opportunities for Native Trout Populations and Their Management—Get Those Roads Out of the River's Flood Plain!

Ray Zubik[1] and Pamela K. McClelland[2]

[1]*Forest Aquatic Biologist, Shoshone National Forest, 808 Meadow Lane, Cody Wyoming 82414-4516, telephone 307-527-6241, facsimile 307-578-1212*

[2]*Bring Back the Natives, National Fish and Wildlife Foundation, 1120 Connecticut Avenue, NW, Suite 900, Washington, DC 20036, Telephone: 202-857-0166, Facsimile: 202-857-0162, Electronic mail: mcclelland@nfwf.org*

Throughout the west roads follow tributary streams, reducing their flood plain and further fragmenting the watershed with culverts that block migration. Squaw Creek a tributary to the Clark's Fork of the Yellowstone River in Park County, Wyoming, was severely degraded by a road in its flood plain and two impassible culverts. This important Yellowstone cutthroat trout stream was restored in partnership with Park County and *Bring Back the Natives* in the fall of 1999 by moving the road up onto a nearby bench and by removing the road fill and impassible culverts. Relocating roads out of the flood plain on other *Bring Back the Natives* projects to restore other salmonids will be discussed.

"TU's Trout in a Frige"

Don Duff

USDA Forest Service, Trout Unlimited National Partnership Liaison, 125 S. State Street, Salt Lake City, UT 84138, 801-524-3945, email: dduff@fs.fed.us

Trout Unlimited (TU) has embarked on a unique management effort with agencies to restore native cutthroat populations using "old refrigerators" as streamside incubators. In 1998, in Utah, in "ole friges", on the Goshute Reservation (Tribe), achieved a 92% hatching success of green Bonneville cutthroat trout (BCT) eggs (250+) to swim-up fry. The project is cooperative with the Goshute Tribe, Utah TU Council (UTU), Utah Division of Wildlife Resources (UDWR), the U.S. Fish & Wildlife Service (FWS), National Resource Conservation Service (NRCS), U.S. Forest Service (USFS), and the Deep Creek Mountain Ranch (DCMR).

In another Goshute stream, in 1998, the Tribe, FWS (Roosevelt,UT), UTU, and rancher Buck Douglass (DCMR) successfully hatched 92% of 5,000 eyed-eggs of triploid rainbow for development of tribal recreational fisheries. And in 2000, rancher Douglass (DCMR) had a 98% hatching success of 300 BCT green eggs. The Ranch has constructed three brood stock ponds and one spawning channel, all simulating natural habitats instead of a hatchery environment, to assist in this streamside incubation project. These native and "wild" BCT being reared on the Ranch are being used in an interagency effort to restore the native BCT to the remote desert mountain ranges along the Utah-Nevada border. In Utah's Colorado River basin, on Trout Creek, tributary to Strawberry Reservoir, the UTU "old frige" had a 90% hatch success of 16,000+ green eggs of Bear Lake strain BCT, a recreational fisheries project in cooperation with USFS and UDWR.

In Nevada, in the Truckee River drainage of the Lahontan Basin, the Nevada TU Council and the Paiute Pyramid Lake Tribe used two "old friges" to hatch 225,000 Lahontan cutthroat eyed-eggs into the Truckee River in May-June 1998, in cooperation with Secretary Bruce Babbitt, Secretary of the Interior. Sec. Babbitt was also in Salt Lake City, in May, 1998, to endorse the use of the "old frige" for BCT recovery in Little Dell Creek watershed, within the Wasatch-Cache National Forest, in a cooperative effort by City of Salt Lake, UTU, USFS, FWS, and UDWR. Sec. Babbitt used rancher Buck Douglass as the example of involving private landowners in cooperative efforts for native fish restoration. He stated to the media and agencies that this Utah example is what is needed west-wide to bring about native fish recovery. The success of TU's working with private ranchers along the Utah-Nevada border is a key component of native fish restoration. The involvement of private landowners (ranches) has been so successful that more significant gains in expanding and protecting Bonneville cutthroat trout populations has been made the last five years than the preceding 25 from state and federal agencies for this subspecies of native cutthroat in the Bonneville Basin.

The "old frige" represents another management "tool" for replenishing salmonid populations for recreational fisheries as well as "jump starting" native trout restoration. It is not, however, a cure-all or mitigation for poor habitat conditions. Management agencies must still be committed to improving poor habitats with on-the-ground management before TU will endorse the use of "old friges" in partnership activities. The "old frige" was successfully developed by Dr. Fred Eales, Lower Green River-Flaming Gorge Chapter TU, of Rock Springs in the 1980's. In cooperation with the Wyoming Department of Game & Fish, this Wyoming (WY) TU chapter has significantly enhanced the recreational fisheries, i.e. brown, rainbow and cutthroat, recruitment into the Green River below Fontanelle Reservoir, WY. In addition, the "ole friges" using Kokanee salmon eggs has successfully succeeded in starting a Kokanee "run" to Flaming Gorge Reservoir, UT-WY some 120 miles downstream.

The Salmon-Challis National Forest, Idaho, under leadership of Bruce Smith, forest fisheries biologist, has successfully used the "old frige" for enhancing salmon, steelhead, and recreational fisheries in the Salmon River basin. The Shoshone-Bannock Tribe & USFS has successfully used this technique and the Tribe has developed a successful educational program for tribal children at all school levels, including a recent link to a NOAA satellite for fish monitoring purposes. Hatching successes for both eyed and green eggs of various salmonid species has ranged from 85 to 99% success to swim-up fry into the receiving waters over the last 5-10 years.

The "old frige" technique has been successful by TU in cooperation with tribes (Goshutes,UT/NV; Pyramid Lake Paiutes, NV; Shoshone-Bannock, ID), state and federal agencies and TU in the states of WY, ID, UT, NV, CA, PA, NY, TX, WA, and NY. National Forest's in the Intermountain Region (R4) using this "tool" with TU and cooperators, include the Ashley, Bridger-Teton, Salmon-Challis, Humboldt-Toiyabe, Uinta, and Wasatch-Cache for inland cutthroat subspecies, such as, the Bonneville, Colorado River, and Lahontan cutthroat.

The FS/TU Partnership Program, in addition to the above, has had requests to assist in use of this "tool" from State's of AZ, NM, MT, & OK in 1999-2000. In NM, for example, assistance will focus on use of the "ole frige" in recovery of the listed "threatened" Gila Trout (Gila National Forest), and the sensitive species, Rio Grande cutthroat (Santa Fe National Forest). These areas have received support from Sec. Bruce Babbitt, hence emphasis by TU & USFS to assist FWS & State's with this "tool" for recovery.

Thus, the "old frige" represents another, and very successful, management "tool" for restoring native salmonid populations as well as replenishing recreational salmonid fisheries. It was designed to assist fisheries managers in "jump starting" native trout restoration for both conservation and sportfish populations.

Wild Trout VII: Attendees and How to Contact Them

Thank you to Lois Evans[1] for providing this Wild Trout VII registration table—data is listed in the following order: Last, First, Organization, Address, City, State, Zip, d_phone, e_phone, fax, E-mail

Aaron, Amy, Trout Unlimited, 1966 13th Street, Suite LL60, Boulder, CO, 80302, 303-440-2397, 303-682-2445, 303-440-7933, aharig@tu.org

Allen, Dale, Idaho Dept of Fish & Game, 2812 Navajo Dr., Nampa, ID, 83686, 208-465-8465, 208-466-8596, mballen@uswest.net

Bartholomew, Dr. Jerri, Whirling Disease Foundation, P.O. Box 327, Bozeman, MT, 59771-0327, 406-585-0860, 406-585-9006, 406-585-0863, whirling3@mcn.net

Bartschi, Kent, University of Montana, 524 Garnet Ct, Missoula, MT, 59833, 327-7469, 327-7469, 327-7469, KBartschi@AOL.com

Bateman, Douglas, CFER-OSU Forest Science Dept., 3200 SW Jeferson Way, Corvallis, OR, 97331, 541-737-7784, 541-752-6893, 541-758-7761, Batemand@fsl.orst.edu

Behnke, Bob, Fishery & Wildlife, CSU, Colorado State University, Fort Collins, CO, 80523, 970-491-5320, 970-491-5091, none

Bergen, Gilbert, Box 505, Oakpace, NY, 11769, 631-581-1005,

Berry, David, Alberta Environment, 2441 89th Street, Edmonton, Alberta, T6K 2Y8, 780-427-8347, 780-462-8851, 780-422-9559, dave.berry@gov.ab.ca

Bloom, Roger, CA Dept. of Fish & Game, 310 N Fulton Street, Ojai, CA, 93023, 805-646-3823, rbloom@dfg.ca.gov

Boeker, Mike, National Park Service, 32 Great Basin NP, Baker, NV, 89311,

Borawa, James, NC Wildlife Resources Commissi, 37 New Cross North, Asheville, NC, 28805, 828-299-7023, borawajc@interpath.com

Breakfield, Jeffery, Alaska Department of Fish & Ga, 43961 K-Beach Rd., Suite B, Soldotna, Alaska, 99669, 907-260-2962, 907-262-1329, 907-262-4709, Jeff_Breakfield@fishgame.state

Brooks, James, U.S. Fish and Wildlife Service, 2105 Osuna NE, Albuquerque, New Mexico, 87113, 505/346-2538, ext 12, 505/858-9933, 505/346-2537, jim_brooks@fws.gov

Buchner, Kathy, Wyoming Trout Unlimited, P.O.Box 4069, Jackson, WY, 83001, 307-733-6991, 307-733-4944, 307-733-9574, kbuchner@wyoming.com

Buktenica, Mark, Crater Lake National Park, P.O. Box 7, Crater Lake, Oregon, 97604, 541 594-2211 X61, 541 594-2261, mark_buktenica@nps.gov

Byorth, Patrick, Chairman, Wild Trout VII, 1400 S. 19th Street, Bozeman, MT, 59718, 406-994-6938, 406-388-4531, 406-994-4090, pbyorth@montana.edu

Carline, Robert, Penn. Coop. Fish & Wildlife, Merkle Lab, University Park, PA, 16802, 814-865-4511, 814-238-3119, 814-863-4710, f7u@psu.edu

Claggett, Larry, Wisconson DNR, Box 7921 FH/3, Madison, WI, 53711, 608-267-9658, 608-266-2244, claggl@dnv.state.wi.us

Clemmons, Micky, NC Wildlife Resources Commissi, 2083 Great Smoky Mountain, Waynesville, NC, 28786, 828-452-3273, clemmomm@brinet.com

Cook, Anita, Nevada Division of Wildlife, 1100 Valley Rd., Reno, NV, 89512, 77-688-1532, 775-337-1908, 775-688-1595, acook@govmail.state.nv.us

Corsi, Charles, Idaho Dept. Fish & Game, 2750 Kathleen Ave., Coeur d'Alene, ID, 83815, 208-769-1414, 208-687-0215, 208-769-1418, ccorsi@idfg.state.id.us

Cremins, Damian, University of Montana, 32 Campus Drive, Missoula, MT, 59812, 406.243.6749, 406.542.1056, 406.243.4184, cremins75@hotmail.com

[1] *Accounting Technician, Conference Services, 280F Strand Union, Montana State University, P.O. Box 174150, Bozeman, MT 59717-4150, 406-994-3333, louise@montana.edu.*

Crookshanks, Chris, Nevada Division of Wildlife, P.O. Box 1109, Ely, NV, 89301, 775-289-1655, 775-289-1649, acook@govmail.state.nv.us

Currens, Kenneth, Northwest Indian Fisheries Com, 6730 Martin Way E., Olympia, WA, 98516-5540, 360-438-1180, 360-357-4142, kcurrens@nwifc.wa.gov

Darby, Neal, National Park Service, Great Basin National Park, Hwy 488, Baker, NV, 89311, 775-234-7331, 775-289-8531, 775-234-7269, neal_darby@nps.gov

Deviney, Jr., Frank, University of Virginia, Dept. of Env. Sci., Clark Hall, UVA, Charottesville, VA, 22903, 804-924-7817, 804-971-7683, 804-982-2300, deviney@virginia.edu

Dillon, Jeff, Idaho Dept. of Fish and Game, 1515 Lincoln Rd, Idaho Falls, ID, 83401, 208-525-7290, 208-523-6340, 208-523-7604, jdillon@idfg.state.id.us

Dolloff, Charles, USFS Southern Reseach Station, Dept. of Fisheries & Wildlife, Blacksburg, VA, 24061-0321, 540 231-4864, 540 953-3926, 540 231-7580, adoll@vt.edu

Downey, Daniel, James Madison University, MSC 7701, Department of Chemistry, JMU, Harrisonburg, Va, 22807, 540-568-6246, same, 540-568-7938, downeydm@jmu.edu

Duff, Donald, U.S. Forest Service/ Trout Unl., 125 s. state street, rm 8236, salt lake city, ut, 84138, 801-524-3945, na, 801-524-3172, tudtrout@aol.com

Duffield, Daniel, USDA Forest Service, 324 25th Street, Ogden, Utah, 84401, 801-625-5662, 801-745-0279, 801-625-5483, dduffield@fs.fed.us

Duffy, Walter, CA Coop. Fish Research Unit, CA Coop Fish Unit, Humboldt State Univ., Arcata, CA, 95521, 707-826-5644, 707-826-1289, 707-826-3269, wgd7001@axe.humboldt.edu

Dwyer, William, US Fish and Wildlife Service, 27 Border Lane, Bozeman, MT, 59718, 406 587 9265 x122, 587 0910, 586-5942, wdwyer6466@aol.com

Ebbers, Mark, DNR Fisheries, 500 Lafayette Road, St. Paul, MN, 55155, 651-297-2804, mark.ebbers@dnr.state.mn.us

Edwards, Richard, National Marine Fisheries Serv, 10215 West Emerald, Suite 180, Boise, Idaho, 83704, 208-378-5645, 208-378-5699, rick.edwards@noaa.gov

Elle, Fred, Idaho Dept. Fish and Game, 1414 E. Loctust Lane, Nampa, Idaho, 83686, 208 4658404, 208 467-9652, 208 465-8475, selle@idfg.state.id.us

Elliott, John, Nevada Division of Wildlife, 1375 Mt. City Highway, Elko, NV, 89801, 775-738-5332, 775-738-2485, acook@govmail.state.nv.us

Emerson, Dianne, NH Fish and Game, 629B Main Street, Lancaster, NH, 03584, 603-788-3164, 603-869-5524, 603-788-4823, fgnorth@ncia.net

Gamblin, Mark, Idaho Dept. Fish and Game, 1515 Lincoln Road, Idaho Falls, Idaho, 83401, 208-525-7290, 208-524-1012, 208-523-7604, mgamblin@idfg.state.id.us

Gordon, William, NYSDEC Fisheries, NYSDEC, SOB, 317 Washington Street, Watertown, New York, 13601, 315-785-2254, 315-639-3847, 315-785-2242, whgordon@gw.dec.ny.state.us

Gottesfeld, Amy, Trout Unlimited, 341 West Grape Street, Lock Haven, PA, 17745, 570-748-1638, 570-748-1638, NA, agottesfeld@hotmail.com

Gourley, Jessica, USFWS, 1677 Harrison Ave., Salt Lake City, UT, 84105, 801-524-5001, 801-583-9491, 801-524-5021, jess_gourley@fws.gov

Gracie, Jane, Brightwater, Inc., 10301 Wetherburn Road, Ellicott City, MD, 21042, 410-418-8476, 410-418-4687, 410-418-8479, jcgracie@home.com

Gracie, James, Brightwater, Inc., 10301 Wetherburn Road, Ellicott City, MD, 21042, 410-418-8476, 410-418-4687, 410-418-8479, jgracie@holonet.net

Gresswell, Robert, USGS-FRESC & OSU Dept. Fisheri, 3200 SW JefFerson Way, Corvallis, OR, 97331, 541-750-7410, 541-424-3020, 541-758-7761, Robert_Gresswell@usgs.gov

Grove, Matthew, Great Basin National Park, P.O. Box 100, Baker, Nevada, 89311, 775-234-7331, 775-234-7269, none

Guffy, Stan, The University of Tennessee, 7028 Crystal Lake RD, Knoxville, TN, 37919, 865-974-0890, sguffey@utk.edu

Guy, Troy, USGS, 8840 NW Oak Creek Drive, Corvallis, OR, 97330, 541-737-2898, troy_guy@usgs.gov

Hamilton, Bryan, Great Basin National Park, P.O. Box 100, Baker, Nevada, 89311, 775-234-7331, 775-234-7269, none

Hammel, Frederick, Sage Country Chapter Trout Unl, 355 County Rd 201, Craig, Colorado, 81625, 970.824.4536, 970.824.3601, rhammel@cmn.net

Hamre, Robert, USFS Retired, 2146 Collyer St., Longmont, Colorado, 80501, (303)485-5348, same, rhhamre@aol.com

Harmon, Terry, University School, 2785 SOM Center Road, Hunting Valley, Ohio, 44022, 216-831-2200, 440-247-9019, 216-292-7808, friebo@us.edu

Heikes, Sunni, Joseph Urbani & Associates Inc, P.O. Box 323, Gallatin Gateway, MT, 59715, 406-763-5750, sheikes@mcn.net

Hendricks, Steve, Oregon State University, 3200 SW JefFerson Way, Corvallis, OR, 97331, 541-758-7762, 541-752-1541, steve_hendricks@usgs.gov

Hepworth, Dale, Utah Div. Wildlife, 2094 Service Berry Cir., Cedar City, UT, 84720, 435-865-6109, 435-586-7563, dhepworth@email.state.ut.us

Hooton, Robert, OR Dept. of Fish & Wildlife, PO Box 59, Portland, Oregon, 97201, 503-872-5252, (503) 646-9279, 503-872-5632, bob.hooton@state.or.us

Hudson, Crystal, USFWS, 5830 Burnt Rd, Belgrade, MT, 59714, 406-582-8656, 406-587-3998, crystal_hudson@fws.gov

Hudy, Mark, US Forest Service, 3451 Ragtown RD, Harrisburg, VA, 22802, mhudy@fs.fed.us

Hulbert, Philip, N.Y. State Dept., Bureau of Fisheries, 50 Wolf Rd., Albany, NY, 12233, 518-457-5430, 607-278-5490, 518-485-5827, pxhulber@gw.dec.state.ny.us

Johnson, Kevin, Wyoming Game & Fish, 260 Buena Vista, Lander, WY, 82520, 307-332-2688, kjohns@state.wy.us

King, Mark, Virginia Commonwealth Univ., 816 Park Avenue Room 202, Richmond, VA, 23284, 804-828-1562, 804-457-2125, 804-828-0503, Mking@SATURN.VCU.EDU

Knapp, William, U.S. Fish and Wildlife Service, 4401 N. Fairfax Drive, Arlington, Virginia, 22203, 703-358-1715, 703-358-1718, 703-358-2240, William_Knapp@fws.gov

Knox, William, OR Dept. of Fish& Wildlife, 65495 Alder Slope Rd., Enterprise, Oregon, 97828, 541-426-3279, 541-426-3821, 541-426-3055, gofish@oregontrail.net

Koppelman, Jeff, MO Conservation Dept., 1110 S College Ave., Columbia, MO, 65203, 573-882-9880, 573-882-4517, koppej@mail.conservation.state

Koppelman, Jeffrey, MO Conservation Dept., 1110 S. College Ave., Columbia, MO, 65201, 573/882-9880, 573/882-4517, koppej@mail.conservation.state

Kovach, Jack, Muskingum College, 160 comin st., new concord, oh, 43762, 740-826-8241, 740-826-4358, 740-826-8404, jkovach@muskingum.edu

Kruse, Mike, Missouri Dept. of Conservation, 1110 S. College Avenue, Columbia, MO, 65201, 573-882-9880, 573-875-2033, 573-882-4517, krusem@mail.conservation.state

Kulp, Matt, National Park Service, 2144 Little Cove Road, Sevierville, TN, 37862, 865 436-1254, 865 428-7733, 865 436-1220, Matt_Kulp@nps.gov

Ledyard, Henry, West Denver TU, 600 Genesee Mountian Road, Golden, CO, 80401, 303-526-0188, 303-526-0188, 303-526-2895, hledyard@mstg.net

Lee, Ronald, PA Fish & Boat Commission, HC 02, Box 1, Tionesta, PA, 16353, 814-755-3890, 814-755-8835, 814-755-3852, dfbcmgtz@penn.com

Leggett, Jack, B.C. Fisheries, 400-640 Borland Street, Williams Lake, British Columbia, V2G 34T1, 250-398-4546, 250-392-5861, 250-398-4214, Jack.Leggett@gems7.gov.bc.ca

Leggett, Jack, B.C. Fisheries, 400-640 Borland Street, 250-398-4546, 250-398-4214, Jack.Leggett@gems7.gov.bc.ca

Lehmberg, Verne, Federation of Fly Fishers, P.O. Box 1595, Bozeman, MT, 59771, 585-7592, 585-7596, fffoffice@fedflyfishers.org

Lentz, David, California Dept. Fish and Game, 1701 Nimbus Rd., Suite C, Rancho Cordova, CA, 95670, 916 358-2831, 916 452-5359, 916 358-2857, dlentz@dfg.ca.gov

Lohr, Sam, U.S. Fish and Wildlife Service, 1387 S. Vinnell Way, Rm. 368, Boise, ID, 83709, 208-378-5387, 208-378-5262, sam_lohr@fws.gov

Long, Michael, US Fish & Wildlife Service, 7000 Airport Pkwy., Cheyenne, WY, 82009, 307-772-2374, 307-632-4232, 307-772-2358, michael_long@fws.gov

LoSapio, Carol, Beyond Words, 509 Richards Lake Road, Fort Collins, CO, 80524, 970-493-0635, 970-689-2110, 970-493-4017, Closa49863@aol.com

Mahony, Dan, Yellowstone National Park, PO Box 168, Yellowstone National Park, WY, 82190, 307-344-2280, 307-344-2223, 307-344-2211, Dan_Mahony@nps.gov

Mamer, Elizabeth, Idaho Dept of Fish and Game, 15754 Lakeshore Drive, Caldwell, ID, 83607, 208/465-8404, 208/454-3790, 208/465-8475, lmamer@idfg.state.id.us

Marwitz, Todd, DNR Fisheries, 1801 South Oak Street, Lake City, MN, 55041, 651-345-3365, 651-345-3975, todd.marwitz@dnr.state.mn.us

May, Christine, Oregon State University, 3200 SW Jefferson Way, Corvallis, OR, 97331, (541)737-6574, 541-924-2765, 541-758-7792, christine_may@usgs.gov

May, Bruce, Forest Service, P.O. Box 130, Bozeman, MT, 58771, 406-586-6707, 406-586-7875, bmayol@fs.fed.us

McClelland, Pamela, Nat'l Fish&Wildlife Foundation, 1120 Connecticut Ave, NW STE 900, Washington, DC, 20036, 202-857-0166, 202-857-0162, mcclelland@nfwf.org

McDonald, Ken, Montana FWP, P.O. Box 21700, Helena, MT, 59620, 406-444-7409, kmcdonald@state.mt.us

McDougal, Leigh, USDA Forest Service, 1323 Club Drive, Vellejo, CA, 94592, 707-562-8940, 707-562-9050, 1mcdougal@fs.fed.us

McDowell, Bob, Wyoming Game & Fish, P.O. Box 6249, Sheridan, WY, 82801, 307-672-8300, bmcdow@state.wy.us

McGuane, Tom, Guest Speaker, none, none, none, none, none, None, none

Miller, Dirk, Wyoming Game & Fish, 528 S Adams, Laramie, WY, 82070, 307-745-4046, 307-777-4611, dmiller@state.wy.us

Miller, Don, Wyoming Game & Fish, 423 Eberhart, Laramie, WY, 82070, 307-745-5180 Ext 238, 307-745-8720, dmille2@state.wy.us

Minard, Mac, Alaska Dept. Fish & Game, 1300 College Road, Fairbanks, AK, 99701, 907-459-7350, 907-488-7156, mac_minard@fishgame.state.ak.us

Moase, Robert, PA Fish & Boat Commission, P.O. Box 88, Sweet Valley, PA, 18656, 570-477-5717, 570-477-2570, 570-477-3090, pfbcafm4@ptd.net

Mohn, Larry, VA Dept. Game&Inland Fisheries, P.O. Box 996, Verona, VA, 24486, 540-248-9360, 540-234-9730, 540-248-9399, lmohn@dgif.state.va.us

Moore, Stephen, National Park Service, 107 Park Headquarters Road, Gatlinburg, TN, 37738, (865)436-1250, (865)428-1456, (865)436-1220, Steve_E_Moore@nps.gov

Moore, Virgil, Idaho Fish & Game, 11627 W Peak View CT, Boise, ID, 83709, 208-334-3791, 208-362-3431, 208-334-2214, vmoore@idfg.state.id.us

Morton, Bruce, Montana State University, P.O. Box 173320, Bozeman, MT, 59717, 406-994-6518, bmorton@montana.edu

Newman, Lee, U.S. Fish & Wildlife, 2800 Lakeshore Drive E, Ashland, WI, 54806, 715-682-6185, 715-373-2865, 715-682-8899, lee_newman@fws.gov

Nicholas, Jay, Oregon Gov. Office, C/O ODFW, 28655 Hwy 34, Covallis, OR, 97333, 541-757-4263, jay.nicholas@orst.edu

Nickum, David, Trout Unlimited, 5765 W Fifth Avenue, Lakewood, CO, 80226, 303-440-2937, 303-235-0041, 303-440-7933, dnickum@tu.org

Pacas, Charlie, Parks Canada - Banff National, PO Box 900, Banff, Alberta, T0L 0C0, 403 762 1418, 403 678 3580, 403 762 3240, charlie_pacas@pch.gc.ca

Parmenter, Steve, CA-DFG, 407 W Line Street, Bishop, CA, 93514, 760 872 1171, 760 873 5736, 760 872 1284, spar@dfg.ca.gov

Pidgeon, Sandy, USFWS, 105 I Paisley Crt, Bozeman, MT, 59715, 406-582-8656, 406-587-3998, pidgeon@montana.edu

Pierce, Ron, Montana Fish, Wildlife, & Park, 3201 Spurgin Road, Missoula, MT, 59804, 406-542-5532, 406-542-5529, efishing@uswest.net

Pirhonen, Juhani, Oregon State University, 104 Nash Hall, Dept. Fish and Wildlife, Corvallis, Oregon, 97331, 541-737-2543, 541-752-4399, 541-737-3590, juhani.pirhonen@orst.edu

Pistono, Chico, Wyoming Game & Fish, 5400 Bishop Blvd., Cheyenne, WY, 82006, 307-777-4559, 307-777-4611, rpisto@state.wy.us

Potter, David, Garcia and Associates, 151 Evergreen Drive Suite B, Bozeman, Montana, 59715, 406/582-0661, 406/388-0212, 406/582-0659, dpotter@garciaandassociates.co

Reynolds, James, Univ. Alaska Fairbanks, 4627 Harvard Cir., Fairbanks, AK, 99709, 907-479-5828, ffjbr@uaf.edu

Rider, Larry, Arkansas Game & Fish Comm., No. 2 Natural Resources Drive, Little Rock, AR, 72205, 501-223-6369, 501-754-3065, 501-223-6461, lridger@agfc.state.ar.us

Riley, Chris, USDA INYO NF, 873 N Main Street, Bishop, CA, 93514, 760-873-2442, 760-873-2458,

Rivers, Pat, DNR Fisheries, 1801 South Oak Street, Lake City, MN, 55041, 651-345-3365, 651-345-3975, pat.rivers@dnr.state.mn.us

Romeo, Nicholas, Aquabiotics Corp., 10770 Arrow Point Drive, Bainbridge Island, WA, 98110, 206 8421708, 2068421708, 206 8427266, nromeo@worldnet.att.net

Romeo, Mary, Aquabiotics Corp., 10770 Arrow Point Drive, Bainbridge Island, WA, 98110, 206-8421708, 206-8421708, 206-8427266, nromeo@worldnet.att.net

Rose, James, University of Wyoming, Department of Psychology, Univ. of WY, Laramie, WY, 82071, 307-766-6719, 307-742-4523, 307-766-2926, trout@uwyo.edu

Rose, Jim, Guest Speaker, none, none, none, none, none, none, none

Roth, Scott, Wyoming Game & Fish, 260 Buena Vista, Lander, WY, 82520, 307-332-2688, sroth@state.wy.us

Ruiz, Leslie, U.S. Fish and Wildlife Service, P.O. Box 39, Pinetop, Arizona, 85935, 520.367.1953, 520.367.1953, 520.367.1957, Leslie_Ruiz@fws.gov

Russell, Kelly, USDA Forest Service - Southern, 1720 Peachtree Rd., NW - Ste. 816N, Atlanta, GA, 30309, 404-347-4082, 404-347-4154, kmrussell@fs.fed.us

Scaife, Dan, USFS, 2013 Eastside, 2nd Street, Sheridan, WY, 82801, 307/674-2646, 307/674/2668, dscaife@fs.fed.us

Schill, Daniel, Idaho Dept of Fish and Game, 1414 Locust Rd, Nampa, ID, 83686, 208-465-8404, 208-939-0064, 208-465-8475, dschill@micron.net

Scully, Richard, Idaho Dept. of Fish & Game, 1967 Syringa Street, Pocatello, ID, 83201-2350, 208-232-3260, rscully@idfg.state.id.us

Seldon, Marty, Federation of Fly Fishers, 1146 Pulora Court, Sunnyvale, CA, 94087-2331, 408-736-5631, 585-7596, mmseldon@aol.com

Sharpe, William, Penn State Univ., 104 Land & Water Bldg., University Park, PA, 16802, 814-863-8564, 814-422-8617, 814-865-3378, wes@psu.edu

Shenot, Jeffrey, FERC Office of Energy Projects, 888 First St., NE, Washington, D.C., 20426, 202-219-2178, N/A, 202-208-0353, jeffrey.shenot@ferc.fed.us

Shepard, Brad, Montana FWP, 1400 S 19th, Bozeman, MT, 59715, 406-994-3243, bshepard@montana.edu

Shum, Benny, Stanford University, Structural Biology, 299 Campus Driver We, Stanford, CA, 94305-5126, (650) 723-7456, (650) 324-9363, (650) 723-8464, bshum@cmgm.stanford.edu

Siesennop, Gary, DNR Fisheries, Box 146, Grand Marais, MN, 55604, 218-387-3057, 218-387-3035, gary.siesennop@dnr.state.mn.us

Soldwedel, Robert, NJ Div. Fish & Wildlife, Box 154, Lebanon, New Jersey, 08833, 609.292.8642, 908.788.5497, 609.984.1414, rsoldwedel@earthlink.com

Stanley, Thomas, Cleveland Metroparks, 7823 Larkspur Lane, Chagrin Falls, Ohio, 44022, 216-635-3240, 440-338-5919, 216-635-3286, tws@clevelandmetroparks.com

Stark, John, Arkansas Game & Fish Comm., 457 Surrey Lane, Lakeview, AR, 72640, 870-424-5924, 870-425-65??, jstark@agfc.state.ar.us

Staton, Linda, USFWS, 920 Technology Bld. Suite G, Bozeman, MT, 59718, (406)582-8656, (406)587-3998, linda_staton@fws.gov

Stewart, Bud, Wyoming Game & Fish, P.O. Box 6249, Sheridan, WY, 82801, 307-672-8300, bstewa@state.wy.us

Stowell, Rick, USDA Forest Service, 9480 Singletree Lane, Missoula, MT, 59803, (406)329-3287, (406)251-8060, (406) 329-3171, rstowell@fs.fed.us

Taylor, Greg, ODFW, 3150 Main St., Springfield, OR, 97478, 541-726-3515 x 33, 541-937-2177, greg.c.taylor@state.or.us

Theis, Ken, Student, 2627 N 1600 E, Logan, UT, 84341, 435-753-5743,

Thorn, Bill, DNR Fisheries, 1801 South Oak Street, Lake City, MN, 55041, 651-345-3365, 651-345-3975, todd.marwitz@dnr.state.mn.us

Todd, Stan, Arkansas Game & Fish Comm., 201 East 5th Street, Mountain Home, AR, 72659, 870-424-5924, 870-425-65??, stodd@agfc.state.ar.us

Turner, W., Idaho Model Watershed, P. O. Box 1222, Salmon, ID, 83467, 208.756.4834, 208.756.4834, 208.756.2190, wsturnerinid@salmoninternet.com

Turner, Spencer, Quail Ridge Publishing, 5701 E. Mexico Gravel Rd., Columbia, Missouri, 65202, 573 474-6477, sturne01@coin.org

Ulmer, Linda, Forest Service, 700 E Broadway, Missoula, MT, 59801, 406-329-3507, 406-329-1710, lulmer@fs.fed.us

Urbani, Joe, Joseph Urbani & Associates, Inc, 1502 Gold Ave., Bozeman, MT, 59715, 406-587-0588, 406-585-9126, urbani@mcn.net

Wade, Karen, National Park Service, P.O. Box 25287, Denver, CO, 80225, 303-969-2503, karen_wade@nps.gov

Walters, Jody, Idaho Dept. of Fish and Game, 2750 Kathleen Ave, Coeur d'Alene, ID, 83815, 208-769-1414, 208-769-1418, jwalters@idfg.state.id.us

Warren, Mark, Nevada Division of Wildlife, 1100 Valley Rd., Reno, NV, 89512, 775-688-1535, 775-688-1595, acook@govmail.state.nv.us

Webb, Rick, University of Virginia, HC4 Box !5, Monterey, VA, 24465, 540-468-2881, 540-468-2881, 804-982-2300, rwebb@virginia.edu

Weber, Robert, PA Fish & Boat Commission, 450 Robinson Lane, Bellefonte, PA, 16823, 814-359-5164, 814-355-8947, 814-359-5163, rweber@fish.state.pa.us

Werdon, Selena, US FWS, 1765 Sierra Highlands Dr., Reno, NV, 89523, 775-861-6328, 775-746-2036, 775-861-6301, selena_werdon@fws.gov

White, Ray, 320 - 12th Ave. N., Edmonds, WA, 98020-2930, 425-672-8268, 425-672-8268, 425-775-7554, rw@seanet.com

Wiley, Robert, Wyoming Game & Fish, 5400 Bishop Blvd., Cheyenne, WY, 82006, 307-777-4559, 307-777-4611, bwiley@state.wy.us

Wiltshire, Bob, Federationof Fly Fishers, P.O. Box 1595, Bozeman, MT, 59771, 585-7592, 222-9369, 585-7596, iffc@fedflyfishers.org

Wilzbach, Margaret, USGS-CA Coop. Fish Research, Humboldt State University - 1 Harpst Str, Arcata, CA, 95521, 707-826-5645, 707-825-8258, 707-826-3269, paw7002@humboldt.edu

Wofford, John, USGS, 570 SE Chester Ave., Corvallis, OR, 97333, 541-758-7792, 541-752-6128, jeb_wofford@usgs.gov

Woodmansee, Gary, U.S. F.S. (Ret.), General Delivery, Curlew, WA, 99118, 509 779 4906, garwood7@aol.com

Yekel, Steve, Wyoming Game & Fish, 2820 State Highway 120, Cody, WY, 82414, 307-527-7322, syekel@state.wy.us

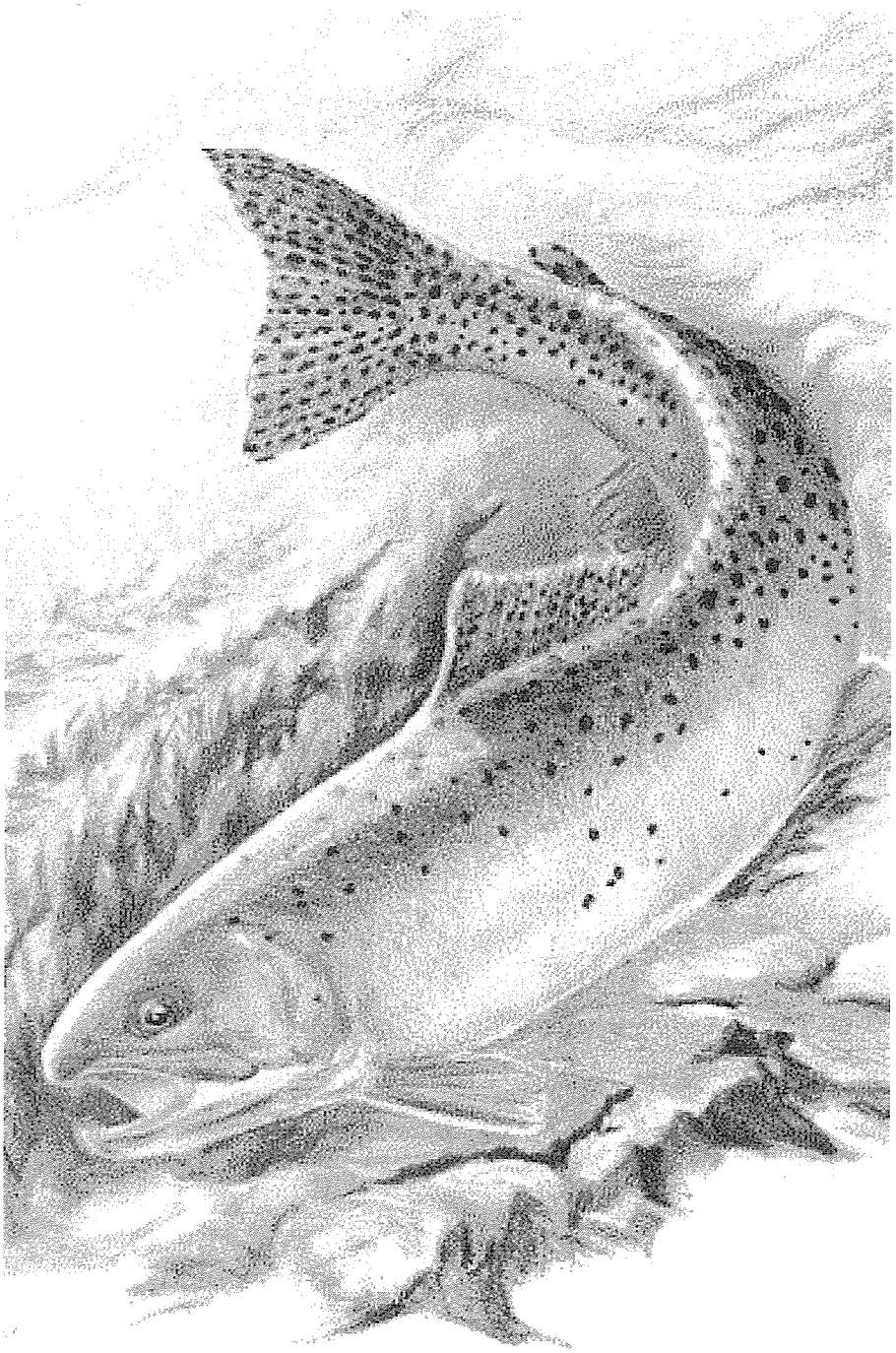
Yturralde, Kasey, NPS - Great Basin NP, 22 Great Basin National Park, Baker, NV, 89311, 775-234-7331, 775-234-7253, beetle_lady@yahoo.com

Yundt, Steve, Idaho Dept. of Fish & Game, 600 S Walnut, Boise, ID, 83707, 208-334-3791, 208-286-7162, 208-534-2114, syundt@micron.net

Ziller, Jeffrey, Oregon Dept.of Fish & Wildlife, 3150 E Main Street, Springfield, OR, 97478, 541 726 3515, 541-687-5846, 541-726-2505,

Zorn, Troy, Michigan DNR, 1581 Halberg Road, Lewiston, Michigan, 49756, 517-786-2613, 517-785-2067, 517-786-5662, zornt@state.mi.us

Zubik, Ray, Shoshone National Forest, 808 Meadow Lane, Cody, Wyoming, 82414, (307) 578-1260, (307) 578-1212, rzubik@fs.fed.us



Artwork by Mimi Matsuda