"Putting the Native Back in Wild Trout"
WILD TROUT VI

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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 author and not necessarily those of the sponsoring organizations.
WILD TROUT VI
Putting the Native Back in Wild Trout

Montana State University, Bozeman

August 17 - 20, 1997

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Wild Trout VI was sponsored by several traditional organizations. A new sponsor that should be prominently mentioned, however, is the Trout and Salmon Foundation, which provided $5,000 in "seed money". Among the regular sponsors, the U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service provided for the printing of these proceedings. We are grateful to them and the rest of our sponsors for their past and future support. These include: Federation of Fly Fishers; Trout Unlimited; Montana Fish, Wildlife, and Parks; American Fisheries Society; Montana Chapter of AFS. Joseph Urbani and Associates sponsored the refreshment breaks.
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Wild Trout VI: Introduction

Pat Dwyer

The Wild Trout Symposia were established as a forum for working professionals and fishery conservationists from across North America to improve awareness of current research and critical issues facing wild trout resources. The objectives of Wild Trout VI were to raise the public awareness of native wild trout, their social and economic value, examine the future of wild trout in a society with increases in urbanization and decreases in funds, and evaluate strategies for restoration and protection of these fish.

Since Wild Trout I in 1974, the symposia, convened every five years in Yellowstone National Park to focus on the ecology and management of wild trout, have become international in scope. The symposia have also evolved over the years to encompass a broader view of wild trout and their habitat. Concerns for wild trout have increased the need to improve communications among managers, scientists, and anglers. The large attendance at Wild Trout V indicated the interest in wild trout remained high and is increasing. To cope with rapid developments and increasing demand for information, the cycle was shortened to three years.

For the first time the symposium was held in a location other than Yellowstone Park. Wild Trout VI was hosted by Montana State University in Bozeman, because we had outgrown the Park. The University had excellent facilities, and many enjoyed fishing the waters of Yellowstone National Park and the blue ribbon rivers of the Bozeman area. An excellent program was developed by Bob Gresswell and his committee, around the theme "Putting the Native Back in Wild Trout." A "Call for Papers" was sent out and the program committee was flooded with abstracts to choose from. All of the papers for the symposium were contributed. Attendance was down, probably for a variety of reasons. Change is often hard for people and therein may be the reason for less attendance of some of the regulars; conflicts with other meetings may have also been a factor. But, regardless of the reason, we will go forward and continue the Wild Trout tradition, started with the visions of great conservationists in 1974.
Wild Trout VI: A Summary

Spencer E. Turner

Wild Trout VI had a different flavor than previous Wild Trout Conferences. It was not held at Mammoth Hot Springs in Yellowstone Park, and no elk bugled all night long. It was held after only 3 years, not 5, and for the first time there was no paper summarizing state by state changes in wild trout management. To me this signaled a major milestone had been achieved. It suggested that most states and federal agencies with wild trout resources now have wild trout management programs. We no longer are attempting to open the door, but rather are now working to improve established wild trout management programs, form partnerships, and target areas where salmonid species or strains are at serious risk.

Wild Trout VI reflected these changes. We heard about partnerships: partnerships between private and public conservation group partnerships between state and federal agencies, and partnerships between anglers, educational institutions, and governments. We learned about problem areas, and salmonid species or races at risk. We learned about new, yet to be identified, salmonids in Mexico and Russia, and we learned more about DNA and Serum Protein Analysis than I wanted to know. I caution researchers who use these new techniques: report on your results, not how you conducted the research. Most old hairy-legged biologists and even a few not so hairy-legged and ones, don’t understand the technology, but appreciate the results achieved and the positive movement in the science you have accomplished.

I will summarize each section and provide a few closing comments.

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1Summarizer’s address presented at Wild Trout VI, Bozeman Mt, August 20, 1997.
2Retired fisheries research biologist Missouri Department of Conservation, member of Mid-Missouri Chapter Trout Unlimited, Missouri, Owner Quail Ridge Publications, 5701 E. Mexico Gravel Rd, Columbia, MO 65202

PLENARY SESSION

The superintendent of Yellowstone National Park, through his representative John Varley, reminded us that our national park system provides a refuge for many unique species and habitats, and loss of park lands or transfer to local control would seriously compromise the Park Service’s goal of managing the parks for the “common good” and “national interests”. The National Park Service and Yellowstone Park now focus on outcomes rather than outputs. Varley reminded us that as more and more people visit the parks each year, public attitudes are changing. Streams and lakes in our national parks are being used by visitors other than sportsmen and women and many view trout as “finny friends,” or “aquatic butterflies.” Afterward, Trout Unlimited and Yellowstone Park representatives signed a historic partnership to restore native trout habitats and native trout.

The U.S. Forest Service, represented by Jim Sedell, explained how the agency was establishing partnerships with private groups, and how forest plans now revolved around biodiversity and protection of aquatic species and habitats. Most species recoveries such as of the spotted owl, will take place on federal lands, including U.S. Forest Service lands. We learned how the U.S. Forest Service now targets critical habitats, usually around streams or stream systems, in forest management plans, and uses partnerships to protect and enhance wild trout habitats.

PUBLIC AWARENESS AND EDUCATION

The meat and potatoes of Wild Trout VI kicked off with the public awareness and education session. Most presenters reviewed successes they’d had working with a variety of private and public constituents, but there were also some notable...
failures reviewed. Alberta’s bull trout task force, working totally outside governmental agencies, stabilized a declining resource and helped restore healthy native bull trout populations in the province, using aggressive public education. On the other side of the coin, a Trout Unlimited partnership in Colorado to restore Colorado River Cutthroat trout had great difficulty working with state and federal agencies because of agency inflexibility.

The Wild Salmonid Center established the most unique partnership. The Center formed a partnership between Colorado State University, the University of Moscow, and trout anglers to research salmonid resources of the Kamchatka region of Russia. Anglers, and several fishing businesses, pay the Center to support research and the program...I volunteered to help, but no one took me up on my offer.

VALUES ASSOCIATED WITH WILD TROUT

Not surprisingly, we learned wild trout have values beyond intrinsic worth. Studies on the Beaverkill and Willowemoc watershed in upper New York demonstrated that wild trout anglers contribute more than $9 million annually to the economy, and trout fishing ranked third among local industries in providing employment. Similarly, California Trout reported wild trout fisheries in California can be maintained for less than $1,000 per mile and returned more than $5 million annually to local and state economies. Put and take trout fisheries, cost more than $10,000 per mile.

Maybe the most discussed presentation at Wild Trout VI was a barbed vs barbless hook summary paper. Once again, the researcher found no difference in trout survival between the two types of terminal tackle, and release times (one argument used by anglers to justify barbless regulations) were not different. In other words, use of barbless hooks should be a personal decision, not one mandated by agency regulations.

In Idaho, 20% of trout-related arrests were for using barbed hooks in barbless waters. I dwell on this to make a point: When agencies enact regulations that have no biological significance, (usually forced by angling group lobbying) they do not improve trout populations or fishing, but risk losing public credibility and support. Then faced with real resource threats, requiring meaningful restrictive regulations, they find little constituent support.

EVOLUTION AND BIOLOGICAL ORGANIZATION OF NATIVE NORTH AMERICAN SALMONIDS

Two researchers reported discovering either new salmonid species or subspecies in widely separated regions. Using DNA analysis, one researcher identified two or more trout species in the mountains of central Mexico, possibly related to Gila trout or cutthroat trout in Colorado and Nevada. Village children “noodled” trout from tiny mountain streams, a collection technique not before encountered by the researcher...she needs a trip to the Midwest.

Similarly, researchers and anglers working on the Kamchatka region of Russia reported discovering three different groups of trout so far: two were similar to cutthroat trout in North America and have yet to be classified, and a primitive form of rainbow. As a scientist and old fish squeezer, I am excited by this discovery, one which will further our knowledge of salmonid evolution. The researcher believed this was just the beginning; he hoped to find additional unclassified salmonids in the region.

We also learned about the evolution and life-history of the Yellowstone cutthroat trout and how misguided management efforts and removal of non-migrating Yellowstone cutthroat trout from a tributary of Yellowstone Lake had altered the population in a relatively short time period; an alternative view to current whirling disease management and the potential consequences to selecting for resistant wild trout populations; how southern brook trout in the Appalachian mountains differed from those in West Virginia and western Maryland; and how wild trout management in Alaska had revitalized trout fishing and the industry supported by the resource.
THREATS TO PERSISTENCE OF WILD TROUT

Yellowstone Lake and problems associated with lake trout introductions came into a great deal of discussion. Recent age and growth studies show that lake trout may have been introduced 15 or more years, not the 5 years once believed. Efforts to remove lake trout continue, but have been relatively unsuccessful because of the size and depth of the lake. Fish and Wildlife Service biologists believe that illegal lake trout “bucket-brigade” stocking will ultimately reduce native cutthroat populations in the lake—and the bear populations, that depend on cutthroat trout for food. It will be years before the full impact is known. This is a good example of the risks of stocking non-native species in new environments.

Whirling disease continues to be a large problem across the country, and continues to spread. The disease has now spread to the Yellowstone River. Whirling disease researchers are currently looking for resistant trout strains.

Other threats to wild trout populations included global warming which could eliminate most wild brook trout populations in the Great Smokey Mountains; interaction between non-native salmonids and cutthroat trout in Snake River, which could reduce native cutthroat population, increase hybridization between rainbow trout and cutthroat trout, and reduce angler catch rates; the complexity and difficulty of implementing bull trout restoration efforts in Montana and Ontario Canada; and the continued loss of cold water habitat for Gila trout caused by over-grazing on public lands.

RESTORATION AND PROTECTIONS OF WILD TROUT

Success stories, on the other hand, were very limited. We learned that most habitat restoration efforts require a landscape perspective rather than a site perspective; how the Itchen River in Great Britain had been destroyed and restored over the last three centuries; the struggle biologists and agencies are having restoring bull trout populations in Montana; how fisheries managers on the South Fork of the Snake River in Idaho were successfully addressing threats to native cutthroat trout from non-native salmonids; and we learned how “Coasters,” lake-run brook trout in tributaries of Lake Superior, once thought extinct, were being restored.

Like John The Baptist and Winne The Poo, who have the same middle name in common, Wild Trout VI demonstrated that we...federal and state administrators, fisheries biologists, researchers, old hairy legged retired biologists, organized anglers, and guides...have a lot in common. We share a love of wild trout, their many colors and flavors, and most importantly the rich, cold environs that support these wondrous creatures. We must work together to accomplish our goals.

Although improvements in wild trout populations, management, and fishing come slowly, however, we have come light years since Wild Trout I through cooperative efforts and partnerships between trout anglers, angling groups, and political agencies governed by elected officials working to improve wild trout resources. I am optimistic for the future of wild trout resources.
The Role of National Parks in the Persistence of Wild Trout

Michael V. Finley¹ and John D. Varley²

Abstract—The world of trout has faced substantial changes in the past three decades, and if our crystal ball is clear, there are more on the horizon. A wise person once said “the only thing people hate worse than change, is sudden change.” In public dialogues such as this Wild Trout series of conferences (of which this is the sixth!), we can dispassionately discuss and share information about trout and change, for better or for worse. The discourse can make change not only less painful, but instead, positive and constructive. We believe it works well for trout, for natural resource managers and biologists, for sportsmen and anglers, for environmentalists, and for our entire citizenry.

INTRODUCTION

We come to you as public land managers and stewards of a great national park. We also are here as taxpayers and as consumers and users of our public lands. In those roles we want to convey to you our concerns about several important issues.

The conservation of natural resources has never been easy in the United States. There have always been conflicts over forest reserve boundaries, national parks, wild and scenic rivers, BLM wilderness designations, and a host of other land and resource issues. In fact, as we look back in history, even Yellowstone—the splendid ecological, sociological and economic success that it has been—had its detractors. Upon hearing of the proposed law to create the world’s first national park, a Helena, Montana, newspaper put it:

“the effect of this measure will be to keep the country a wilderness, and shut out for many years the travel that would seek that curious region...we regard the passage of the act as a great blow struck at the prosperity of the towns of Bozeman and Virginia City.” When the United States bought Alaska, a prominent New York City newspaper said, “Alaska is a sucked orange, and we should pay the Russians to take it back.”

As the great debates continue over how, we, as a nation, will manage and protect our considerable and great natural resources, we are troubled by several trends and see the need for greater emphasis in certain areas. Who amongst you share some of these concerns:

THE NATIONAL INTEREST OR AGENDA, AND THE COMMON GOOD

Have we as a society lost the sense of the common good or the national interest? There are certainly numerous signs. Our historically contentious society seems more contentious than ever. The number of lawsuits in progress at any given time is astronomical, and the overburdened court systems sometimes seem moribund. Congressional statesmanship appears to have been replaced by parochialism.

Yet, in the face of all of this, individual Americans still make sacrifices and support various causes and interests, and it’s clear they care deeply about natural and cultural resources.

What are these disturbing trends attributable to? There are numerous contenders: perhaps the fault lies with Political Action Committees or the single focus agendas and positions held by what are euphemistically called “public interest groups.” Or perhaps it is just our culture’s natural response to the large size of our society or society’s complexity in contemporary times. We don’t have the answer but we have the concern.

We also see discrediting of national institutions in favor of local control. On the surface, it sounds good and efficient to delegate power to local levels but seldom do local interests and institutions have the long-term vision or the political will to protect

¹Superintendent, Yellowstone National Park.
²Chief of Research, Yellowstone National Park.
resources for the nation; for the national interest. Commissioners in Nye County, Nevada, for example, are certainly not concerned about the well-being of the national forests in the year 2050 except where it relates to their own narrowly focused interests. Americans at local levels are certainly capable and innovative; it’s just that if we, as a people, want certainty of standards—a persistence of vision—through future generations, a national system has been, to date, the only large scale solution that has worked even partly well.

We are seeing the legitimate concern for property rights being used as a scare tactic or as a way to oppose public initiatives that might be advanced for the common good. For example, the opposition in some segments of society to the federally-sponsored program establishing heritage areas is puzzling. Heritage areas are promoted as local, grassroots initiatives with no federal land organization or oversight, but there continues to be strong political opposition.

We can wonder, in today’s political world, if we would have ever had the unity and vision if we were now considering, for the first time, the interstate highway system.

Given the reality of all of this contention, there is an irony our society needs to resolve that relates directly to the national parks and other public lands. Contrary to the disturbing trends outlined above, we believe the national interest would best be served by more public lands for recreational sites and facilities, not less. Consider the factual projection that the U.S. population may reach 400,000,000 by 2020. As great believers in the Law of Supply and Demand, and however the orange is sucked, or by whom, the recreational demand of our society continues to increase, and the supply of recreation areas in proportion to that increasing population continues to decrease. With that reality to face, doesn’t it seem entirely inappropriate to be discussing national park closures and divestitures? Or selling-off the public lands?

These public lands are much too valuable from an ecosystem and recreational standpoint to even half-seriously consider their liquidation. Do we really need less bikeways, greenbelts, wild and scenic rivers, parks, or fishing holes? We are convinced most Americans would say (and vote) for more, not less.

What is even more exasperating is that according to some people and groups (although they don’t say it this bluntly), our society should not even be addressing the needs of Americans yet unborn. It’s like saying our progeny won’t need or want these outdoor pastimes. This sounds a lot like use now, pay later. Only in this case, let our children either pay later or simply do without.

**NATURAL RESOURCES: LOCAL, NATIONAL, AND INTERNATIONAL**

We clearly need to understand and manage natural resources on a broader scale than the localized attention so common today. We need to look at scales that are regional, national, and even international to expand and capitalize on some of the good preliminary work already started.

Even now, ecosystems or components thereof can be identified, and conservation efforts could begin. The benefits would be instantaneous for resident species and a good start for species that need more room to roam. More knowledge about the migrant and emigrant (or exotic) creatures that cross state and national boundaries is essential, but we have enough knowledge now to begin conservation initiatives that would help.

But the sad and disconcerting fact is that not one regional ecosystem initiative in North America has gotten off the ground in any way more substantially than just rhetoric. The plight of the salmon and steelhead in the U.S. northwest is a perfect example and a priceless lesson in how not to manage a regional and international resource. The problems associated with neotropical birds—birds that migrate between North, Central and South America—are yet another perfect example. In addition to the lack of recognition of the need for such management, most areas within their wide-ranging habitats are being subjected to fragmentation and regional human population growth problems.

Yellowstone elk offer another example and lesson. Nine discrete herds summer in the park but only 12 spend their winters there. Outside the park, their warmer, low-snowfall winter ranges are being cut up by people for a variety of human enterprises, and most often, the elk lose. The species in question may not be elk in Louisiana, Maine, or California, but the story is the same for one species of wildlife or another throughout the Americas.

Or should we say *Fish and wildlife*? According to the American Fisheries Society, well over half of the native freshwater fishes in the United States and Canada are declining in numbers and distribution and require some sort of substantial public interven-
tion to stop the decline. The news about the status of amphibians, crayfish, and freshwater molluscs is even worse.

So what is the role of the national parks in light of all we have said previously? There are several roles and even more lessons we can learn from the national parks. Foremost and most obvious is the fact that the aquatic resources contained within parks have been, and will likely continue to be, increasingly vulnerable to the complex set of environmental factors that occur in- and outside park boundaries. The margin of error on whether this biodiversity is preserved in the future has always been small but never smaller than it is today. Second, it simply isn’t possible to preserve trout (or any other native fish) when their habitat is so degraded that it won’t grow crawfish and molluscs as well. So if we care about fish, we cannot ignore the environment a fish lives in and the creatures fish come mingle with.

THE CONFLICT BETWEEN SPORTSMEN AND ENVIRONMENTALISTS

Said in another way, if you are a sportsman, a hunter, or angler, you cannot afford not to be an environmentalist. Theodore Roosevelt could be turning in his grave if he was an observer to many of the conflicts observed today between sportsmen and environmentalists. If you are a sportsman using the outdoors and you are not an environmentalist, you are committing fraud; scamming the resource that is serving you.

In most ways, it is inconceivable that these two groups are at odds; are adversaries so many issues over the entire continent. Many of us can remember the “Sporting Paradise Lost,” the place or places you left part of your heart. Are they still there? Or have they been transformed into something entirely different; a subdivision or factory, or maybe they were just choked-off or poisoned like the Everglades, Great Lakes, or the Columbia and Snake Rivers. If you are a sportsman—or woman—but especially if you want your children to follow your path, you need to secure their future. We don’t know how that is done unless we embrace the environments you cherish.

In his book entitled Footsteps in the Jungle: Adventures in the Scientific Exploration of the American Tropics, noted biologist Daniel Janzen said:

Within the next 10 to 30 years, whatever tropical nature has not become embedded in the cultural consciousness of local and distant societies will be obliterated to make way for biological machines that produce physical goods for direct human consumption. In short, biologists are in charge of the future of tropical ecology. If the tropics of the world go under, the biologists of the world have no one but themselves to blame “It is up to us to make the world conscious of its interactions with the tropical living world. If we cannot set aside our personal interests, research and development, and put our entire effort to affixing permanently some of tropical nature, then we have sold the tropics= long-term fitness for a handful of instant gratification. We are the generation for whom the only message for a tropical biologist is: Set aside your random research and devote your life to activities that will bring the world to understand that tropical nature is an integral part of human life.”

Metaphorically, we would submit that from Yellowstone to Wood Buffalo, from Everglades to Denali, the whole world is the Janzen=s tropics, and we all are the tropical biologists.

In your professions and off-job pastimes, many of you have attempted to bring this concept and philosophy to the forefront. But we regret to say that in our view, it’s not enough; the ship is still sinking and probably faster than ever. Today, more than any previous time in history, it needs more and constant emphasis and above all else, it needs a hard-wired coalition of both sportsmen and women and environmentalists.

CONSERVATION AGENCIES NEED TO BE MORE FOCUSED ON OUTCOMES AND LESS ON OUTPUTS

This statement is the essence of Government Performance and Results Act (GPRA) passed in 1993 by Congress with overwhelming bipartisan support. It has not been noticed too much outside the federal government, but it potentially has great value in terms of our thinking about natural resource management.

For example, GPRA means it is less important how many visitors come to a national park than is the quality of the visitor’s experience. Many people in the fisheries business have known and promoted that concept for years. But now it is part of the statutory basis of the natural resources management business. In another example, it is less important how many board feet of timber is harvested from a forest than it is that the health of the land be maintained in a sustainable way.
Perhaps there is some hope in how we go about our jobs in the future.

**CHANGING THE REWARD SYSTEM FOR LAND AND RESOURCE MANAGERS**

We could instantly improve the state of the resource world if we could change the reward system for land and resource managers. The present system (with a few exceptions) far too often punishes the resource managers who step forward in the name of the national interest or who take the action necessary to promote good stewardship. All too often the measure of performance for a mid- or upper level government official is whether or not few issues arise during his or her evaluation period. In other words, "He is doing a good job because we never hear much political concern from the land or resource he is managing."

This is exactly the wrong test and precisely the wrong reward. No one wants to see or hear discord simply for the sake of discord (and there is some of that), but resource managers who stand for good resource stewardship should be rewarded by the resource agencies. Those rewards should be for making tough choices and decisions that promote sustainable resource practices. Instead, the measure of stewardship is typically the agencies' performance standards which almost invariably reward policing the status quo.

There are credible stories of Park Service executives in previous administrations losing their bonuses for taking positions that favor the land and not acquiescing to improper political pressure. We know of several who lost their jobs for the same reasons. We all know of events where land managers are not supported by their administrators. This negative feedback system is not lost on younger, developing land and resource managers, and it does not promote honest and professional management.

If the government system does not reward its individual managers, the non-government organizations and special interests will, which assures a higher level of chaos in our culture. All of us have an important role in preventing this from happening. We live in a time of questionable government credibility. In order to restore public confidence in governmental stewardship, it is critical that each of us share and buttress the courage and integrity of the resource stewards who are currently at the helm, and the younger men and women who are poised to take responsible positions in the future.

Finally, and without equivocation, it is clear that the world of trout, all over our nation including national parks, is changing. In the past several decades in Yellowstone, we’ve witnessed a remarkable change in public attitudes toward the wolf. In just 25 years, the idea of wolves evolved from an animal scourge and enemy to be avoided at all costs to today where they are our three million visitors’ “most desired wildlife to see.” This proves that not only are public attitudes changeable, they are also reversible!

This matters to those of us concerned with wild trout because we are learning that public attitudes about the aquatic life are changing too. Streams and lakes are no longer the sole domain of sportsmen. Non-game fish and other aquatic organisms have new constituencies that have T-shirts, letterhead stationary, and lawyers! All of the special interests that have affected resource managers in recent years such as the animal welfare and rights movements, the increasing interest in non-game species, and the entrance into the arena of non-consumptive user groups, are appearing in our lives with more and more strength.

This year, more people will watch fish in Yellowstone than will angle for fish. In fact, nearly twice as many visitors will observe fish than will fish for fish. Many will watch trout with the same affection they have for songbirds. Many of us are old enough to remember when the public viewed fish only as something to “limit-out on”, or to be recycled through a human digestive tract. Like it or hate it, there is a growing public out there who view trout not as objects of sport, but as finny friends, perhaps even as underwater butterflies.

To a great extent, the concerns of many of these people can be addressed by the way trout and other fishes are viewed philosophically in national parks. We treat fish more like first-class citizens. We recognize their equality with elk or grizzly bears or eagles. We restrict human consumption of fish so they can play out their role in the ecosystem by eating smaller wild creatures, and in turn, being eaten by larger wild creatures. We emphasize a substantial favoritism of the native fishes over the species that were introduced by the hand of modern humankind.
Trout Family Values
Wild Trout VI Banquet Address

Paul Schullery

I’m really pleased to be here. For many of us involved in trout over the past quarter of a century or so, the Wild Trout conferences have become landmarks in our professional lives, and it’s a real honor to participate like this.

A few years ago I was driving along the Yellowstone River a few miles north of Gardiner, looking for a good place to fish. As usual, it all looked good, so I chose a spot that also had a nice view. I parked my car, and, finding a sort of trail, climbed down the high steep bank to the river. On my way down I noticed a spin fisherman who had spread his gear out on some big rocks and was standing watching the water. There being miles of unoccupied river, I didn’t especially mind seeing him, and just assumed I’d pass him and walk upstream a ways.

But as I approached him, I noticed that among his other gear was a huge stainless steel handgun; it was a .44 magnum, but somehow it looked even bigger. Now I have to admit that even in my abruptly increased caution, I experienced the brief surge of disappointment associated with that class of Guy Moments in which you realize that someone else has brought a toy with him very similar to one that you left at home.

But this is Montana. If you run into someone equipped like that, you don’t just ask him what he’s doing; he might be waiting for the commies (or, even worse, the feds) to come up the river in their black gunboats, and he may just wonder if you’re some sort of advanced recon. specialist looking for a skirmish. But as it happened we struck up a conversation, and he seemed pretty normal for a fisherman, so I asked him what he was using the pistol for. He happily explained that he was ‘shocking suckers.’ By spotting a sucker and then shooting right next to it, he could stun the fish. He didn’t keep them. It was sort of a blast and release approach. He just stunned them and let them drift away.

Now the usual response of a high-strung fly fisherman to this sort of behavior might be condescension: what a dumb thing to do! Only a stupid redneck would waste time on something so pointless, instead of the eminently reasonable practice of snagging a fish in the mouth with hooks hidden in chicken feathers, playing it to exhaustion, and then letting it drift away.

But my own boyhood experiences out on the fringes of sporting propriety asserted themselves. In an instant, I was reminded of my pre-gunpowder years when I haunted the brushy margins of a small Ohio town with a BB gun and no idea at all of what I was legally allowed to shoot. The finest moments of that time-that is, the closest I came to approaching something like real sport-were spent with a friend trying to shoot minnows in the local canal. This provided a special challenge, because in order to hit a small, moving minnow, one had not only to lead it properly, but also to correct for parallax; the deeper the minnow, the bigger the correction. I got pretty good at it.

And so my response to this fellow was sympathetic, if still cautious. I said, “That, uh, sounds like fun. Is it legal?”

He took the question well, though it apparently hadn’t occurred to him to wonder about such a thing here in Montana. In fact, his reaction was pretty impressive: rather than pause to worry that he might be breaking the law, he immediately tried to imagine why it shouldn’t be legal, and the only thing he could come up with by way of objection was that the slugs, lying in fairly shallow water, might find their way into the digestive tract of some other animal, causing lead poisoning. Where we

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stood, surrounded by high banks, there was no risk of a bullet skipping across the water out into an inhabited area. We talked about it a little more, and I moved on. Of course I wondered if he really used the gun for trout, too, but I had the good taste not to ask.

As a nature writer I’ve devoted a good bit of energy to asserting that we should respect these so-called trash fish as much as any other animals, and to wondering why we don’t. But here was a wonderfully stimulating approach to the non-sport fish.

Judging from this guy’s attitude, it was clear that to him that suckers were appropriate targets because they were good for nothing else. They were biological junk, so they were essentially exempt from ethical consideration. Suckers had no moral context. For many years, suckers have swum around in those murky waters out beyond the boundaries of our sporting consciousness. Then this guy came along and ventured out there onto the frontier of sporting definition and, whether illegally or merely extralegally, pioneered a way to turn them into a sporting quarry—a way that might even involve letting them live after he had had his sporting way with them. That’s almost never achieved with a gun, so I don’t mind admitting that I was impressed.

Over the past several centuries, we sportsmen have engaged in such adventurism countless times. Every day, someone somewhere is testing a tradition, rearranging a personal sporting code, or simply trying something that seems new even if it probably isn’t. Some of these people are eventually hailed as great philosophical pioneers, and others just get arrested. But they’re all part of the great chaotic flow of ideas and techniques by which we redefine sport.

This conference is a great testament to this evolutionary process. I know that you all value native trout for other reasons than sport, but sportsmen continue to be the primary driving force behind trout management, and it must be some measure of their changing values that those of us who work for the management agencies are spending more and more time worrying about native fish. But like the sucker shocker I met that day, we probably have a lot more to worry about than we have time for.

For some years now, I’ve spent a lot of time studying concepts like ‘native,” and ‘wild,” and ‘wilderness.” Our culture’s perception of nature has changed dramatically in the past 30 years. The rise of environmentalism, not only as a major political force but also in academic disciplines ranging from conservation biology to resource economics to environmental history, has stimulated a very exciting and unsettling dialogue on the relationship between humans and the rest of the world.

Consider our perception of wilderness. Traditionally, and in many circles even today, we tend to define wilderness as a kind of pure natural Eden—a place outside of our control and free from the kinds of human interference that would occur in a settled or ‘civilized” landscape. Until very recently most history textbooks portrayed North America prior to 1492 as a “pristine” wilderness. Then, oddly, they acknowledged that it was a wilderness with people living in it. Humans lived there, these textbooks implied, but they were innocent primitives, subsisting on what they grew in small gardens and what they could take from nature’s overflow: roots, berries, fish, and the occasional deer or elk.

Well, we will be a long time sorting out how it reality was, but it’s already clear that for thousands of years Native Americans were aggressively managing and reshaping large parts of what we think of as North America’s “native ecosystem.” After all, there were probably at least seven million people living in North America in 1492, and more than that in South America. All you have to do is think of the food they required, and the sewage they produced, to realize that this may have been a wonderful place, but it probably wasn’t pristine, and it surely wasn’t Eden.

It is partly because of these new revelations about human influences on ancient landscapes that modern resource management dialogues bog down in endless semantic swamps. We may know more, but we keep applying our traditional values to our new information. Some people point to the pervasive human effects on the planet’s landscape over the past 10,000 years and announce that there is no such thing as wilderness, that nothing is wild any more. Predictably, they follow this assertion with “therefore, we have to do this or that to the
landscape, usually something to make more money or satisfy some moral or religious imperative they hold dear.

Other people attempt valiantly if inconclusively to persuade the rest of us that we must somehow rethink all of this so that humans are fully integrated into the rest of nature—that when it comes to nature, there is no qualitative difference between an osprey, an otter, and a dry-fly fisherman. These assertions are likewise supported by equally heartfelt moral, religious, or economic impulses.

I wish all these philosophers the best; they’re on a noble quest, and in the long haul they’ll probably have more effect on public attitudes about nature than all the ecological studies we place so much faith in. I just wish they were paying more attention to trout, because we have some wonderful questions to answer about trout and how we choose to deal with them.

Sixty years ago, Albert Hazzard defined a wild trout as one that was planted in the stream when it was small; by growing up and surviving there, it became wild. Over the years since then, we came to regard that as too easy a definition; we wanted our trout to be several generations in residence before they were wild.

But wild isn’t the same as native, and among managers, conservationists, and apparently a growing number of fishermen, native is getting to be a pretty important word. As we have introduced non-native fish not only to fishless waters, but also to waters containing native fish, we have lowered a kind of ecological eggbeater into some glorious native ecosystems, resulting in changes that, though they may have been wonderful for fishermen, were disastrous for these beautiful little worlds that had been cranking along just fine since the last ice age without our help.

Those of us who love trout and trout fishing are going to take an increasing number of hits for this behavior; we already are, so I think it’s worth considering how we look to people who value nature and nativeness for other reasons. We go into a trout stream or lake and we roll rocks and build deflectors and otherwise reshape it to our purposes. We introduce non-native sport fish whose qualities we prefer. We either ignore their effects on the native fish, or actively seek to remove those natives, perhaps even introducing non-native forage fish to further complicate the evolutionary crapshoot we’ve set in motion. We do all these things, and in no time at all we’re celebrating the high quality of the “wild trout fishing” we have created. In some circles, of course, humans by definition can’t create something wild in the first place, but in even more circles, there’s not much wild about such a manufactured fishery.

On the other hand, our growing interest in native fish seems to be the next step in reconsidering what really constitutes a wild trout. Managers who sustain huge, complex fisheries through non-native or exotic species, whether those species are fresh from the hatchery or 100-year resident populations, have been made pretty nervous by the native trout recovery movement, and they have reason to be, because the logical consequence of this new direction is revolutionary. We’re exercising some pretty major value judgments here. We appear to be heading toward a new definition of wildness, admitting that in fact the wildest trout is the one that is the evolutionary product of the ecosystem in which is lives.

We therefore seem to have recognized a new standard of authenticity, one that has as much to do with preserving native ecosystems as with preserving native trout. It’s a big assignment, and in many places it is more or less impossible with today’s technology and social needs, but it gives us reason to dream about the fishing we may have someday in the future. In short, since Hazzard’s time, wild trout fishing has become more and more a setting-dependent sport.

Anyone who has read Walton knows that for centuries, fishing writers have stressed the importance of the surroundings of fishing in beautiful places, whether their definition of beautiful required a manicured rural countryside or a howling wilderness. But now, the fish and the setting are becoming more integral; the best setting, according to this new view, is the setting that still has the trout that developed there in the first place, whether they have survived continually or we have restored them.

But we still have some hard questions to answer, and some hard decisions to make. Letting trout be totally wild, and enjoying them on the terms that “totally wild” implies, isn’t as simple as it sounds.

It is a common human vanity to assume that the earth as we see it today is somehow a finished product. Fishermen tend to presume something like
that. But all the processes that shaped the modern American landscape, whether geological, biological, or climatic, are still acting today, unless we change them or stop them. Nature isn’t done with our trout streams. We’re still mighty uncomfortable with all those things that ecologists think of more neutrally, as disturbance. We’ve eased off on killing trout predators, but we still hate spring floods, debris flows, fire, anchor ice, and everything else that may kin fish or put the water out of shape for fishing. We’re still a long way from accepting wild, native trout on the terms of the world that created them.

In 1988, Yellowstone’s wilderness put fishermen’s attitudes about wild trout to the test, and a lot of us who claim to prefer our trout wild got pretty low grades in that test. Though fires on this scale have been shaping this landscape for thousands of years, we got pretty ticked off about the short-term aftermath of that shaping process. In 1989, we found some of our favorite trout pools surrounded by blackened forests, places that, though already covered with the first new green growth, would lack the old photogeneity for many years, probably longer than our remaining lifetimes.

For these people, picturesqueness and stability were more important than naturalness, and I do have some sympathy for them. If you only had a few days to spend here, and that week a summer thunderstorm washed a huge amount of loose ash down through your favorite stream, the fires of 1988 wouldn’t seem like a pretty awful thing. You might object that maybe trout fishing shouldn’t be quite this wild.

But even if the thousands of fire-fighters who spent the summer here had been able to stop these fires, I’m convinced it would have been a bad idea. No one can claim to care more about Yellowstone fish and fishing than I do, or to feel more indebted to these wonderful streams for all they’ve added to my life, but here, at least, we can define wild trout as trout that live in a really wild place—not a perfect wilderness, but a remarkably good imitation of a North American landscape prior to the arrival of Columbus. Those same summer thunderstorms were also washing nutrients into the streams, and jump-starting vast and vital ecological processes across the landscape. I refuse to believe that even if we were able, we should short-circuit all that just so that trout can see my dry fly better.

The poet Robinson Jeffers asked: “What but the wolf’s tooth whittled so fine/ The fleet limbs of the antelope.” Far less poetically but at least bluntly, I would ask: What but the wild river’s unbridled power shaped/ Every single quality we love in trout? The very forces that had so much to do with shaping the trout we admire—the violent extremes of environment that provided these species with the tests that turned them into our favorite fish—are a critical part of their wildness.

I have benefited beyond measure from the things we do to trout streams and trout in the name of good fishing. From the highest smallest Sierra creek to the lowland rivers that empty onto the eastern Piedmont, I’ve immersed myself in the joy of this great pursuit and the wonder of the fish that I am always surprised to catch. But I’m enough of a naturalist to know that there’s some difference—some tangible and important difference—between the brook trout I catch in the Sierra creek and the superficially identical fish I catch in the Blue Ridge. Neither fish is less a marvel, but in evolutionary terms, one has the weight of thousands of years behind its occupancy of its little pool and the other just arrived shortly before I did. Context makes the catching different in a way that matters to me even if it doesn’t lessen my delight at catching a fish at all.

I don’t always give a lot of thought to all this as I fish. But every once in a while, when I pause to admire a brook trout taken from a Yellowstone stream, I get a flash of memories of the Blue Ridge, the Green Mountains, the Smokeys, or some other place where I’ve similarly admired its kin. Then my mind is off on another rumination of how far these trout traveled on their own, and how much farther they came with our help, and I can’t help feeling that we’d have been better off if we’d never taken them anywhere.

So in the past few years I’ve come to some conclusions that I have to admit surprise me. They come from trying to integrate my feelings about the natural world generally with my love of trout fishing. I’ve decided that if an adequately powerful fish deity came along and gave me the choice, I’d probably prefer that the Madison River contained the kind of cutthroat and grayling populations that Lewis and Clark found here.
If I had my druthers, I'd rather that today's Letort contained the tremendous populations of native brook trout encountered there by George Gibson, one of our first sporting journalists, when he learned to fly fish on that stream in the 1790s.

I'd rather find today's Ausable full of the Michigan Grayling that Fred Mather caught there in the 1870s. As much as I enjoy fishing for them, I'd give up browns and rainbows and brookies in a lot of places if I could have the real thing instead.

I recognize that on the immediate practical level, this is an academic exercise, if not sheer fantasy; those non-native fish are here to stay, and I'm not going to avoid any of those streams because they don't have native fish. I may be a purist but I'm not stupid, and having an ideal does not mean abandoning reality; it means keeping perspective, and knowing the difference between wonderful trout fishing and wild trout fishing.

In our urge to protect native trout we are struggling toward a kind of authenticity that we long sensed was lost to us. We are not alone in that impulse. Our society, through a raft of protective legislation sponsored and passed by people who care about nature without necessarily caring about fishing, has decided that native life matters. The realities of our technological limitations and our social preferences ensure that native trout restoration and native trout fishing purism aren't likely to change too many things too fast. But it should help us to have ideals of this sort, however unachievable, against which to measure our progress in the real world.

It should also help us in a world where more and more people are suspicious of us anyway. Fishermen still tend to think of themselves as harmless types, doing this peaceful thing in beautiful places, but the entire world is now the sphere of conservation biologists and other people who place a previously unimagined premium on ecological wholeness. In the eyes of many of these people, earlier generations of fisheries managers and fishermen are now seen as the chief culprits in the diminution or destruction of thousands of native aquatic systems. The precious few remaining waters that are still in pretty good shape are guarded jealously, often by people who haven't the slightest interest in fishing; they just love native systems.

Of course we also need to be on better behavior because fishing is getting increasing attention from the same people who are currently making life so hard for hunters-people who just can't imagine what fun it could be to kill fish, and who may regard catch and release as an even greater moral outrage. Our own values are under attack by people who see themselves as enjoying nature in a superior way, one in which the beauty and wonder of nature are best appreciated without such direct hand-to-mouth use of its creatures. Few minds ever change in such debates, but the extent to which we successfully defend our own values will probably be the extent to which we aggressively care for the kinds of values we find in native trout ecosystems. In doing so, we will also show we are still the best friends that wild trout have.

Starker Leopold, world renowned scientist, dedicated teacher, distinguished author, outstanding naturalist, beloved angling companion to many who shared streamside visits, and an influential speaker at both Wild Trout I and II died in 1983. His death occurred about a year before Wild Trout III at his home near the Berkeley campus where he had taught and was the retired head of the Zoology Department. So many of us miss him.

I was privileged to share membership with Starker on a number of commissions and advisory boards on fish and wildlife issues during my career in the U.S. Department of Interior. I saw him last at an evening angling trip on the Lamar River where he cooked a skilletful of cutthroat for a few of us who stayed in the park following the 1979 Symposium.

Nathaniel Reed, former Assistant Secretary of Interior and the federal official who first publically announced the idea of a Wild Trout Symposium in 1973, suggested that recognition be given to individuals who over their lifetime have made substantial contributions to the conservation of trout and salmon and their environment; the award to be given in honor of Starker. The organizers of Wild Trout III enthusiastically concurred and the first recipients were recognized at the 1984 Symposium. Since then the awards have been given at each Wild Trout Symposium to one each in the professional and non-professional category. I think you will agree with me and the Awards Committee that the recipients at this gathering fit well the high standards called for in the selection process.

The Awards Committee is made up of former medal honorees (see Wild Trout II, IV, and V). Today the A. Starker Leopold Medals will be presented by Marty Seldon of Sunnyvale, CA, a 1984 recipient, and Gardner Grant of Purchase, NY, a 1994 recipient.
Ernest G. Schwiebert

Ernest G. Schwiebert became a serous angler at the age of 5 when his cast into a Michigan creek yielded a 12 inch book trout. He holds a doctorate in architecture and urban planning from Princeton and enjoyed a career as a respected teacher and planner/designer.

Ernie's contributions to wild trout and salmon, their genetics and their habitat have been principally in his writings, (books, magazines, newsletters) his lectures (conservation and fishing organizations, educational institutions) and in his research in fishing-relevant stream entomology. Thru his writings and lectures over the past forty years, he has given generations of anglers and fisheries professionals insight into the importance of wild salmonids. The well-known editor, John Merwin, wrote:

Ernest Schwiebert has probably written more authoritative flyfishing material than any other author, living or dead. Subsequent books to Matching the Hatch, such as his remarkable Nymphs and the lavish two-volume Trout, have demonstrated his extraordinary depth as a writer, and a keen perception of flyfishing's most intriguing and enjoyable problems. He is a master at instruction by anecdote, and I caution you not to miss the lessons between his lines.

The lessons between the lines have always centered on preservation and enhancement of the environment vital to wild trout and salmon.

Ernie was a pioneer in the environmental movement and was involved in the founding of Trout Unlimited, Theodore Gordon Flyfishers, Federation of Flyfishers, and other similar organizations. He has served as a director of both Theodore Gordon Flyfishers and the Atlantic Salmon Federation, and on the scientific advisory boards of TU, FFF, the Nature Conservancy, and others. In recognition of his contributions, a chapter of T.U. in New Jersey was named for him.

Many here will recall that Ernie was our banquet speaker at Wild Trout IV in September of 1989. His address, "Elegies and Epilogues" was eloquent and beautiful and gave special meaning to the scientific and management efforts that were the subject of our deliberations there.

Ernie has spent much of his life as a teacher, as befits a Ph.D.. Past recipients of the Leopold Award have been recognized chiefly because of their leadership or active participation in work beneficial to wild trout and salmon. Untold numbers of anglers and fisheries professionals have gained knowledge and inspiration to spur their efforts thru the spoken or written words of Ernest Schwiebert — and it is this vital contribution that merits Leopold Award recognition.
Roger A. Barnhart

The Wild Trout VI A. Starker Leopold Award, in the professional category, has been awarded to an individual who has been involved in these Wild Trout Symposia since the beginning, devoting tireless effort to our benefit. He presented a paper on Pacific Slope Steelhead Management at Wild Trout I in 1974 and a paper on a FFF Whitlock Vibert Box hatching system project at Wild Trout II in 1979. He was Chairman of Wild Trout III in 1984 as well as serving on the Programs, Logistics and Editorial Committees. He was Program Chairman and on the Logistics Committee in 1989 at Wild Trout IV and in 1994 was Symposium Cochairman of Wild Trout V.

We have the honor to present the Symposium's A. Starker Leopold Award to Roger Barnhart, former Leader of the California Cooperative Fishery Research Unit, Humboldt State University, Arcata, California.

Dr. Roger A. Barnhart received his BS, MS, and Ph.D. in Fisheries Science from Colorado State University. For 28 years he was Leader of the California Cooperative Fishery Research Unit and Professor of Fisheries, Humboldt State University, Arcata, California, retiring in December 1995. Dr. Barnhart planned and supervised research particularly emphasizing investigations of factors affecting anadromous salmonid production in coastal streams and estuaries. During his tenure at Humboldt State University, he personally supervised the research of over 50 graduate fisheries science students, the majority of whom are actively working as professional fisheries scientists today.

Dr. Barnhart was an active member of the American Institute of Fishery Research Biologists, Pacific Fishery Biologists, and the American Fisheries Society. He served as President of the Humbolt Chapter of the American Fisheries Society in 1994-1995 and in 1997 received the Western Division American Fisheries Society Award of Excellence. He has presented several papers before these scientific societies and is the author of over 20 published papers.

Dr. Barnhart sought to provide research with practical management applications as was his work on the Hat Creek Wild Trout Project, life history studies of the steelhead of the Klamath-Trinity River system, and research on aquatic habitat improvement and rehabilitation. He planned and co-sponsored the first national symposium on Catch and Release Fishing as a Management Tool, in 1977 and a follow-up symposium, Catch and Release Fishing - A Decade Later, in 1987.

He previously was Leader, Georgia Cooperative Fishery Unit, at the University of Georgia and was a Senior Fisheries Biologist with the Colorado Department of Fish and Game. Dr. Barnhart has been an educator, a long-time consultant to the California Department of Fish and Game, and a widely sought fisheries committee member. He is presently a member of the California Advisory Committee on Salmon and Steelhead for the State of California, and is actively supporting programs to mark all hatchery steelhead, and require the release of all wild steelhead.

Dr. Barnhart has devoted his entire professional life to improvement of our wild trout fisheries and the development of exceptional graduate students to carry his efforts on into the next century. In 1991, he received the Trout Unlimited National Conservation Award for professional activities in behalf of wild trout management and conservation. He is well deserving of this year's A. Starker Leopold Award in the professional category.
The Role of Public Education in Native Trout Management

Robert H. Wiltshire

Abstract—Fisheries managers increasingly are utilizing innovative strategies for preserving and restoring native trout populations. These new strategies often conflict with long held angler beliefs. Yet, anglers are the core supporters of most wild trout issues. If public support is important to the success of a native trout program, a broad-based education effort must be undertaken. Education has already caused trout anglers to dramatically change their attitudes and actions. From an ethic of catch and keep they have progressed to catch and release and a preference for wild trout. This change has come over a period of time, the result of repeated exposure to the new ethic. If anglers are to take the next step, valuing native populations over introduced populations, the native species message must be repeatedly reinforced. To effectively teach about native trout all types of education and communication need to be used. Managers must look beyond normal agency efforts and utilize all possible education techniques.

INTRODUCTION

Most native trout restoration or preservation strategies use existing management. One of the most basic, and effective, tools used by managers is controlled harvest. By adjusting seasons and limits managers can profoundly affect wild trout populations. No kill, slot limits and reduced harvest have all been used successfully for many years to enhance fishery resources across the country. Managing for natives has lead managers to explore additional uses of regulations. Species specific regulations have become common in many areas. These regulations encourage harvest of non natives while native populations are protected. In a still more aggressive action several waters now have mandatory kill regulations that mandate that all non natives must be killed and not returned to the water.

Restrictive regulations are a viable long term native trout solution on relatively few streams. Far more common are waters with the capability to maintain significant native populations that need total rehabilitation. On these waters the non natives must be removed and all opportunities for reentry eliminated before restoration can be successful. These restoration efforts often become subject to intense public scrutiny. As would be expected the degree of public interest correlates strongly with the level of fishery supported by the subject stream. In barren headwater areas there is generally little opposition to a restoration project. However, when a possible project includes a popular public fishery there is often significant opposition to the proposal.

Often the opposition to restoration projects comes from those that should be advocates for the process. Anglers in general and fly fishers in particular are the natural constituents of wild trout managers. Anglers are providing the funding and feedback that are the basis of most management programs. When anglers strongly support a project or concept there is generally nothing that can stop the success of the project. However, if the angling public does not feel a part of the process they quickly move to modify the undertaking. This is not a new development as anglers have always had a profound impact on fisheries management decisions.

Today, however, there are many new constituents for fish. While traditionally anglers were the only client group to be considered in making management decisions, today new voices have entered the debate over the future of our fishery resources. These new voices represent a wide range of opinions and ideals often not advocated by anglers. Some argue for increased protection for our fishes while others believe that fish must fit into their notion of what the natural world should be. Let’s look at an example.
In May of 1997 American Wildlands filed a petition to list the west slope cutthroat trout as a threatened species throughout its range. While American Wildlands is a dedicated conservation organization working to improve the health of the Northern Rockies Ecosystem, they are not known as a fishery organization. Their interest in a healthy ecosystem led them to conclude that the WCT could be a focus point for their campaign to change public land use. The result is an entirely new client group that has a significant interest in the management of our native trout.

This is just one example of the types of new voices that enter fishery management debates. Others with significant interest include various industrial concerns, animal rights activists and other water recreationists. These groups and individuals have an increasingly important voice in how our fisheries resources are managed. Many biologists and managers today are finding that having the best possible science is no longer the only requirement for establishing management priorities. Today science is only one factor, often not a large factor, in making management decisions. Many decisions are being driven more by political and social pressures than by research and data. In too many cases we find that administrative decisions favor those who speak the loudest, or into the right ears.

For the biologist or manager attempting to proceed with a native trout program these new realities require new strategies for success. The single most important ingredient of native trout management plans is public education. Gone are the days when an agency could implement policy changes because they were best for the resource. Today to be successful in changing management it is critical that the public in general and anglers in specific be partners in all changes of policy. These partners will only be developed through education.

When we set up an education program geared toward native trout we can use the old journalism standby. Every education effort should include: who, what, where, when, why and how. Most of these are very easy for us to answer. The who is the fish. The what is the proposed project. The where and when are easily answered with project specifics as is the how. The education problem we face is the why.

Why should we care about our native trout? Some form of this question is asked whenever a native fish project is proposed. Unfortunately we do not seem to have a ready answer. Most of us know that we very strongly believe that we should manage for the natives. However, we cannot articulate to others why this is. Those of us who are pressed have found our own ways of stumbling through an answer, but, few of us have found a way to communicate to others what we really feel.

When the notion of wild trout management first started to develop, we found a willing audience to listen to a story many professionals never had to tell. Wild fish are superior to hatchery fish. The thrill of fishing for a trout produced by wild parents in a free flowing water carried a glamour that was easy to communicate. Scores of writers competed to publish stories extolling the virtues of wild trout. As a fly fisher it was hard not to be exposed to the story of wild trout. This movement had a strong message that played well with its audience.

Similarly catch and release fishing was an easy sell to the angling public. The message was clean and simple. “A good game fish is too valuable to be caught only once.” Again we saw this message bombard us, from the covers of magazines to the Saturday morning fishing shows to our local club meetings we were constantly reminded that the ethical angler practiced catch and release.

If we contrast this with native trout issues, we find a very few public endorsements of native fish. Magazines, books, videos and public speakers all focus on the sport, wild trout and catch and release. We need to get out the message of why we should care about our native species. Unfortunately, as opposed to catch and release and wild trout, there is no easy answer.

It seems to me that the answer to “why native fish?” will vary according to the person asking. We all have our own values and ideals. Since we have been unable to come up with a one size fits all answer to why we need to tailor our answer to fit the questioner. If we are to do this we must have a why that will suit anyone.

Two fundamental philosophies usually determine how we view our natural world. These are the anthropocentric (human centered) and the biocentric (life centered) philosophies. Anthropocentrists believe that our natural resources should be managed for human use, now and in the future. Biocentrists believe that we should manage our resources not for their worth to humans but for their value as a part of the natural world. While the two philosophies often
feel that the same action is correct they can reach that conclusion for very different reasons. As we look at native fish preservation issues, we see are very valid reasons from both philosophies for preserving these species.

ANTHROPOCENTRIC VALUES OF NATIVE FISH

Recreation Value

Native fish represent unique forms and often offer sport that is not attainable from other sources. When the last redband trout is gone, we will never again have the opportunity to say "I caught one." Our native fishes also present us with unique attributes that are often not found in introduced species. As an example many of our cutthroat trout have evolved in unproductive waters making them aggressive feeders thus more vulnerable to angling. As such, they give anglers with less refined skill the opportunity to catch fish. Many a child has caught a native cutthroat trout as their first fish.

Nutritive Value

Native fish offer a different nutritive value to the angler. Many anglers prefer the taste of native fishes to those of introduced species. They also can offer a variety of nutrition as in white flesh or red flesh, dry or oily etc.

Aesthetic Value

Native fish can do much to improve the aesthetics of our natural world. The colors of a Golden Trout taken fresh from a high mountain lake are never to be forgotten, The sight of Yellowstone Cutthroats swimming under fishing bridge in Yellowstone Park fires the imagination. Natives add to the beauty of our natural experience.

Economic Value

Native fish have tremendous economic value. This has been proved repeatedly in scientific studies. Their contributions have been measured in several different ways. The presence of native species has long been used as a tool for measuring the health of a natural system. Those systems that have native species are healthy systems. Studies show direct links between the health of an area's natural systems and the health of that area's economy. A healthy environment and a healthy economy are directly related.

The value of native species has been shown even more directly through several studies.

In various studies respondents indicated that they would be willing to spend between $7 and $181 per household per year to preserve native trout and salmon species. Other studies have documented the one time payment value of natives at up to $17 per person. These studies were all for the passive or existence value of the fishes.

Many other studies demonstrate the value of fishes for active (fishing, viewing etc.) uses. There have been many studies about the economic value of native fishes. For the sake of this paper we can just assume that there is definitely an economic value to native fishes.

Potential Value

This is the value that we have yet to realize from these fishes. It can be value of several types. The most obvious is unrealized value. This is a value that we have yet to discover. It could be a medicinal value or an agriculture value, or could be a value such as a resistance to certain disease. We will be far poorer if it turns out that a now extinct race of rainbow was the one that was resistant to Whirling Disease. Because we have no way of knowing what we don't know about a fish it always has a potential value.

Cultural Value

Many native fishes have a strong cultural value. To many Native American peoples certain fish have a unique and irreplaceable value. We also find a cultural value from a sporting history perspective. Many families pass along a fishing heritage by joining together to fish for native species. Here in Montana it is very common to hear people reminisce about learning to fish while pursuing native trout.
Bequest Value

This is the value to us that comes from knowing that we are passing on to our future generations the opportunity to fish for these unique native species. This value must not be underestimated. We all want to know that we have done our best to leave happiness to our children and grandchildren.

Satisfaction Value

This value comes from knowing that we have done our best to aid a species. Of course as with all of the other values this varies among all of us. However, to many the satisfaction of knowing that they have helped cannot be given a value.

Legal Value

Native trout have definite legal values. This is most directly demonstrated by the Endangered Species Act. Under this legislation our native fishes are given strong legal protections.

Future years may see an increasing degree of legal value placed on our natives. Organized groups and individuals maintain that our fish have rights of their own. While not a mainstream belief at this time we might find a future political climate that is accommodating to this point of view.

BIOCENTRIC VALUES OF NATIVE FISH

Speciation Value

This is the value that comes about through evolution. Native species are unique products of evolution as such they need to be cherished and protected. In addition native species present unique opportunities for future evolution. No one can know what a species will evolve into. Therefore, we must preserve the greatest number of species possible to allow for the greatest amount of future evolution.

Healthy Watershed Value

To protect and preserve our native species we must protect and preserve their habitats. We cannot save a native species without saving its watershed. This has a benefit to the natural world beyond the fishes. Healthy watersheds mean habitats for bids mammals. Insects and all life. By protecting the native fish we protect the natural world.

Existence Value

This says that fish, and all life, have an inherent value of their own purely through existence. This is the value that is involved when we feel that we need to preserve a native species because it is the “right” thing to do. This value has been talked and written about for a long time. I feel that it is well described in the words of Holmes Rolston III (1991) “The deepest reason to deplore the loss of these fishes is not senseless destabilization, not the loss of resources and rivers, but the maelstrom of killing and insensitivity to forms of life and the sources producing them. This final imperative does not urge optimal human use and pleasure or prudent reclamation, but principled responsibilities to biospheric earth.”

As we examine the various why’s we find that to each of us one or more of these seem important while others seem insignificant. Yet, if we were to compare our most important why’s we would quickly see that we don’t all agree. By presenting many answers to why, we allow an individual to choose the answer they most want to hear. We must allow that the acceptance of any of these answers is the result we need to achieve.

Most of us accept that we need to do a better job of communicating why we should be concerned about native trout. The preceding has been intended to give you some possible answers, but, we still need to explore the best ways to convey the message. We need to look at telling the native trout story in as many ways as possible. We need to look for new ways to communicate that involve all types of media.

To try and cover communication and education would take far more time and space than we have available. I will cover briefly what I believe are some of the areas that can be most effective.

The most effective method of telling the native story that is available to most biologists and managers is the personal presentation. This includes formal and informal presentations. All types of meetings including, sporting groups agency public meetings, professional society meetings and special topic meetings would be examples of formal presentations. Other formal situations would include classroom presentations and media interviews.
In all formal situations you will have some opportunity to prepare your presentation and with a little advance planning you should be able to include the message about native trout in any formal presentation. Informal situations require you to be ready to talk about natives with no advance notice. You can only be successful at informal presentations if you are comfortable with your message and have presented it in enough forms that it flows freely from you. Informal presentations occur everywhere, in the grocery store or post office, at the local coffee shop, or on the streambank. Look for the opportunity to tell the native trout story and you will find it.

Besides verbal presentations there are many opportunities to communicate through written presentation. These include agency publications, popular press articles, streamside signing club and society newsletters, and press releases. These all require some planning and preparation however, all are available to most fisheries' managers.

It is especially important to get the native trout story into the popular press. If anglers are an important constituent group, they must be reached through efforts geared at them. This means getting the story into the magazines and newsletters that they read. While many might agree about the importance of this, they question their ability to get their story into press. It is not difficult to get the story of native trout into the popular press. It is not necessary for biologists and managers to write the stories to convey the message. It is quite easy to interest freelance writers in telling your story for you.

Many writers are constantly looking for new ideas to form the basis of their work. They are often very grateful to the professional that alerts them to a new story. They are experienced in writing to anglers and will put your native trout story in a form that readers want. They are often eager for the information that a fisheries scientist can give them and many will repeatedly call for information on other fisheries issues.

To successfully communicate the native trout message we must also develop effective visual education materials. Many people find a discussion of the value of a native trout to be rather abstract until they are presented with visual images. This presents a major problem for most native trout because there are few visual materials that focus on natives. To instill the public with a sense of value for our natives it is important that we develop the necessary visuals. This starts with photos. Many native trout are only found in small numbers scattered across their historic range. This makes it difficult for those who are interested in the fish to find them. It makes it impossible for the non-angler to be exposed to them. It is critical that every fishery professional who works with native trout makes a serious effort to gather quality photos of the fish, and further, to try to distribute these photos. If the only way to know some of these fish is through photos we must insure that the photos are available.

Besides photos there are many opportunities to create video records of these fishes. Agencies often have staff who can work with field personnel to create quality video presentations. These can be used in many ways and are always a valuable addition to the story of native trout. In addition there are opportunities to partner with the commercial producers of video products to get out the message. These potential partners include local television stations and freelance video producers. These video professionals are much the same as print professionals. You will often find that they are easily excited about a story that you bring to them.

There are certainly other excellent opportunities for public communication. The expanding world of telecommunications and the Internet open the doors for many exciting opportunities. Radio has long been a source of information for many people and you will find that it is quite easy to get air time for public service announcements as well as news coverage for press releases. There are many innovative possibilities for achieving greater visibility for native trout. Corporate partners, adoption by school and community groups, native trout festivals, computer promotion opportunities (how about a set of native trout screen savers), songs and stories, coloring books, etc. are all possibilities. There are no bad ideas, anything that increases the visibility of the native is beneficial.

The success or failure of native trout management will be affected by many factors. We must all work to insure that lack of education is not a factor in the failure of any program. Continual efforts to tell the story of our native trout will result in an educated public that will support all reasonable efforts. Day in and day out we must look for every opportunity to convey our message. Education is the responsibility of all of us.
Lure Them Into Learning...
The ABCs of Aquatic Education

Rebeca Franco

Imagine yourself a ten year old trying to sit still while a fishery biologist speaks extensively about fish adaptations. How about imagining you've just put in a long day at the office and are attending an evening neighborhood watershed meeting. The local expert spends 20 minutes describing how contaminated ground water affects aquatic species. For some, it's interesting to learn a scientific concept via the expert's vocal chords. For others, active learning works better. Movement education has become popular in its effectiveness to teach a myriad of subjects through creating a whole body experience. We all learn differently, so why not convey information with that in mind? This session will give the "how to's" of capturing interest to accomplish learning.

PREPARE YOUR TACKLE BOX

Fish are interesting on their own, so the trick is enhancing the information delivery system. Whether the audience is in kindergarten or career professionals, have some handy tools to complement your topic. Sometimes groups request information about fish in general and the specifics are up to you. As a fisheries enthusiast, this is a perfect time to present favorite subjects like water quality, riparian systems, aquatic insects, or fish anatomy.

Do you have all the teaching aids you will need, especially for an indoor program? Following are a few examples of how to prepare for your presentation:

Water quality: Water samples containing silt, sodium chloride, vinegar, etc. for the audience to test with pH paper, a secchi disk or other testing devices.

Aquatic Insects: Bring macroinvertebrate samples and Discover Scopes (small plastic field magnifiers) or a microscope. Laminate a simple insect key and let them decide what they are looking at while receiving guidance from you. At that time, you might point out the functional differences and where the insects are found in the stream.

Fish Anatomy: Dissect a fish, point out organs, and have the audience guess how they are used. It is easier to understand fish if compared to humans. No real fish available? Use a model to take apart or even distribute a simple fish drawing for the group to fill in the names of the parts as they are discussed.

What about the location of the presentation? Are the facilities what you want? Look at tables, moveable chairs, a screen, outlets, room size, air circulation, and the nearby outdoor area if that is part of the plan. If outdoors, will there be a bell ringing or a lawn mower working during the session? Distractions can sometimes be deadly or be a "teachable moment", if it's wildlife!

Who is the audience? It is very possible to draw upon the same presentation for both a third grade class and a group of adults, especially with an interactive approach. Adjust the communication up or down as needed, and implement some of the techniques mentioned in "Lure Them In." With most groups, sending information ahead will go a long way to preparing them for you.
Lure Them In

Most of us grew up learning one way. Our teacher who "knew everything" lectured all day long. We would become excited when slides, a movie, or a guest speaker changed the routine. Going outside was the best school day possible, and that happened all too infrequently. People generally teach as they were taught, recycling the same methods. Thank goodness the contemporary education system is including more relevant concepts and methods.

Now you are there. Introduce yourself and tell a little about your background. If possible, try to meet audience members to increase familiarity. Go ahead and show your enthusiasm. It is contagious! Ask questions that lead to where you want to take them. Establish eye contact. Walk around the room and interact with the audience.

Focus their attention. Provide structure and activity. Look around constantly to be certain the crowd is with you. Help them sharpen powers of observation. Provide worksheets and activity. Break them into smaller groups for analysis or brainstorming and ask them to report the outcome. Keep everyone on task. Change voice inflections for greater effect. If with young students in the classroom, make sure the teacher is there to help with discipline and organizational support.

Direct the experience by providing an atmosphere where learners explore and find answers for themselves. They will remember the subject matter much better that way. If there are inquiries you cannot answer, and with natural resources that may occasionally happen, don't misinform. It is better to research answers and get back to people than to give erroneous information. After a question, repeat or rephrase it for the benefit of the rest of the group, or redirect it to other experts who may be present. Throughout the session, continually ask questions to summarize and reinforce what you want them to know. Keep the presentation active. Have fun and use humor! Once lured in, enjoy your catch! If slides and/or overheads are in the program, now is the time to show them.

Testing the Waters

Providing post information can be helpful in reinforcing the learning that occurred while you were there. In a classroom situation, teachers appreciate other related information for their lesson plans. They may also test students based on your presentation and follow-up.

Using the fish anatomy example from “Prepare Your Tackle Box,” materials on how fish are like airplanes or on the evolution of derived characteristics, from prehistoric to current times, could be helpful in enhancing the anatomy basics you originally conveyed. Many of the federal hatcheries have connect-the-dot fish, crossword puzzles, and other fun activities for public distribution that can be added to your post information packets.

Different Bait for Different Fish

What does it take to help people truly learn what you are trying to disseminate? People absorb information differently, and the key to teaching effectively involves using multiple senses. Writing, problem solving, art, music, movement, interpersonal communication and self-directed activities can all be ways to learn. It would be a huge task to appeal to all learning styles. Interactive presentations will do much towards using assorted senses than a lecture. Guiding someone through a problem as they work it will impact the memory more than giving all the answers up front.

While often the same activity can be conducted with both adults and children as mentioned before, there are differences in how they learn.

1. Adults want to learn something they can use right away; much of what children learn is meant to be used throughout their life.
2. Adults bring a wealth of experience to a learning opportunity; in comparison, children’s life experiences are very limited.
3. Adults know what they want to learn; children often don’t.
4. All adults learn differently and at different rates; children’s learning styles can be different, but they are at similar developmental stages (CamoZZI 1994).

Fish’s Assistant

Whenever anyone on the stream bank or in a social situation asks you a question related to our finned friends, you become the fish’s assistant. You have
the time to know those aquatic jewels and they in turn may have brought you interesting insights. The way to spread accurate information about habitat needs, migration patterns and other aquatic ecosystem facts is through education. The way to truly reach others with your message is by appealing to the senses. Some easy to use activity guides that can help are Project WILD Aquatic, Project WET, and Project Learning Tree. Contact your state aquatic education specialist about these and other free or inexpensive teaching aids. A masters degree in education is not required to teach! Practice the techniques presented in this paper and find how easy it is to lure them in...

Acknowledgments

I'd like to credit Sandy Noble who helped edit this manuscript and Carol LoSapio for answering many questions.

Literature Citations


M.K. Brewin

Abstract - Bull trout were historically the most abundant and widely distributed trout or char in Alberta. Angler overharvest, habitat degradation and introductions of non-native salmonids have since led to severe declines in the species historical range and abundance. In 1993 increasing concerns about these declines led to the establishment of the Bull Trout Task Force (Alberta) (BTTF). Until disbanding in 1997, the BTTF took an active role in bull trout management issues and public awareness efforts to increase support for bull trout recovery efforts. This manuscript describes the BTTF’s history (i.e., its establishment, role in management issues, and public awareness initiatives). The manuscript also summarizes some of the indicators of the BTTF’s success in increasing public awareness and support for provincial recovery efforts. Although provincial, or federal task force’s are often appointed and administered by governments, the BTTF included, but was not appointed or administered by government. This, and the BTTF’s focus on increasing public awareness about the plight of Alberta’s bull trout, were instrumental in the widespread support that developed for changes to pre-BTTF management policies for bull trout. The BTTF provides a good example of a human dimensions instrument, and as such, it serves as a useful model for dealing with traditionally controversial issues and for facilitating cooperative management solutions.

Bull trout (Salvelinus confluentus) were historically the most abundant and widely distributed trout and char species in Alberta (AB). However, overharvest by anglers, habitat degradation, and introductions of non-native salmonids have caused severe declines in the species historical range and abundance (Berry 1994, 1997; Roberts 1982, 1987; Brewin and Brewin 1997).

Concern among stakeholders about the declines led to a special resolution for protective regulations at the 1982 AB Fish and Game Association (AFGA) Convention; this resolution calling for "no-kill regulations" (except where harvestable surpluses existed) was supported by several stakeholder groups [i.e., AFGA, Federation of AB Naturalists (FAN), Trout Unlimited Canada (TUC), and the Edmonton Trout Club] (Roberts 1982). By 1985 Fisheries Branch, AB Energy and Natural Resources [now called Fisheries Management Division (FMD), AB Environmental Protection (AEP)] had a draft provincial management plan for bull trout (Carl 1985) with fishery regulations that would: "protect bull trout stocks during spawning and rearing"); and "regulate fishing in line with the production surplus". The draft plan also called for a "public relations program to help anglers identify bull trout and to explain management strategies". However, the plan was never approved and the 1992-93 angling regulations still permitted anglers to harvest two bull trout/day over 40 cm (total length) (AFWD 1992).

The 1980's also saw the bull trout become a ‘species of special concern’ in AB by the American Fisheries Society (Williams et al. 1989). The proposed status for bull trout by the Committee On the Status of Endangered Wildlife In Canada is ‘vulnerable’ (Campbell 1990).

By the early 1990’s increasing concerns about declining bull trout populations led stakeholder groups to become more active in public awareness initiatives for bull trout. In 1992 as part of a plan to raise awareness about the

1 Alberta Council Manager and Biologist, Trout Unlimited Canada, Calgary, Alberta (also Chairman, Bull Trout Task Force)
species plight, the AB Council of TUC proposed that bull trout become AB’s official fish emblem (Blake 1997). In early 1993, TUC joined with government agencies and other stakeholders to form the Bull Trout Task Force (Alberta) (BTTF) in hopes of stimulating recovery efforts. During its history (1993-1997) the BTTF undertook a various initiatives to facilitate bull trout recovery efforts in AB. Many of the BTTF efforts which are described in this manuscript were focussed at increasing: public awareness about the species plight; and support for recovery efforts. The manuscript also summarizes: some of the indicators of the BTTF’s success in increasing public awareness and support for provincial recovery efforts; and the importance of using human dimensions to involve stakeholders in resource management decisions.

**BTTF’S ESTABLISHMENT AND OBJECTIVES**

The BTTF was established in January 1993. It included representation from conservation organizations, federal and provincial government agencies, industry, and private and academic biologists. (See Acknowledgements for list of members; affiliations are in Brewin 1997).

The BTTF’s Mission Statement was: to facilitate the recovery of bull trout populations in AB. Its Objectives were to: stimulate management strategies for the recovery of bull trout; increase the scientific knowledge and understanding of bull trout; and increase public awareness and appreciation of bull trout. The Tasks selected by the BTTF to help it meet its Objectives were to: organize a conference on bull trout and publish its proceedings; adopt bull trout as an official provincial emblem; produce a bull trout status report; identify research needs for management; secure funding to achieve objectives; and develop a media communication strategy.

Although the provincial, state, or federal task force’s are often appointed, funded and administered by governments, the BTTF included but was not appointed or administered by government. Administration of the BTTF was handled by TUC. Although the BTTF received various government grants and contracts (Brewin 1997), it did not receive base funding for administration, or other expenses, directly from the province. After completing all of its objectives, the BTTF disbanded in August, 1997.

**ROLE IN POLICY CHANGES**

‘AB’s Bull Trout Management & Recovery Plan’

A draft management plan for bull trout was developed by FMD (Carl 1985), but it was never implemented. The creation of the BTTF in 1993, and the widespread support it developed for bull trout recovery efforts among stakeholders, led to the creation of a new province-wide management and recovery plan for bull trout. This plan, ‘Alberta’s Bull Trout Management and Recovery Plan’ (Berry 1994 and 1997), was released at the Friends of the Bull Trout Conference in Calgary (May 5-7, 1994). It was officially implemented by FMD on April 1, 1995.

The BTTF influenced this plan in several ways. The BTTF and its member organizations provided input on early drafts of the plan and also forwarded management plans and technical reports from other jurisdictions to FMD. Comments from federal government agencies, private and academic biologists, and conservation organizations, provided a broad spectrum of constructive input. In addition, the BTTF’s efforts to raise awareness about bull trout and public support for recovery efforts facilitated FMD’s internal approvals.

**Regulation Changes in the National Parks**

On April 1, 1994 Banff National Park, AB (BNP) became the first jurisdiction in Canada to implement a jurisdiction-wide, no-harvest regulation for bull trout (Parks Canada 1994). On April 1, 1995 all of the other Rocky Mountain National parks [Jasper (JNP), Waterton Lakes (WLNP), Yoho and Kootenay, of which JNP and WLNP occur in AB] implemented no-harvest regulations for bull trout (Parks Canada 1995). The BTTF did not have the same opportunities for direct input into decisions for improved protection of bull trout in the National parks as it had for provincial fisheries. However, the BTTF influenced bull trout management within the National parks by: increasing support for improved conservation measures for bull trout throughout AB; and helping National parks staff expand their knowledge about the management and biology of bull trout (e.g., attendance at BTTF conferences and workshops and forwarding information from other jurisdictions to the National parks).

**Conferences and Workshops**

The Friends of the Bull Trout Conference in Calgary, AB (May 5-7, 1994) was the BTTF’s largest undertaking. Its objectives were to: 1) facilitate the exchange of information on the biology and management of bull trout; 2) produce an authoritative document on bull trout management and biology by publishing the Conference Proceedings (see Mackay 1997); 3) enhance post-conference networking opportunities throughout the species range; and 4) increase public awareness about the plight of AB’s bull trout. The Conference attracted 49 oral
presentations, ten poster presentations and 198 delegates.

The BTTF hosted the ‘No Black - Put It Back’ Workshop in Red Deer, AB (September 26-27, 1994), at the request of the Fisheries Advisory Committee (FAC) for the Fisheries Management Enhancement Program (FMEP) and Fisheries Habitat Development Program. The FAC, the major funder of fisheries related projects in AB, allocates trust fund monies generated from the sale of angling licences. They indicated they would direct $200,000-400,000 annually over a 3-5 year period to bull trout-related projects, if the BTTF would develop the framework for a 3-5 year, provincial research, inventory, and awareness program for bull trout (BTTF 1995a).

Most people who attended the Workshop also attended, or knew of, the Friends of the Bull Trout Conference. This, and the distribution of draft manuscripts from some Conference presentations to workshop delegates, allowed information shared at the Conference to be incorporated into a provincial research, inventory and awareness program for bull trout. Workshop results and the subsequent recommendations by the BTTF were published in Walder (1994) and BTTF (1995a), respectively.

PUBLIC AWARENESS INITIATIVES

The major objectives of the BTTF’s public awareness program were: 1) to increase awareness about the bull trout’s plight in AB; and 2) to increase support among the angling and general public for a provincial bull trout recovery program. In addition to changing angling regulations, the BTTF also believed the following were needed for protection regulations to be the cornerstone of a successful recovery program (BTTF 1995a): 1) anglers needed to know new regulations designed to better protect bull trout existed; 2) anglers would need to understand why more protective regulations were necessary so that they would better support the changes; and 3) anglers would need to be able to properly identify bull trout from species that they could harvest.

With these objectives in mind, the BTTF undertook a variety of public awareness initiatives. The following text briefly describes most of these initiatives. For more detail see Brewin (1997) and BTTF (1995b, 1996 and 1997).

Official Provincial Emblem Designation

In 1992 the AB Council of TUC resolved to sponsor the bull trout as AB’s official fish emblem (Blake 1997). After the BTTF was established a year later, it was able to capitalize on the progress that TUC had already developed for the designation.

Approximately three years after it was proposed, the bull trout was proclaimed AB’s official fish emblem. Bill 208 (Emblems of AB Amendment Act 1995) was introduced into the AB Legislature by Mr. S. Woloshyn on February 15, 1995. The second reading of the Bill on April 12 included a two hour discussion of the merits and benefits of the Bill by various Members of the Legislative Assembly of AB (MLAs) (Hansard 1995). After the two hour debate, the Bill was supported by both the ruling government, and official opposition, MLA’s. The third and final reading was passed on May 2. Shortly thereafter, the Bill received Royal Assent and was proclaimed.

‘Save the Bull Trout’ Poster Campaign

The ‘Save the Bull Trout’ Poster campaign was initiated in the spring of 1993 immediately after the BTTF was established. The original poster (21.25 X 35 cm): 1) discussed the plight of AB’s bull trout; 2) described proper identification of bull trout from salmonids in AB’s rivers and streams; and 3) promoted voluntary release of bull trout among anglers. These posters were distributed to AEP and Parks Canada offices, various conservation organizations, tackle shops and other selected venues throughout the province. The start of the poster campaign also closely coincided with columns in the two largest daily newspapers in AB, the Calgary Herald (Masternak 1993b) and Edmonton Journal (McKeen 1993).

Several modifications of the poster occurred. After protective regulations for bull trout were implemented in 1995, revisions were made to highlight the new regulations (Figure 1). Parks Canada developed a bilingual version of the poster. The original poster was also modified by Montana Fish, Wildlife and Parks (MFWP) for use in Montana. MFWP expanded the use of their poster by also using it as a place mat which included a bull trout word game and bull trout quiz on the back.

‘No Black - Put It Back’ Slogan

The BTTF’s ‘No Black - Put It Back’ slogan was developed to help anglers remember that: if they capture a trout or char with no black spots or markings anywhere on its fins or body while angling in AB’s flowing coldwater habitats, then it is likely a bull trout and it should be carefully released and returned unharmed back into the water. A distinction was given to flowing waters because lake trout (S. nayancush), which lack black spots or markings anywhere on their fins and body, also occur in AB. However, there are less than twenty lakes and reservoirs in AB with lake trout that occur within the bull
Figure 1. Modified version of the ‘Save the bull trout poster’ used after protective regulations for bull trout were implemented.

trout’s range.

Other jurisdictions have also used the ‘No Black - Put It Back’ slogan. MFWP has used the slogan on posters and other educational materials [e.g., full color identification brochure bull trout, lake trout and brook trout (S. fontinalis), and key chains (pers. comm., M. Long, MFWP, Missoula)]. In Idaho the slogan was used in educational materials such as a black and white ‘What’s the difference’ brochure for bull trout and brook trout (pers. comm., S. Elle, ID Department of Fish and Game, Nampa). The Oregon Department of Fish and Wildlife (ODFW) also called the BTTF for permission to use the slogan (pers. comm., B. Hooton, ODFW, Portland, OR).

Stream-side Signage Program

To help improve angler awareness about protective regulations, in 1995 the BTTF developed an all-weather, coroplast sign (30 X 40 cm) (Figure 2) that explained: province-wide protective angling regulations for bull trout; the plight of bull trout in AB; and how to properly identify bull trout. Anglers, AEP staff, conservation organizations and other concerned stakeholders assisted with the distribution and erection of approximately 2,100 signs.

‘You’re in Bull Trout Country’ Signs

The BTTF organized a second signage program to increase public appreciation for the types of environmental settings where bull trout habitats are found. These signs had no graphics and their only text read ‘You’re in Bull Trout Country’. Two sizes of these signs were produced (30 X 120 cm and 60 X 240 cm). These signs were installed under existing AEP signs along highways and at selected sites (e.g., Forestry Recreation Areas, Parks, campgrounds). Several industry partners also purchased signs and erected them on roads and other private property. The BTTF also gave signs to several municipalities which were erected at various locations (e.g.: along rural and municipal roads; on municipal bridges in rural areas and in towns; and at entrances into urban and rural municipalities).

Bull Trout Panel Displays

Information panel displays (two panels, each 90 X 180 cm) about bull trout were developed by the AFGA with input from FMD staff, and the BTTF, for display in offices and at sportsman’s shows, etc. Initially, six copies of the displays were produced, but their popularity led to another six copies being made. The panels, kept on display at various offices throughout the province (e.g., FMD, AFGA and TUC), can be loaned by others for display booths.
Historical Photo Contest

The BTTF organized a Historical Photo Contest to: 1) access existing information in the diaries, photo albums and memories of anglers concerning the historical abundance, range and species composition of fisheries in AB; and 2) develop a photo library of historical bull trout catches in AB. Prize categories, sponsors, and contest rules were published in BTTF (1995b). Contest posters with attached entry forms were distributed to: all Fish and Wildlife (AEP) offices in AB; selected tackle shops and conservation organizations; all known museums and historical societies in the province located in the historical range of bull trout; elected MLA’s within the bull trout’s historical range; and a variety of other selected locations. Although the contest had fewer entries than expected (about 35 photos submitted), some useful information was collected. For example, one photograph of some anglers beside a pool in the Highwood River (circa 1900) indicated that at the same pool three anglers had captured 101 bull trout during three hours of fishing on a Sunday morning (pers. comm., S. Callahan, Red Deer, AB).

An historical photo display was developed that features many of the historical photos collected during the contest. This display, kept at the TUC office in Calgary, is available on loan to stakeholders.

Bull Trout BULLetin

The inaugural issue of the Bull Trout BULLetin, the BTTF’s newsletter, was published in March, 1995 (BTTF 1995b). Two subsequent issues (BTTF 1996, 1997) were also published. The Bull Trout BULLetin was developed to: 1) encourage exchange of information on the management and biology of bull trout throughout its international range; 2) increase networking among individuals and groups who are interested in bull trout conservation efforts; and 3) to increase the distribution of information relating to public awareness initiatives for bull trout. Each issue also included a list of citations for recently published bull trout-related reports and manuscripts. This section was included to help increase awareness about, and distribution of, recent reports and manuscripts, particularly the grey literature. The Bull Trout BULLetin was distributed free upon request to anyone within the bull trout’s international range.

Bull Trout Education Contests

The BTTF initiated an education contest in 1995 to help increase bull trout awareness and improve compliance with province-wide no-harvest regulations among anglers. The contest was free to contestants who completed a questionnaire with four ‘True or False’ questions. Contest kits provided by the BTTF included: prizes (generally a Limited Edition print and two bull trout t-shirts); entry forms with the questionnaire; and a contest poster (Figure 3). Contestants could find correct answers to questions by reading the contest poster. Having answers on the poster encouraged contestants to read the answers several times while filling out the entry form. It was hoped this repetition would improve contestants’ knowledge about bull trout. Contest kits were distributed to: various TUC chapters, and AFGA clubs who held contests at special events they organized; Parks Canada; and various schools, secondary education institutions and tackle shops, throughout AB. Contest kits were also distributed by FMD to every Fish and Wildlife Regional and District Office in the province, as well as other selected AEP offices.

The Education Contest was revised in the fall of 1996. Two ‘True or False’ questions were removed from the contest entry form, but two were kept so contestants...
would still read the contest poster. The removed questions were replaced with three questions to collect data about: 1) awareness of protective regulations for bull trout; 2) where contestants had heard messages about bull trout; and 3) how important they viewed conservation programs for bull trout. These contests were held at a variety of places (e.g., Sportsmen shows, TUC and AFGA events, tackle shops). Groups hosting these contests sent questionnaires back to the BTTF from 903 AB contestants; the results are summarized by Baayens and Brewin (1997).

Public Service Announcements

The BTTF produced three 30 second Public Service Announcements (PSA’s) for radio and television in 1994 and 1995 to help increase awareness about: the plight of the bull trout (1994); the bull trout’s provincial emblem designation (1995); and new province-wide no-harvest regulations (1995). Copies of the PSA’s were distributed to all television and cable stations in AB. Soundtracks of the PSA’s were also distributed to radio stations with broadcast areas overlapping the bull trout’s range. In the package sent to these stations was a cover letter asking Program Managers to play the PSA’s in unsold time slots. The BTTF also taped a looped series of the PSA’s onto a VHS video cassette which is used for display booths.

To increase potential use of the PSA’s among radio stations, a radio promotion was developed. The BTTF provided participating stations with: ten bull trout t-shirts to distribute to listeners; and ten bull trout-related questions and answers. To win, the BTTF recommended that listeners answer a skill-testing question about bull trout. This promotion was also revised by individual radio stations. For example, some stations chose not to use the PSA’s and gave t-shirts out to a pre-determined caller (e.g., seventh caller with correct answer).

Although the BTTF was not notified when the PSA’s aired, the investment appeared to be a good one ($3952 CAD to produce the PSA’s and all copies of videos and soundtrack). For example, one radio station played the PSA’s five times per day (from about 6:00 AM to 10:00 PM) every day of the four summer months in 1996. If the BTTF would have been charged normal advertising rates for this air-time, the bill would have been approximately $8,000 (CAD).

Outdoor Writer’s Newspaper Columns

In 1995 seven of AB’s award-winning outdoor writers who write about fisheries-related topics were asked to write a 300-500 word column about bull trout for the BTTF. The BTTF then sent this seven-part series to all weekly newspapers in the bull trout’s range in AB to use in consecutive issues during the summer. Although use of the columns was less than hoped for (approximately three weeklies used them), the columns did help increase bull trout awareness in rural areas. Additionally, although most weekly newspapers did not use the BTTF’s columns, receiving the columns led some newspapers to write local articles or columns about bull trout.

BTTF’s Award Program

The BTTF developed the ‘Journalistic Excellence in Promoting Bull Trout Conservation and Awareness Award’ in order to: 1) recognize outstanding contributions of AB’s outdoor writers and media reporters who help publicize conservation issues; and 2) promote involvement among outdoor writers and media in bull trout conservation issues. In 1995 the Award’s name was changed to the ‘Garnet Anthony Excellence In Journalism Award’. Any Canadian journalist, writer, broadcaster, photographer, or individual involved in the production of any form of public information that satisfies the criteria of the BTTF (e.g., newspaper and magazine articles, video tape, and television and radio news broadcasts and talk shows) is eligible for the award. During its history the BTTF gave the award out five times (two for Lifetime Achievement Awards and three for Annual Contributions).

The BTTF also established the ‘Conservation and Education Award’ to recognize outstanding contributions by enforcement officers towards fisheries conservation and education in AB. Presented ‘when warranted’, this Award was open to all enforcement officers (i.e., federal Fisheries Conservation Officers and National Park Wardens, provincial Fish and Wildlife officers, and provincial and municipal Park Rangers). It was presented twice by the BTTF.

Since the BTTF disbanded in August 1997, it passed administration of these two awards to the Standing Committee on Fisheries Information and Education (SCFIE). SCFIE was established by FMD in 1995 and includes representation from several non-government organizations and sectors. Although the focus of the awards will be expanded from strictly bull trout-related efforts to other fisheries conservation issues, they will still concentrate on native fish species.
Bull Trout Lapel Pins and T-shirts

During its history the BTTF purchased two types of bull trout t-shirts and two types of bull trout lapel pins. The t-shirts and lapel pins were distributed to BTTF member agencies and organizations to promote bull trout awareness and for volunteer recognition. Uses of t-shirts and pins included: prizes in the BTTF's education contests and radio promotions; rewarding anglers who reported catching bull trout with fly anchor tags; and recognizing volunteers who helped with bull trout recovery efforts. Some of the t-shirts were also used for fundraising purposes. In total the BTTF purchased approximately 1200 t-shirts and 2500 pins.

Other Awareness Initiatives

The BTTF also undertook several other public awareness initiatives. These included: 1) buying advertising space in selected magazines to improve awareness about changes to angling regulations; 2) submitting articles written by BTTF members to selected magazines; 3) being interviewed by the print and electronic media; 4) preparing and distributing News Releases on selected topics to the media and selected stakeholder groups; and 5) oral presentations by BTTF members to school classes, youth groups and seminars.

SUCCESS OF AWARENESS EFFORTS

Like elsewhere within the bull trout’s range (Stuart et al. 1997), bull trout were considered undesirable by many AB anglers during the early 1900's (Colpitts 1993) through to the 1950's (Berry 1997). During this period anglers and fishery managers intentionally reduced bull trout numbers in some AB waters (e.g., Colpitts 1993; Berry 1997), including within the National parks (e.g., Brewin 1994; Donald and Stelfox 1997). Although less common, many of these old attitudes were again documented in 1993 (Boxall and LeFrancois 1997). The turnaround from being seen as an undesirable predator to becoming the province's official fish emblem helps illustrate the success of the BTTF's efforts to increase public awareness and appreciation for AB's native bull trout stocks.

The ratio of anglers who knew about changes to angler regulations for bull trout also indicates how well the BTTF's efforts to inform anglers about the new regulations worked. About six months after the changes were implemented, Haines Elliot (1996) reported 84.4% of 588 AB anglers sampled knew about the bull trout’s protected status. Results from the BTTF’s education contests (1996-1997) indicated that 89.6% of 903 AB contestants knew about protective regulations for bull trout (Baayens and Brewin 1997).

The BTTF’s ‘No Black - Put It Back’ slogan received widespread use and recognition. The slogan was first released in the Calgary Herald as the “battle cry” of the BTTF on April 3, 1993 (Masterman 1993b). By August 1995, it was described as having “the fame of a popular song” (Scammel 1995). Haines Elliot (1996) conducted a telephone survey of anglers and non-anglers in AB. Although the slogan had predominantly been promoted in the western half of the province (i.e., within, or near, the bull trout’s range), Haines Elliot (1996) reported knowledge of the ‘No Black - Put It Back’ slogan was similar to several older, province-wide programs. They found knowledge of the slogan (58.7% of anglers; 23.3% of non-anglers) was comparable to the Bucks for Wildlife Program (63.3% of anglers; 24.7% of non-anglers), and the FMEP (55.8% of anglers; 26.5% of non-anglers). At the time the ‘No Black - Put It Back’ slogan was about 2.5 years old, while the FMEP and Buck for Wildlife Program were six and 20+ years old, respectively.

The use of the BTTF’s ‘No Black - Put It Back’ slogan and ‘Save the bull trout!’ poster by U.S. jurisdictions provide further evidence about how others view some of the BTTF’s awareness initiatives.

Baayens and Brewin (1997) evaluated the effectiveness of various communication media used by the BTTF. They reported most people had heard bull trout messages in Alberta Guide to Sportfishing (i.e., publication with provincial angling regulations). They also reported that radio, road signs and magazines were effective for transmitting bull trout messages (i.e., more than 23% of contestants reported hearing about bull trout messages from each of these mediums). Other effective communication tools reported in Baayens and Brewin (1997) were: (in decreasing order) television; signs/posters in stores; word-of-mouth; sportsmen-oriented, non-government organizations (combined); and government agencies/staff.

The BTTF received two awards for its effectiveness at conservation efforts. The BTTF received the Special Minister’s Order of the Bighorn from the Honourable Ty Lund, Minister, AEP, in 1995. The Order of the Bighorn Awards were established in 1982 to recognize outstanding contributions made by private individuals, organizations and corporations to fish and wildlife conservation in AB. This was only the fifth time in its history that the Special Minister’s Award was awarded. In 1996 the BTTF received the Neville Linsay Memorial Award for its efforts
to conserve and raise awareness about bull trout. This award is presented annually by the AFGA to the member organization which runs the best fisheries-related project.

However, the best indicator of the BTTF’s success may be in the relatively few complaints that government agencies and the BTTF received after protective regulations prohibiting the harvest of bull trout were implemented. FMD reports having received very few complaints after the no-harvest regulation was implemented in 1995 (pers. comm., D. Radford, FMD, Edmonton). The BTTF printed its telephone number on its stream signage and posters for people wanting more information, or wanting to provide input. Despite having over 2,000 stream-side signs and several thousand ‘Save the bull trout’ posters installed, only a single call was ever received. This caller, a senior citizen, did not call to complain about the no-harvest regulation. He called because he had previously believed bull trout were a “garbage fish”, not worthy of protection, and he was concerned that his past actions to reduce bull trout numbers may have been based on misinformation he been led to believe.

Many people believe the lack of controversy was the result of the public appreciation and support for recovery efforts that was raised through such initiatives as the provincial emblem designation, and through the voluntary release program for bull trout in 1993 and 1994 that the BTTF promoted through the ‘Save the Bull Trout’ poster campaign and the ‘No Black, Put it Back’ slogan. These two initiatives were undertaken for two years before the no-harvest regulation was implemented. Many believe that these initiatives helped create widespread support and acceptance among anglers that bull trout populations in Alberta could no longer tolerate angler harvest.

CONCLUSIONS

Although government department's are sometimes reluctant to implement decisions that are potentially controversial (e.g., prohibiting the harvest of natural resources), the AB experience with changes to angling regulations for bull trout suggests this reluctance is sometimes unwarranted. Existing information clearly indicated bull trout had experienced serious declines in both their historical abundance and distribution. There was also general agreement that angler overharvest was the largest contributing factor to these declines and that major changes to harvest policies were needed. Consequently, the establishment of a multi-agency stakeholder group, which led public awareness initiatives served as a useful tool for building support for a provincial bull trout recovery program with province-wide, multi-jurisdictional, no-harvest regulations for bull trout.

Although provincial, state or federal task force's are often appointed and administered by governments, the BTTF included, but was not appointed or administered by government. It is generally agreed that this factor and the BTTF’s focus on increasing public awareness about the plight of the bull trout, were instrumental in the widespread support that developed for changes to pre-BTTF management policies for bull trout.

Fisheries managers are often very good at analysing results from fisheries inventories and fisheries research. However, management of recreational fisheries can often be as much about managing people (i.e., anglers, industry involved in land-use management, and other stakeholders) as it is about managing the fishery resource. Based on the wide variety of public awareness initiatives undertaken by the BTTF, it obviously placed a high priority on people management. However, rather than just attempting to build support and awareness among anglers for recovery efforts, the BTTF also undertook several awareness initiatives that targeted the general public (e.g., provincial emblem designation, ‘You’re in bull trout country’ signs).

The importance of involving all stakeholders and not just clients of fisheries agencies (i.e., anglers) in fisheries management decisions in AB, and in other jurisdictions, has grown rapidly during the past decade. As this importance continues to grow, fishery managers, their agencies, and stakeholders are better recognizing the need for many management decisions to be made by placing as much emphasis on human dimensions as a science as is put on fisheries biology as a science. Some state wildlife agencies (e.g., NY) began integrating human dimensions and resource management 20 years ago, while others like CO and MT have shown good progress in recent years (Decker and Enck 1996). However, despite its importance integrating human dimensions as a science into management decisions is difficult for most biologists. The following from Decker and Enck (1996) helps explain why fisheries/wildlife agencies must strive to overcome this difficulty. They stated most resource managers/biologists have traditionally been trained to believe that: “good biology alone would tell us what we ‘should’ do. Most experienced managers have learned that the ‘should’ part is a matter of human values and preferences, including those of the managers themselves. Good biology is needed to set bounds on what is possible, but biology alone does not tells us what is best for the many stakeholders served
by the manager. And neither does the best human dimensions information in most situations, because what people want as consumers of a resource may not be in the best public interest, now or for the future.”

Gill (1996) discusses: the importance of developing human dimensions instruments to effectively involve the public in participatory policy-making and conflict resolution; and how the failure to do so too frequently results in public policy-makers developing “policy alternatives based upon what they perceive the public desires”. These human dimensions instruments can take many forms (e.g., ranging from citizen task forces, to focus groups and stakeholder surveys, to broad public input processes for strategic and long-term planning).

The BTTF was a ‘human dimensions instrument’ (i.e., a task force with representation from public interest groups and government agencies) that was used to find a non-controversial solution to a potentially controversial management decision. This partnership approach between public interest groups and government agencies should serve as a useful model for dealing with traditionally controversial issues and for facilitating cooperative management solutions.

ACKNOWLEDGEMENTS

Many individuals, government agencies and non-government organizations contributed to the success of the BTTF. Although space does not permit all of them to be listed in these Acknowledgements, some individuals deserve special mention; in particular, the other members of the BTTF (J. Allan; G. Anthony; D. Berry; T. Blake; B. Bond; T. Enzo; B. Fenson; F. Girdwood; J. Harvie; M. Kraft; A. Lees; B. Mackay; W. Roberts; G. Szabo; K. Van Tighem; and P. Wiebe). The viewpoints and knowledge that these individuals brought to the table were critical to the successes that the BTTF enjoyed. I also thank them for their support and for having made my role as Chairman of the BTTF memorable and rewarding. Many of the BTTF’s successes were also made possible from the contributions of the BTTF’s contract staff, D. Monita, and M. Monita and TUC staff, P. Brewin and D. Baayens.

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The Yampa River System Legacy Project Funds for Colorado River Cutthroat Trout

Rick Hammel¹

Abstract—Sage Country Chapter of Trout Unlimited is a very small rural chapter of TU. The chapter joined in a partnership with a large, diverse group of partners to submit a highly successful grant application to Great Outdoors Colorado Trust Fund (GOCO) a recipient of the Colorado Lottery. The major partners include federal, state and local governments and nonprofit and community organizations. This organization is known as the Yampa River System Legacy Committee. The grant was in the sum of $6 million. $100,000 has been earmarked for the conservation of Colorado River Cutthroat Trout.

This paper will show the effects of the agency downsizing in reference to implementing a well-funded project. It will show how the Forest Service is unable to make mid-year adjustments in work loads. It will show the attempts, both failures and successes, of a small TU chapter to work with the Forest Service, Bureau of Land Management and the Colorado Division of Wildlife.

Finally, it will show how we enlisted the help of a doctoral candidate from Colorado State University to set up some of the needed aspects of the project.

This paper is a work in progress.

Introduction

My wife and I moved from Southern California to Craig, Colorado in 1993. Craig is at the western end of the Yampa Valley in Northwest Colorado. I had a considerable amount of involvement with the BLM, participating in the listing process for the desert tortoise and as a member of the Rand Mountains Technical Review Team.

We joined Trout Unlimited and became members of the Sage Country Chapter of TU. I was assigned the duty of Project Director for the Chapter. In early 1994, I had a meeting with the fisheries biologist for southern sec-

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tion of Routt/Medicine Bow National Forests. He had a few projects but no budget for them. Of special interest to me was the “Conservation Plan for the Colorado River Cutthroat Trout in Northwest Colorado.” This species is also referred to as the CRN. This plan had been developed in 1992 by the Forest Service, BLM and Colorado Division of Wildlife (DOW). Very little work had been done on the plan, as no money was really available for implementation.

I have become involved in various natural resource organizations, representing Colorado Trout Unlimited. One was the Yampa River Basin Partnership (YRBP), comprised of federal and state agencies, local government and private and public entities.

The Grant Application

The Grants Coordinator for the City of Steamboat Springs made a presentation in early November, of 1995, to the YRBP. She informed us that the Great Outdoors Colorado Trust Fund (GOCO, and the recipient of the Colorado Lottery) had made a $40 million error in their projection of income for the life of the lottery legislation. They had underestimated the desire of the citizens of Colorado to fund wildlife, open space, state parks and outdoor recreation and local government projects. She informed us that GOCO had developed a new grant program called Legacy. Legacy is a multi-year program that will fund projects up to $10 million per project. She was asking the members of YRBP if they would care to become partners of the Yampa River System Legacy Committee. As a representative of Trout Unlimited, and always looking for money for projects, I volunteered.

I conferred with the Forest Service fisheries biologist about the Legacy Grant program. He said that we should try to do something for the CRN. I left his office and went to my first meeting of the Legacy committee. I was informed that we had until the end November to get a concept paper submitted to GOCO. The meeting was on November 8th. We brain stormed, coming up with a variety of projects that fit the criteria laid out by GOCO. GOCO has a funding quadrant system. The quadrants are: Wildlife, Open Space, State Parks and Outdoor Recreation and Local Government Outdoor Recreation Projects. A project had to benefit at least two of these quadrants. After many meetings, we narrowed the project down to five elements: purchase of conservation easements and leases to keep land in the Yampa Valley in agricultural production, consistent management of Yampa River access sites by Colorado State Parks, integrated access management and the development of trails along the Yampa River, environmental education and conservation of seven streams within the Yampa River system for CRN. This project included all four of the quadrants and qualified for funding.

The concept paper was submitted on time to GOCO. After some clarification, our paper and five others, out of 68 statewide, were accepted and formal applications were requested.

Our group decided that we needed a name and a somewhat formal structure. We adopted the name of The Yampa River System Legacy Committee. The partners numbered six when we submitted the concept paper. We actively solicited more partners with the belief that this was a community driven project and the partners should reflect that concept.

Unlike most grant applications, this grant asks for detailed answers to 30 questions. For the CRN element, most were quite straightforward. Even at that, it required seven and one-half single spaced pages for the narrative and four pages for the budget. Other elements required more detail than the CRN element.

Besides writing this grant application, the Committee held a series of public meetings throughout the Yampa Valley. This was done in the months of January and February 1996. Blizzards were commonplace. But we convinced these communities to buy into the project. We had input from south Routt County ranchers to folks from western Moffat County, some 170 miles apart.

The Grant Awards

The GOCO Board awarded the Yampa River System $6 million over a three and one half year span. There is $100,000 allocated to the trout element. There is $55,000 awarded to the trout project by the Colorado Division of Wildlife (CDOW) as part of the cash matching funds. Matching funds in this case is 15%. There was an application for matching funds made to the Central Utah Project Completion Act. The amount that I had applied for was $73,000. After speaking with the CUP people, we
determined that there was sufficient money to proceed without CUP funds. The $73,000 would be held as a fall-back, if needed.

The time is June, 1996. We are sitting here with $228,000 doing nothing. The Forest Service can't change their annual workplan until the start of their fiscal year, October 1. The Division of Wildlife can't really invest funding until they get a contract with GOCO and approval from the State Attorney General. I see a field season slipping away. All is not lost. We did get a considerable amount of planning accomplished.

**Academia Input**

In the Fall of 1996, Trout Unlimited awarded a $2000 award, the Lee Wulff Scholarship to Ms. Amy Harig, for her doctoral work on the three Colorado native cutthroat trout sub-species, the Rio Grande, the Colorado River and the greenback. I spoke with Amy at length about her research. It was apparent that she would need help in funding her research. I spoke with Whit Fosburgh, TU’s Coldwater Conservation Fund administrator. Whit told me to submit an application. The thrust of the application was that Amy was doing research on why there is a 40% failure rate of stream rehabilitation for the three sub-species of cutthroat trout in Colorado. It was decided that Amy’s work would really benefit the local chapters of Colorado Trout Unlimited. Her work would reduce the failure rate and would ultimately save the Chapters hard earned money. The Coldwater Conservation Fund awarded Amy Harig $10,000 for her research on Colorado native cutthroat trout.

For the 1997 field season, Sage Country Chapter of Trout Unlimited will be collecting the required data for Ms. Harig’s project within the Yampa River basin.

**Forest Service Downsizing**

The downsizing of the federal government has prompted the people within the agencies to develop minimized work forces. There are forest management agencies that have been combined, and people moved around within those forests. More responsibilities have been placed on individuals, with less time to accomplish those tasks.

The Forest Service is training one full-time crew of two and one part time crew of two to do the basin-level inventory work this summer. There are seven streams that this project encompasses. I am quite concerned that we will not finish before it snows, or hunting season starts. The Yampa River drainage is one of the premier hunting destinations in the United States. There are about 40 stream miles involved. If the crews are able to complete one mile per day, with no injuries, the inventory should be completed by the second week in September. It is the hope of all of us on the project, that with the data collected, that some migration barriers will be placed prior to the coming of winter.

**Colorado Division of Wildlife**

The Forest Service is not the only governmental agency that is in the process of downsizing. Both the Bureau of Land Management and the Division of Wildlife are making major readjustments in personnel and operations. The various management areas around the state of Colorado are being reorganized in both size and the scope of work they are expected to accomplish.

The Meeker Area Manager is my principle contact with the DOW. At the start of this project, all of the streams that are involved with this project were in his area. Now there are only three. There is a new area manager for the Steamboat Springs area. The new area manager has relinquished the streams in her area to the Meeker Area Manager. This keeps this project under one person.

The DOW has other major problems brought on by this reorganization. No longer can the area managers enter into contractual agreements with outside vendors. Moreover, there is a hiring freeze, statewide. There is a coordinator position budgeted for this project. So far, the DOW area managers have not come up with a solution as to how to hire a person for this position.

The added responsibilities that the area managers now have take a tremendous amount of time. They are not desk-bound as one would think. These people are in the field most of the time. What time is left is spent at meetings around the state. I complained to the Colorado Wildlife Commission. Their answer was that they could not do much to help. The Forest Service and the DOW are going to try to work together to save on costs. From
what I am told by the Forest Service biologist, it is a logistic nightmare.

The Role of a Small TU Chapter

Sage Country Chapter of Trout Unlimited is a very unique chapter. Geographically, it encompasses all of northwest Colorado. There are members in the five northwest counties. Sage Country has about seventy five paid members in Trout Unlimited. However, as in most fishing organizations, there are very few that actually do the work. Sage Country is no exception. We have six to eight active members. Since my retirement at the first of this year, I have been spend a great amount of my time trying to get this project organized. As I mentioned earlier, there is no coordinator for this project. That responsibility has fallen on my shoulders. The learning curve is not the usual bell curve. It is hit the ground running, and if I make mistakes, I will fix them when I can.

When this project started, I knew I was in for some new experiences. I never written a grant application. I assumed that the Legacy Committee would write it. Wrong. I was told that the writing would be up to me. I would be provided input as I went along. This was indeed provided. But, it required much research on my part. The closest I had ever been to grant application was payroll sheets for the people that worked for me.

After the awarding of the grant, we started to get organized. During this period, I felt something was missing from our organization. I received a conservation agreement for the Colorado River cutthroat trout in the State of Utah. I decided that this project needed something of this nature to define specifically what we were about. I went to work, and using the Utah document as a guide, came up with a preliminary draft. All of the partners in the project thought it was a good idea. Each agency had its own concerns about the agreement. After four edits, we are almost to an agreement.

Where Do We Go From Here?

There is already interest in this Legacy project. There is a group of ranchers on the main stem of the Little Snake River who want to restore their riparian areas and fishery. The Little Snake River flows in and out of northwest Colorado and southwest Wyoming. These ranchers are very enthusiastic about their project. If these people are successful, there are two factors that will emerge. One, the Little Snake River will have the most stream miles of any conservation project in the Pacific Basin. Two, this partnership of ranchers will serve as a model for the agricultural community. It will show that agriculture and fisheries can co-exist.

Conclusion

This has been a very unusual experience for me. I came from a theatrical background where a project was conceived, designed and executed in a two month timeframe. The shock of slowing down is sometimes frustrating. However, the reward over-shadows everything. If we can recover these fragmented populations of Colorado River cutthroat trout, it will all be worthwhile.

I made a presentation to the Colorado Wildlife Commission a couple of years ago on volunteerism. I said at the time that a volunteer has to feel that, he or she, are making a difference in what they do. That is what I feel that I am doing now. I hope that other volunteers can find other projects that will make a difference in how the rest of us view life.
The Kamchatka Steelhead Project: a unique approach to understanding and conserving steelhead and trout of the Kamchatkan Peninsula, Russia

Peter W. Soverel, K.A. Savvaitova, K.V. Kuzishchin, S.V. Maximov, S.D. Pavlov

Abstract--The Kamchatka Steelhead Project (KSP) is a twenty year research project initiated to provide a vehicle for the study and conservation of steelhead in the Kamchatkan peninsula of the Russian Far East. Much of the funding to support this research has come from angler-sponsors who aid in the collection of data while practicing catch and release fishing in the rivers of Kamchatka. The Wild Salmon Center, a non-profit conservation organization is responsible for providing funding and arranging all field expeditions. Moscow State University is responsible for coordination of the international scientific study of steelhead and trout of Kamchatka.

INTRODUCTION

The Kamchatka Steelhead Project (KSP) is a long-term survey of steelhead trout in the rivers of the Kamchatkan Peninsula in the Russian Far East during the 1995-2015. Goals include: 1. survey steelhead and trout populations to determine distribution, age diversity, run-timings, population trends, genetic diversity, life history adaptations, and kinship relations between resident and migratory trout, including new forms of trout discovered by the KSP (see Proebstel et al. this volume), and anadromous steelhead; 2. develop management regimes, based upon the scientific information derived from the cooperative study program, which conserve steelhead; and 3. promote sustainable utilization of steelhead and trout resources to produce local economic benefit.

Under the terms of various agreements among participating organizations, universities, scientific institutions and the Koryak Autonomous Okrug, the Wild Salmon Center is responsible for arranging, conducting, directing and providing the principle funding for all scientific steelhead expeditions in the Koryak Autonomous Okrug. Only expeditions under the joint Moscow State University/Wild Salmon Center direction may conduct steelhead data collection.

Moscow State University is responsible for the scientific work of the Kamchatka Steelhead Project, including coordination of the international scientific effort and coordination of the special permits from the Russian Ministry of Environmental Protection that are required for the collection of samples from species listed in the Russian Red Book of Rare and Disappearing Species (steelhead/rainbow trout).

The 1996 Annual Report of the KSP consists of three parts. The first section, presented below, focuses on the field collection efforts of the anglers in September-October 1996. It is also a review of the Project’s American sponsorship and its methods, written by Peter W. Soverel, President, Wild Salmon Center. The second part, prepared by Moscow State University’s Ksenya Savvaitova and colleagues was translated by the WSC’s Serge Karpovich. It is the third in a series of annual reviews of the project’s scientific findings. The third part was prepared by Randy Reeve, fisheries biologist, on loan to the project from the Oregon Department of Fish & Wildlife. This section describes the migratory movements of radio tagged Utkholok River steelhead during September and October 1996. Parts II and III of the 1996 Annual Report and Annual Reports from the 1994 and 1995 field seasons of the KSP describe the

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methodology, conditions and results of the joint Russian-American Kamchatka Steelhead Project field work, laboratory analysis of collected biological data and description of migratory behavior observed in Utkholok River steelhead monitored by implanted radio tags. These reports are available upon request from the Wild Salmon Center: e-mail: Soverel@u.washington.edu

**ANGLER DATA COLLECTION AND FIELD CONDITIONS**

**Framework and Field Work Conditions**

The Wild Salmon Center and Moscow State University co-direct the Kamchatka Steelhead Project, a long-term survey of Kamchatka's steelhead and trout populations which have been incompletely cataloged in the past. In addition to providing nearly all of funding, the WSC's KSP collects the preponderance of biological samples through catch and release fly fishing. The anglers, in addition to providing manpower for the scientists, provided approximately 70 percent of the funds for the conduct of the expeditions.

The KSP envisions a large scale, sustained, multi-year scientific program of data collection which is hugely dependent on catch and release fly fishing, something never attempted, anywhere, in the past. Based upon three years of experience, the concept has proved to be extremely effective. Approximately 90 percent of all biological samples has been collected by anglers.

**Angler Data Collection Teams**

Anglers work in two man teams to: 1. measure length and girth; 2. determine sex by physical conformation; 3. take ten scales to determine age, life-history and migratory behavior 4. take a tissue sample (15mm X 15mm X 15mm portion of the pelvic fin) for DNA genetic typing; and 5. insert a Flyo spaghetti tag

Each team has sample kit with scissors to take the tissue sample, a Flyo tag gun, tape measure, tweezers, alcohol vials for sample preservation, scale envelopes and a write-in-the-rain log book for recording data. Each team member is trained in the data collection methodology, tagging procedures and record keeping. Data collection by the anglers is supervised closely by WSC and MGU personnel. Although novices in the collection business, all anglers learned the necessary skills without difficulty. The WSC/MGU supervisors check all samples and record-keeping each evening to ensure accuracy of the data.

The anglers have established the utility of this data collection method--it is easy, effective inexpensive, and non-lethal. Although the skill level of individual anglers bears directly on the number of samples that each individual angler collected, all anglers collected some data. Several anglers collected large numbers of samples. Anglers take pleasure and pride in their participation and recognize that they are making a significant contribution to a resource they love.

**1996 KSP Data Collection Program River Conditions**

Annually, the KSP mounts several expeditions to remote regions of Kamchatka. To date, the KSP has collected biological samples from the Tigil, Sedanka, Palana, Snotalvayam, Kvachina, Utkholok, and Sopochnaya rivers. During 1996, the KSP expedition program consisted of a two week float of the Sedanka/Tigil rivers to target trout, and separate steelhead collection efforts on the Snotalvayam, Kvachina, Utkholok and Sopochnaya rivers operating from base camps, generally located near the top of tidewater.

The WSC/MGU coordinated the activities of sponsoring and participating volunteer flyfishers for the purposes of collection biological samples of fishes from the Tigil, Sedanka, Snotalvayam, Kvachina, Utkholok and Sopochnaya rivers in accordance with the terms and conditions of the Kamchatka Steelhead Project under authority granted by the Russian Ministry of Environmental Protection.

**SEDANNA RIVER September 7-17, 1996**

The expedition of two scientists and four anglers, led by Peter Soverel (WSC) and Kiril Kuzishchin (MGU), floated the length of the Sedanka River collecting biological samples from fishes. The principle angling species is a form of rainbow trout (see Proebstel et al. this volume). These fish range in size from 12-14 inches in length to almost ten pounds. There are a great number of 2-4 pound trout. Especially in the upper Sedanka River—from its source in a lake downstream for about twenty miles, it is
possible to hook trout on almost every cast.

In addition to trout, the Sedanka has a substantial population of Dolly Varden which were beginning to spawn during this period as well as sockeye and chum salmon. We presume that at other times during the year coho and chinook utilize the Sedanka for spawning.

Interestingly, the expedition was unable to capture any small trout. Approximately 15 miles downstream from the source lake, we fished the only substantial tributary of the Sedanka—an unnamed stream entering from the north. This 20-30 foot wide-stream was full of Dolly Varden, but in spite of intensive effort over the lower five miles of this system, we were unable to collect anything but Dolly Varden samples. We collected no biological samples from any other species in this small system. The Dolly Varden were spawning. We did observe several Stellar eagles and collected hundreds of edible mushrooms.

The Sedanka sources in a 5-7 acre, spring fed lake in a large lava field and flows northwest for approximately seventy miles to join the Tigil River about 100 miles from the sea. From the out flow of the source lake to about 40 miles downstream, the Sedanka is a modest sized stream some 50-70 feet wide flowing briskly over basalt outcroppings and small (pea to golf ball sized) pebbles. For the most part, this section of the river is a long, almost continuous riffle 2-4 feet deep, ideal spawning areas for salmon and trout. There were a great number of spawning redds, including some very large redds, presumably constructed by earlier spawning Chinook.

The surrounding country is gently rolling, open birch forest and grassland. The river gradually grows in size, primary from springs since the stream has few tributaries, over its course. Where it joins the Tigil, it is a substantial stream that cannot be forded.

The expedition party made use of four trapper cabins dispersed over the length of the river—about 20 miles apart. The cabins are conveniently located and provide protection against grizzly bears of which there are a great number. Both banks of the river are crisscrossed with numerous, well-worn bear trails. Every point along the bank has a bear fishing station. We observed large numbers of sockeye and chum salmon which the bears clearly feed upon heavily.

The Sedanka is a perfect fly fishing river, especially in the upper forty miles—easily waded, of gentle flow and full of large, aggressive, surface oriented trout, flowing through beautiful, pristine country. During September, the trout feed heavily upon voles and lemmings. One specimen had seven such creatures in its stomach. Mouse patterns fished on a tight line swimming the fly across the surface were the most effective. Although fish would take small dry flies, the trout appeared to be keying on larger prey—either mice or small fish. Since we captured no juvenile trout, the river must contain some small forage fish that we were not able to capture/identify. Large numbers of freshwater shrimp are distributed throughout the length of the system and form an important part of the trout diet. Not surprisingly, shrimp patterns are extremely effective flies.

This float trip was an idyllic wilderness outing—perfect weather, no bugs, abundant fish and wildlife. The expedition party collected mushrooms to compliment trout that had been killed for morphological and taxanomical examination and ducks killed by the hunters.

Kvachina/Snotalvayam (September 20-November 1, 1998).

The Kvachina and Snotalvayam join at a substantial estuary bay at the sea. Both are small (70-100 feet across), shallow rivers with extremely long estuaries in which the tidal zone extends upstream 8 to 10 miles. In the tidal areas, there are several long, deep holes. In the ten miles or so above the tidal zone, both rivers are low gradient, shallow streams with relatively few well developed pools. For the most part, the water is less than 8 feet deep and in many pools the water is more typically 4-6 feet deep. The bottom consists of small pea sized gravel. Each river has a very large population of freshwater shrimp (3mm to 25mm in length), typically brown or olive in color.

Both rivers provide world-class steelhead fly fishing. Their small size, shallow depth and substantial steelhead runs are ideal for steelhead fly fishing. Anglers with the most basic casting skills can expect to hook steelhead in both rivers. Skilled anglers may hook many steelhead. The best angler day was 19 steelhead to the fly. Although this was an unusual day, many anglers hooked 5-9 steelhead on their best days. Steelhead movements are clearly linked to tidal conditions with fish riding upstream on the tide. Some of the best fishing was in the top one or two runs and pools in the uppermost part of the tidal zone.

Fly patterns did not matter although the steelhead were
reluctant to take dry flies. Anglers collected steelhead specimens from the top one or two miles of the tidal zone to approximately ten miles upstream—the limit of navigability by jet boat. Steelhead were present in the system when we arrived (September 20) and continued to enter the system daily until we departed on November 1. As detailed in the scientific report, the early steelhead appear to be larger and consist of a higher percentage of repeat spawners. I do not know what accounts for this apparent phenomenon. Perhaps the repeat spawners do not return to the Pacific but rather spend the summer in the Sea of Okhotsk.


The Utkolok River is a modest sized river (approximately 120-150 feet across) with moderate flow. It carries approximately two to three times as much water as the Kvachina and drains a substantial watershed. The WSC/MGU established a camp at approximately river mile 20 (ATV crossing) and conducted data collection efforts from the river mouth to about river mile 30. Downstream from the camp, the terrain is open grassland and tundra with sparse willow clumps along the river. Above camp, the terrain is more rolling, especially on the north bank, with more trees, grassland and virtually no tundra. In several places above camp, the river bottom consists of bedrock. Elsewhere, the bottom is pea to golf ball size gravel. The bottom is extremely porous and feels spongy under foot. As on the Kvachina, hordes of small gray, olive and brown freshwater shrimps live in the gravel.

The tidal influence extends upstream from the sea approximately 15-17 miles on the highest tides. River mile 0 to river mile 8, the Utkolok is extremely shallow at low tide with several bars that cannot be crossed at low tide in a jetboat (less than six inches deep). Throughout river miles 8-17 the river has many long, deep, "lakey" holes with little current and no definition. In this same stretch of river there are 6 or 8 runs with moderate current flow over shallow gravel bars and tundra clumps. So long as the river is flowing (i.e. the incoming tide does not overcome the river current), this section of river produces excellent fishing for a large population of steelhead. From river mile 17 to 30 (the upper limit of our sampling) the Utkolok is a series of runs, riffles and pools—a classic steelhead stream. Immediately downstream from camp, a modest sized tributary enters the Utkolok. In high water flows, P. Soverel ran upstream by jet boat approximately 10 miles. Although this tributary hosts coho, no steelhead were captured in this stream. At low flows, this tributary is not navigable.

Steelhead were present in the Utkolok when the expedition arrived and continued to enter the river throughout the period we sampled the Utkolok. The early run appears to contain more large fish than those arriving later in the fall. Competent anglers can expect to hook 3-5 steelhead per day. A high percentage of the steelhead are very large, over twenty pounds with a significant number of fish pushing 30 pounds—world class steelhead fishing. In addition to true steelhead, anglers caught large numbers of big rainbow trout, up to 8-10 pounds including some rainbows that had clearly been down into the sea—loose scales and sea lice. These fish were not present on the Kvachina.

The Utkolok is an extremely stable river. It takes about 30 hours of steady rain to raise and discolor the river. It takes about 30 hours for the river to return to fishing condition after the rain stops. Based upon two years of observation, unfishable river conditions is a rare event.

Of the rivers sampled, the Utkolok produces the best steelhead fishing—i.e. the most favorable combination of productive water suitable to fly fishing, numbers of fish present, ease of fishing and river stability. The presence of significant numbers of large rainbow trout is an important bonus. This river is capable of supporting a substantial recreational, catch and release fishery of perhaps 15 to 20 rods. To protect this remarkable fishery, the Utkolok warrants special protection and careful monitoring.

Sopochnaya River (2-6 and 16-23 October, 1998).

The KSP expedition established a camp at 56-01 degrees North, 156-03 degrees East near "Grandmother" mountain on the south bank of the river on a gravel bar. The Sopochnaya is a large river, especially down stream from its principle tributary, the Russoschchnaya River, at least 4,000 to 5,000 cfs. Upstream of the Russoschchnaya, the flow is perhaps 3,000 cfs. The Sopochnaya is not fordable. The Russoschchnaya is usually discolored—muddy. The Sopochnaya above this tributary is clear and remains a large river upstream for another 30 river miles (telegraph
line crossing) which is as far upstream as we observed the river. Tidal influence extends from the mouth to approximately where we located our camp—approximately 30 miles. The tidal zone can clearly hold great numbers of steelhead although it appears to be ill-suited to fly fishing—very deep, often discolored. Above camp, the Sopochnaya is a beautiful river with runs, riffles, pools and glides.

P. Soverel and Fen Montaigne ran approximately seven miles upstream in the Russoshechnaya. This is a handsome, but discolored river. It had rained hard a few days prior to our arrival and it may be that this river clears in the fall although Poloskov said that it was normally discolored. If it clears, it appears that it would provide excellent fishing (if steelhead ascend it).

Steelhead were present in the Sopochnaya on arrival and could be observed by numerous strong wakes to be migrating upstream in significant numbers. The fish hold in classic steelhead water--deeper runs with broken current. Because the of the river’s size, actual fishing for steelhead on the Sopochnaya is considerably more difficult than on the other rivers sampled. The fish appear to hold in deep water and prefer deeply presented flies. This requires fly equipment more similar to winter fly fishing equipment--fast sinking lines, heavy flies. The best water is easily recognized but not easily fished.

On October 4, 1997 Soverel, Savvaitova, Pavlov, Montaigne and Poloskov conducted a reconnaissance upstream by jetboat to the telegraph crossing. There are many miles of excellent looking steelhead water. The telegraph line caretaker had netted three steelhead the previous week so as early as the last week in September steelhead are at least 50-60 miles upstream from the mouth indicating that the run on the Sopochnaya may commence at an earlier date than on the more northerly rivers.

Although we were on the Sopochnaya for a relatively short period, for unknown reasons we captured no rainbow trout and few Dolly Varden or kundzha.

The few steelhead captured were all large fish—16 to 20 pounds -- and based upon observation of wakes from migrating fish, the steelhead were traveling hard which may also explain the relatively low success rate per unit of effort: Traveling steelhead are less inclined to bite. Altogether, based upon first impressions, although the Sopochnaya appears to have a substantial steelhead population, it may be difficult to fish. Nonetheless, this is an important steelhead river requiring further, extensive survey work.

**SUMMARY**

In summary, based upon three years of survey work, western Kamchatka has at least four rivers with large steelhead populations. The upper reaches of many western Kamchatka rivers may host large populations of trout. Each Kamchatka river surveyed by the KSP has been discovered to contain significant numbers of steelhead or big trout. As yet, we have not determined either the beginning or end of the steelhead migration. However, we can say that the best fishing appears to fall between about the first week in September and the third week in October. Steelhead migrate into these rivers at least into November, but as the river temperatures drop towards 33-34 degrees at the end of October, the fishing success falls off quickly; steelhead are present but lethargic. Earlier, although there may be fewer steelhead present, the water is warm, the fish more aggressive and, therefore, the fishing is more productive.

The Sedanka River is a trout stream of the highest quality.

Much work remains to be done to sort out steelhead run timings, population sizes and the host of related scientific questions under Moscow State Universities purview, but, based upon my experience as steelhead fisher who has fished the best steelhead rivers of north America during the peaks of their various runs, the four Kamchatka rivers sampled offer steelhead angling that compares favorably with the best steelhead rivers in the world. The Kvachina, Snotalvayam, Utkholok and Sopochnaya deserve special protection and monitoring. There are almost certainly other rivers in western and perhaps eastern Kamchatka that have substantial steelhead runs. What is certain is that the Utkholok River is one of the very best steelhead rivers in the world.

The KSP has established the feasibility, value and effectiveness of:
- cooperation between the angling and scientific community;
- funding donated by participating individual conservationists which provides a secure financial basis to conduct the proposed survey of Kamchatka’s steelhead and trout resources;
- basing collection of biological samples on catch and release fly fishing.
Abstract... The Gila Trout is not like the Grizzly Bear, the Whooping Crane, a migratory bird, or even a species of salmon. It does not require many years and a vast hunting territory to mature, only to have an agonizingly frugal birthrate. It has not been disturbed to the point of disconnecting its sexual/species identity. It does not cross myriad private property lines as it migrates north and south with the seasons. It does not enter vast oceans, subjecting itself to the greed of foreign nations. It needs only a few small streams, entirely under federal control and primarily within Wilderness Areas. Given remotely favorable habitat conditions, it can produce countless offspring in a single breeding cycle. Through decades of cautious groundwork, the scientific community has generated endless technical papers and careful studies addressing the bits and pieces of the effort to recover this beleaguered species. Yet, after nearly a quarter of a century as a charter member of the endangered species list, the Gila Trout remains at risk. This paper relinquishes the traditionally constrictive focus of the scientific community, in favor of a candid reassessment of the history of the species, its habitat, and the issues surrounding its recovery.

**IT IS CLEARLY NOT THE SPECIES’ FAULT.**

Contrary to rightwing rhetoric, endangered species are generally not inherently to blame for their own endangered state. There is, for example, nothing intrinsically deficient in the Gila Trout, *Oncorhynchus gilae gilae* (Behnke 1992). These iridescent copper and gold natives are not bony, nor inherently stunted, nor prone to disease. They are not unfit to compete, nor unable to adapt, nor otherwise lacking in worth. They are not unduly hampered by conditions that are favorable to other trout. As trout go, they are quite durable, even admirable.

For most of their history, Gila Trout thrived within their native range (Figure 2). As the *Gila Trout Recovery Plan* (US Fish and Wildlife Service 1993) indicates, “historically, Gila Trout probably inhabited the Gila River and most of its tributaries upstream from the confluence of Mogollon Creek.” The document also quotes information collected by F. A. Thompson, an early game warden.

...in 1896 Salmo Gilae ranged as far down the Gila River as...about 7 miles northeast of Cliff... ‘Speckled trout’ were once...abundant in Gilla [sic] and Willow Creeks (tributaries to the Middle Fork of the Gila)... Native trout fishing was good on South Diamond Creek and Black Canyon... on certain parts of Mogollon Creek, particularly the West Fork...there was an overpopulation of native trout... In 1898 the Gila Trout was found in all of the Gila headwaters... In 1915 trout were caught as far down the Gila as the mouth of Sapillo Creek...

Sublette, Hatch, and Sublette (1990) also acknowledged Gila Trout as well suited to their habitat.

...in the absence of supplemental stocking in comparable habitats, it is unlikely that *Oncorhynchus mykiss* can provide more desirable populations for sport angling than *Oncorhynchus gilae*. In addition, *Oncorhynchus gilae* should maintain higher standing crops and more stable populations than Brown Trout...

Gila Trout mature quickly, exhibit no unusual reproductive difficulties, and can be successfully propagated (Giesecke and David 1993, personal commu-
nication). Efficient in utilizing constricted space, they have modest habitat needs; unless displaced, they display few migratory tendencies (Rinne 1991); and their original range, in the Gila National Forest and Gila and Aldo Leopold Wilderness Areas, has been under public stewardship for a century or more. Both anecdotal evidence (Williams 1995) and more formal sources (Rinne 1991) suggest they may be relatively adaptable to warm water temperatures.

Angling for Gila Trout is not permitted; but, flyfishers can attest to the sporting quality of their closest relative, the Apache Trout, Oncorhyncus gilae apache (Behnke 1992). Once endangered, like Gila Trout, Apache Trout were rumored to be unable to grow beyond the eight inch length that was common in the tiny headwaters to which they were confined at the time; however, we now know that, in proper habitat, Apache Trout can exceed twenty inches in length and several pounds in weight. Gila Trout can also be expected to match the Apache Trout’s fondness for surface feeding on terrestrial insects, a quality prized by flyfishers, especially in a rare or unique gamefish. Thus, recovered populations of Gila Trout would even represent significant economic assets.

There has been concern for the Gila Trout since the 1920s (Rinne 1991); they had been listed in the “Red Book” by 1966 (Williams 1995); and they were listed under the Endangered Species Act in 1967 (Sublette, Hatch, and Sublette 1990). As recovery efforts go, the Gila Trout should have been one of the easy ones. Yet, despite the fact that Gila Trout are inherently robust and readily propagated, despite their potential economic value, despite their modest habitat requirements, despite most of their native range having remained under the care of the US Forest Service, despite the fact that the species was thought ready for downlisting in 1987, despite the genetic diversity that is lost with each breeding season in which recovery is delayed, despite ongoing and costly recovery efforts over nearly three decades, Gila Trout are arguably more endangered than ever before. The recovery efforts for the Gila Trout continue to be disastrously unsuccessful.

SO, WHAT SEEMS TO BE THE PROBLEM?

The problem has been stated simply enough (Sublette, Hatch, and Sublette 1990).

The decline...has been the result of habitat degradation, hybridization...and competition with...introduced trouts...

Gila Trout continue to be impacted, first, by ongoing habitat degradation, to the point of habitat elimination, and, second, by hybridization with exotics that, even now, are still being dumped into their native range. Perhaps one tenth as many Gila Trout are alive today as there were in 1986 (Schock 1997, personal communication), occupying far less than ten percent of the linear stream miles that they occupied as recently as the 1920s.

Even this picture grossly overestimates the habitat now available to the Gila Trout. Today, habitat degradation in downstream reaches has driven them into a few isolated headwater streams. At only a few cubic feet per second, the flow in these tiny refuges remains far less than the average volume for other waters within their native range. Moreover, these highly fragmented headwaters represent only the marginal top edge of their historic native habitat. As recently as the First World War, their habitat extended far downstream, through a variety of healthy riverine environments, supporting interwoven metapopulations that were never all simultaneously subject to any single transient impact, thus enabling the species to rapidly recolonize stricken reaches. Today, the species is no longer afforded such resiliency. In the tiny streams that are all that is left to them, any change in optimal conditions is fully felt by the stream’s inhabitants. Thus, a summer drought, a heavy rain, a localized fire, a severe winter, or any one of many otherwise normal occurrences will damage or even extirpate a fishery. Today, none of their tiny, fragmented, headwaters refuges provide buffer capacity to mitigate stochastic events or even normal environmental variations, a situation that has consistently proven to be more than simply a abstract risk factor. Over the past decade, the recovery effort has repeatedly been disastrously delayed, stymied, even reversed, by stochastic events and normal environmental fluctuations that the Gila Trout must have coped with thousands of times over the course of their evolution.

Chew It to the Dirt and Stomp the Leftovers!

In the winter of 1824-25, James Ohio Pattie recorded his observations (Pattie [1833] 1988) as he reached the Gila River from the Santa Rita Mine, near what is now Silver City, New Mexico (Figure 2).

...began to ascend the...stream... fatigued by the...high grass, which covered the heavily timbered bottom... we...crossed the river, here a beautiful clear stream...running over a rocky
bottom, and filled with fish... We were obliged to scramble... through a thick tangle of grapevines and underbrush... where the river forked... We found here a boiling spring so near the main stream, that the fish caught in the one might be thrown into the other...

Pattie's description of hot springs at a river fork implies that he had reached the confluence of the East Fork with main stem of the Gila River. As his testimony reveals, Gila Trout evolved under the cooling shade of mature riparian vegetation.

In the summer of 1995, the conservation group, Gila Watch, conducted a periodic review of conditions within the original range of the Gila Trout. The authors were joined by Dr. Luna Leopold, former US Secretary of the Interior Stewart Udall, riparian ecologist Dr. Robert Ohmart, Wilderness Watch's Bill Worf, Trout Unlimited's David Nickum, a respected coldwater fisheries biologist with the Forest Service, and representatives of other conservation groups, including the Forest Service Employees for Environmental Ethics. Near the top of the watershed of the East Fork, Wall Lake should be a refuge for this endangered trout; however, we witnessed excessive and inappropriate livestock grazing in surrounding meadows, in the stream feeding the lake, and in the shallows of the lake itself. Constant erosion, siltation, and organic pollution had transformed the lake and its outfall into what had been described as "a tepid, festering stew of algae and bacteria" (Williams 1995), marginal, at best, for trout.

Further south, we entered the Aldo Leopold Wilderness to view a now dry section of Main Diamond Creek in the heart of the original range. In Pattie's time, this stretch was a perennial coldwater fishery, connecting Gila Trout populations in the headwaters with populations in the Gila River, forming a viable metapopulation. In 1995, we saw only a dry gravel wash, what New Mexicans call an arroyo, cutting through a desert of sparse grass and hot dry sand. Dr. Leopold pointed out the few remaining older living cottonwoods, as well as the long dead cottonwood stumps scattered along the arroyo, all with trunks over two feet in diameter and all surrounded by younger encroaching pinion and juniper. Dr. Ohmart examined the few cottonwood sprouts that had emerged since the last time that cattle had passed, as well as the cropped remnants of saplings that had unsuccessfully tried to establish themselves in earlier years, noting that their presence confirmed that the dry pasture had recently been too wet for the pinion and juniper that now encroached upon it. This dry arroyo is the last remnant of Main Diamond Creek and the desert pasture is all that is left of a riparian area that should have been preserved in accordance with 36 CFR 219.19 and 219.27(b).

Our learned companions noted how, in some areas, removal of riparian vegetation and the trampling of streambanks had caused the stream to become wider, shallower, and to lose its moisture to the sun above and the porous sands below. In other areas,
continuous removal of groundcover and organic material from the soil, over decades, had reduced the ability of the soil to hold moisture, to support full vegetative recovery, or to resist the scouring effects of surface runoff. Erosion had then slashed the soil to channel formerly complex surface drainage down into what is now the eroded arroyo. Incised into the valley floor, the arroyo became a lateral drain, pulling moisture from surrounding soils, dropping the watertable, and eliminating the former riparian area. These changes have been so severe that, unless younger saplings are allowed to survive their early vulnerability to grazing before the remaining older cottonwoods disappeared, the last visible evidence of the riparian area will disappear.

Conditions on Main Diamond Creek are reflected on South Diamond Creek, on Black Canyon (Figure 3), and across the Gila National Forest. Even within designated Wilderness, riparian corridors are no longer filled with “high grass,” nor “heavily timbered,” nor covered by a “thick tangle of grapevines and underbrush.” River rocks are now choked with silt; the East Fork of the Gila River, once a “beautiful clear stream” filled with Gila Trout, is now a marginal warmwater fishery, only seasonally punctuated by winter stockings of hatchery reared exotics.

Further down the arroyo, young cottonwoods and willows form what New Mexicans call a bosque. The only reason for this change from desert to lush woodland is a barbed wire fence, nothing more than protection from livestock, and Mr. Worf related that what an ecosystem looks like today may bear little resemblance to its “original state” or its intrinsic, but always dynamic, ecological potential. Persistently applied, even gradual forms of artificial stress can force an ecosystem to assume a new, artificially induced, “altered state,” often at very different levels of biomass and diversity. Prolonged or cyclical stress can even impose a “synthetic equilibrium,” mimicking natural conditions that occur, entirely without external stress, in other places or climates. When chronic stress is lifted, an altered system may rebound toward its original or “natural” state; however, prolonged or severe stress can modify underlying physical features or eliminate critical species or biotic relationships, thus damaging the system’s ability to recover. When such stress and associated responses persist for long periods, there may be no remaining recollection or record of the original character of the system and the “altered state” may then be accepted, even defended, as normal. Oregon’s Camp Creek (Hunter 1991) illustrated this condition. A trout stream draining wet meadows in 1875, by the 1960s, overgrazing had reduced Camp Creek to ephemeral wash and its meadows to arid range. Wayne Elmore, as an employee of the BLM, then restricted livestock access to portions of the original riparian area. By 1991, after years of gradual recovery, the again perennial stream was healthy enough to be considered for the reintroduction of trout.

What about Habitat Stewardship?

Unfortunately, the Forest Service often ignores the lesson of Camp Creek, managing damaged riparian corridors on the basis of the “altered states” into which overgrazing has driven them. Main Diamond Creek lies deep within the endangered Gila Trout’s native range; yet, Gila Watch is still being forced to pursue legal action, simply to prompt the agency to acknowledge and manage the full length of the creek in accordance with riparian standards, rather than the standards for the arid range that overgrazing has forced so much of it to mimic.

This pending action is only the latest chapter in a long conflict over Gila Trout habitat, with the Diamond Bar Allotment clearly illustrating the stewardship tradition that has endangered this species. At over one hundred and forty thousand acres, this allotment stretches across both the Gila and Aldo Leopold Wilderness Areas, virtually covering the watershed of the East Fork of the Gila River and the bulk of the native range. Even after the listing of the trout, overgrazing was allowed to continue, deepening a pattern of livestock damage that stretches back to the last century. By the early 1980s, the allotment was in such poor condition that it could no longer support the 1,188 head on which the remaining mortgage was based, forcing the permittee off the allotment. By 1983, four years of study finally brought the Forest Service to the same conclusion as the permittee and an effort was made to reduce stocking levels to 833 head; but, the Federal Intermediate Credit Bank of Austin, Texas, having foreclosed on the previous permittee, brought influence to bear and extracted an unusual “memorandum of understanding” from the agency. The Forest Service was to allow fifteen stock tanks “to be bulldozed out of wilderness springs, seeps, and wet meadows that feed...Gila Trout habitat” (Williams 1995). The presence of these stock tanks was to be the rationale for the continued grazing of 1,188 head, essentially exchanging assured abuse of the upland
watershed for a possible reduction in ongoing damage to riparian areas. Before the agency even completed site studies for the fifteen stock tanks, the bank had sold its interest and a new permittee was demanding over thirty tanks. Only then, nearly two decades after the listing of the Gila Trout, did conservationists insist on an Environmental Impact Statement to document the lunacy.

While the process crawled along, the permittee built a reputation for trespass grazing and well over twelve hundred cattle continued to trample streams, foul water, and denude riparian areas. Although a “nine year old could tell you there’s no grass left” (Williams 1995), a university range science team, tightly aligned with the livestock industry, danced through years of “scientific” studies that routinely yielded results that defied common sense. Their view remained constant, that the allotment needed more cattle and an extensive stock tank system, deep in the Aldo Leopold Wilderness, so that underutilized forage could be profitably harvested. There was no lack of contrary input. Harold Olson, then Director of the New Mexico Department of Game and Fish, indicated his “concerns with... 1,180 cattle” in correspondence dated June 3, 1988. Director Olson’s successor, Bill Montoya, also stated objections in correspondence dated May 20, 1991.

...habitat degradation...has been observed in riparian and upland areas on the Diamond Bar Allotment... number of livestock currently being grazed is having a profound impact on terrestrial and aquatic wildlife habitat... recommend that the number...be reduced to...around 300 head... Gila Trout is...of particular concern...recommend...management...to protect the existing population in South Diamond Creek and...potential habitat in Black Canyon and Lower Main Diamond Creeks...also recommend...terrestrial management prescriptions to improve aquatic conditions on the East Fork...

In a biological opinion issued in July of 1991, the US Fish and Wildlife Service warned that Gila Trout “do best in riparian areas that are in late successional stages.” Another opinion, dated December 3, 1992, warned that in order for “a stream to support a viable Gila Trout population, it must be in the best possible condition” requiring the “control of livestock grazing.” Yet, in the “draft” Environmental Impact Statement for the Diamond Bar Allotment Management Plan (DEIS), which finally appeared in October of 1993, the “preferred alternative” still promoted twenty stock tanks, in designated Wilderness, to support six to eight hundred head. Review of the DEIS lasted nearly two years, again as hundreds of cattle continued to trample, foul, and denude the allotment. By the spring of 1995, starving cattle were dying. As the issue of animal cruelty was raised, the Wilderness District Ranger ordered all but one hundred head removed from the allotment through the year’s end, offering other allotments, all in better condition, to the permittee at no cost. Yet, he refused to move his cattle, to allow them to be moved, or to otherwise allow any reduction in stock, asserting “private property rights” over public lands, even within the Aldo Leopold Wilderness, and suggesting that any interference with such “rights” would meet armed resistance. Armed resistance was unnecessary; influence reappeared. Within days, the Wilderness District Ranger and the Southwest Regional Forester were summoned, on immediate overnight notice, to Washington, DC, to meet with personnel from the offices of US Senator Domenici and US Representative Sweeney (both R/NM), where they were scolded for their impact on the permittee’s business interests and pressed to alter their approach. Overwhelmed, the District Ranger dutifully returned to her post, canceled her assessment of the condition of the allotment, and rescinded the stocking reductions that she had previously ordered (Cartwright 1995, personal communication).

After a decade of study, the Environmental Impact Statement for the Diamond Bar Allotment Management Plan, with an accompanying Record of Decision, was finally issued by the Gila National Forest on June 19, 1995. A modified version of the “preferred alternative” had been selected; however, the decision was immediately recalled for review at the agency’s headquarters, where headquarters personnel ultimately had to direct a revised decision, restricting grazing levels on the Diamond Bar Allotment to three hundred head. This revised decision was issued on August 30, 1996. Although the permittee, still claiming “private property rights,” had long since disavowed his permit and stopped paying fees, it was not until the late spring of 1997 that his herd was finally removed.

This revised decision has gone a long way toward improving the future for Gila Trout habitat; however, unresolved issues remain. First, on this large and rugged allotment, livestock numbers have always been difficult to monitor. The number of cattle on the allotment has not always been limited by the permit and trespass grazing has been a constant
problem. Given this history, if any cattle are allowed on the allotment, it will remain vulnerable to abuse and must be monitored and managed. Second, critical riparian areas, particularly along Main Diamond Creek, remain unprotected. Without such protection, cattle will continue to “camp” in these areas.

Undesirable Aliens and Unwanted Affections

Cattle are not the only undesirable exotics in the Gila National Forest and habitat damage is not the only challenge facing the Gila Trout. Hybridization with introduced Rainbow Trout, *Oncorhynchus mykiss*, remains a serious threat; contamination of reintroduced populations has been a problem; and populations that were considered pure in the past are being reassessed. Although it is difficult to discount the possibility that stream renovation activities may not have fully eliminated exotics prior to the reintroduction of pure Gila Trout, there is little doubt that fish barriers can fail, risking significant and costly rework and an undermining of recovery efforts. In fact, for many years, the recovery team has suggested that hybridization with Rainbow Trout may be the primary danger to the Gila Trout. Although the authors believe that this position may be based as much on a reluctance to confront difficult habitat issues as on any objective ranking of relative risk factors, hybridization is still clearly a critical obstacle to Gila Trout recovery. The risk of direct competition with exotic trouts, primarily Brown Trout, *Salmo trutta*, is also a problem, although not to the same extent as the damage caused by hybridization.

An ironic aspect of the hybridization and competition problems is their source. The only salmonid native to the upper Gila River is the Gila Trout. Although the range of the Apache Trout lies adjacent to that of the Gila Trout, the two species have occupied different watersheds for millennia. To preserve genetic diversity, the recovery team works to maintain five distinct strains of Gila Trout; however, no other trout naturally shares the species’ native range, either in downstream reaches or as a migratory cohabitant. Without human intervention, there would be no other species of trout within the native range of the Gila Trout.

Another tragic aspect of the hybridization problem is that, even as the recovery team spends tax dollars to protect the species from hybridization, other personnel, from the same agencies, are spending tax dollars to perpetuate that risk. Even now, a hatchery outside Glenwood, New Mexico, roughly five miles south of Alma, is producing “catchable” Rainbow Trout and stocking them in “put and take” fisheries throughout the Gila National Forest, including the East Fork and main stem of the Gila River. Without this hatchery, the Rainbow Trout, rather than the Gila Trout, would be the species that is slowly being hybridized out of existence in the Gila National Forest. Yet, although this hatchery is one of New Mexico’s most expensive in cost per pound of production, the New Mexico Department of Game and Fish continues to operate the facility, at tremendous cost to the taxpayers and tragic cost to the Gila Trout. Efforts to address this situation have been rebuffed. The stocking operations are stubbornly defended on the grounds that Rainbow Trout are only stocked into reaches that are well downstream of Gila Trout populations and that those populations are protected by fish barriers. Such rationalizations are grossly myopic, first, because they ignore the migratory tendencies and abilities of the Rainbow Trout; second, because they assume that fish barriers are perpetually reliable; and, third, because they betray the attitude that protection of the Gila Trout is the responsibility of the recovery team, not to be shared by or allowed to intrude upon the other activities of the New Mexico Department of Game and Fish. In truth, some stocked Rainbow Trout clearly do survive to migrate long distances; even the best fish barrier is clearly not invulnerable; and, clearly, the preservation of an endangered trout should never be approached like a game of “capture the flag,” complete with opposing, taxpayer subsidized, teams.

The risk posed by a constant influx of exotic trout is actually exacerbated by the unusual political climate of Southwest New Mexico. This region has a long history of hateful isolationism. A century ago, upon
first learning that government protection would be extended to the woodlands that would eventually become the Gila National Forest, the inhabitants of Catron County showed their disapproval by burning thousands of acres of the public lands. In the 1980s, the area nurtured the “Sagebrush Rebellion” ideology. In the 1990s, these seeds blossomed into the “county movement,” a local militia, and threats against both federal and state civil servants. In this climate, the recovery effort has always faced the possibility of sabotage (Montoya 1994) and one of the most vulnerable avenues for such sabotage has been the presence of Rainbow Trout in proximity to fish barriers that protect Gila Trout populations, providing an easy opportunity to show displeasure with government simply by transporting exotics past a barrier, contaminating a protected population, and destroying years of recovery work.

Where’s the Recovery Team?

The Gila Trout Recovery Team has been discrete. For example, the Gila Trout Recovery Plan is discrete in addressing the impact of overgrazing.

Studies that specifically investigate the effects of livestock grazing on Gila Trout have not been done; however, there is considerable information documenting the effects of livestock grazing on other trout species and their habitats. Improper livestock grazing has usually degraded streams and their riparian environments, resulting in decreased production of salmonids. The extent of livestock grazing in habitats occupied by Gila Trout is limited due to the location and topography of the streams, and is not considered a principal factor in the decline of the species, or restricting its recovery.

In reality, “livestock grazing in habitats occupied by Gila Trout is limited” only because habitat damage, due to the overgrazing of riparian areas, has already driven the Gila Trout into remote marginal areas, where sparse forage, little water, and rugged terrain discourage heavy grazing. Such areas are, however, also marginal for trout. Repeated, emergency, “helicopter rescues” have been needed, simply to retrieve genetic stocks from populations that were in danger of “blow outs” in the highly vulnerable headwater streams to which the species is now confined.

Efforts to address the risks of hybridization have been ineffective. Although the Gila Trout Recovery Plan is quite clear regarding these risks, New Mexico continues hatchery operations at Glenwood.

The recovery team has been unable to effectively address either habitat degrading land uses or the risks of hybridization. Instead, it seems to have confined its efforts to attempts at sealing “specimen” populations in tiny headwater preserves, avoiding controversy by focusing only on marginal areas that, again due to their remote isolation and rugged terrain, are of the least value for grazing and other commodity operations. Again, however, these areas are also marginal for the trout and this “backed into a corner” approach has not resulted and can never result in viable populations or longterm survivability for the species. It is merely a deathwatch.

After unending setbacks, the recovery team has begun to explore a more realistic approach (US Fish and Wildlife Service 1993).

A second, preferred, strategy is to accelerate expansion... of Gila Trout... into larger, more stable, resilient habitats. Adoption of this strategy would greatly reduce the likelihood of local extinction caused by natural, stochastic events and human-induced disturbances...

Unfortunately, this new strategy will inevitably be restricted to those portions of the species’ historic range that can be restored to coldwater habitat status in a timely manner. The reticence of the team in dealing with habitat issues, from the very beginning of the recovery effort, will ultimately hamper recovery. These new efforts may be too little, too late, particularly if they remain constrained to the same level of discretion that the team has displayed in the past.

The US Fish and Wildlife Service has also been discrete. Early in the assessment of the Diamond Bar Allotment, the District Ranger requested Section 7 consultation on the effect of grazing on Gila Trout and the agency promptly returned a “jeopardy” opinion. The Southwest Regional Forester then objected, seemingly only on the grounds that, under his preferred procedures, any request for consultation should come to and from his office. His subsequent request for the same consultation, however, yielded a “may affect but not likely to adversely affect” opinion and the earlier response, now characterized as only a “draft,” was purged from agency files (Schock 1997, personal communication).

SO, WHAT’S THE SOLUTION?

It may be too late for a solution. Yet, we must learn from what has happened and what continues to be allowed to happen in the Gila National Forest.
First, we must learn that, in the same way that it is futile to build a structure without a foundation, it is futile to attempt to recover a species, without also protecting and restoring sufficient habitat to reliably support viable populations. Past a point, fragmented or excessively vulnerable habitat is no habitat at all. In the case of the Gila Trout, we have made progress toward halting livestock damage to the Diamond Bar Allotment; but, grazing damage still remains a critical problem for much of the rest of the species’ original range. For example, Wall Lake and Taylor Creek, at the top of the watershed of the East Fork of the Gila River, continue to be grotesquely overgrazed. In addition, despite habitat loss throughout the trout’s original range, no “critical habitat” was ever established. For species whose habitat occurs on private property, setting aside “critical habitat” can admittedly be difficult. For the Gila Trout, whose native range lies virtually entirely on public lands, there is no excuse.

Second, we must learn to avoid situations in which one arm of an agency is being paid to undermine the efforts of another arm of the same agency. In the case of the Gila Trout, the stocking of exotics from New Mexico’s hatchery at Glenwood must be stopped immediately, ending an unnecessary and grossly unacceptable risk of hybridization, sabotage, and disease. If this hatchery can be converted to the rearing of Gila Trout, thus aiding and not undermining recovery efforts, then that option should be explored, especially if downlisting ever opens sport-fishing. Otherwise, the facility must be closed to stop any further taking of this endangered species.

Third, we must learn to consistently manage recovery efforts. Recovery teams must have some level of accountability. Teams that are implementing successful recovery efforts should, of course, not be distracted; however, in the case of recovery efforts that show poor progress, recovery teams must be realistically monitored to ensure that they continue to be comprised of the best possible mix of capabilities and that team members remain fully engaged with and committed to the goals of the effort. A lack of management can produce the same results as genuine mismanagement. In this context, it is highly inappropriate to allow a clearly unsuccessful recovery effort to drag on, year after year, with no effective review of or adjustment in the composition of the recovery team. We must also be more careful to guard against potential conflicts of interest in team members. For example, where recovery efforts must deal with the damage caused by commodity operations, a university or other institution that has business or funding relationships with those same commodity interests should not also be permitted to have personnel seated on the recovery team. As a corollary example, in cases where recovery efforts must deal with grazing damage, agencies should avoid filling seats on the recovery team with individuals whose personal, professional, or academic backgrounds are heavily skewed toward range management and livestock operations. Similarly, a recovery effort’s research support contracts should not be directed toward universities, agencies, companies, or other institutions with which team members are directly or financially affiliated. Finally, some effort should be made to review the personal ties of recovery team members and those personnel in agencies sharing responsibility for recovery efforts. Any of these situations can potentially result in inappropriate influence or conflict of interest.

These simple lessons are taken for granted in other areas of public service. Yet, if we have learned them at all, we may need to review our efforts to effectively implement them.

Citations


Cartwright, C. 1995. Discussions with Southwest Regional Forester and Wilderness District Ranger on April 21st.


An Economic Impact Assessment of the Beaverkill-Willowemoc Trout Fishery

Vishwanie Maharaj and Joseph McGurrrin

Abstract—In 1994, Trout Unlimited initiated a socio-economic study of the Beaverkill-Willowemoc trout fishery, to provide information that governments and businesses could use to manage development in ways that both conserves the watershed, the trout fishery, and sustains the local economy. Economic impact data was collected through angler surveys and a survey of local businesses. Results indicate that anglers spent 90,200 days fishing the BeaMoc in 1994 compared to 161,700 days in 1988. The total angler expenditures in Roscoe and Livingston Manor was computed to be $9.1 million based on the intercept survey. The survey of area businesses confirmed this figure with angler related revenues estimated to be $10.1 million. Results of these two surveys were combined to calculate the economic impact of these expenditures. Based on the community model designed specifically for this project the direct economic impact in Rockland was $4.8 million (wages, local spending, local taxes, profits). About 53% of all angler expenditures made locally “leaks out” of the local economy due to business spending elsewhere. The trout fishing industry is the third largest employer, providing 159 jobs to local residents.

INTRODUCTION

The Beaver Kill-Willowemoc (BeaMoc) watershed in New York State's Catskill Mountains is about a two hour drive from the New York Metropolitan area. In this watershed, most sport fishing takes place in the public access areas along the lower reaches of the Beaver Kill and Willowemoc Rivers. The upper reaches of the Beaver Kill (about 9 miles long) are not easily accessible since the land is privately owned. This watershed has traditionally been a popular destination for trout fishing. In 1988, 21,310 anglers fished the Beaver Kill River, and 7,180 fished Willowemoc Creek (Connelly et. al., 1990). Using aerial surveys, the New York State Department of Environmental Conservation (NYSDEC) concluded that angler trips to the Beaver Kill decreased by 45% from 1988 to 1994 (Figure 1).
Although there are a number of factors involved, it is hypothesized that drought during the summer of 1991 and 1993 decreased the watershed's trout population and was chiefly responsible for this fall off in angler usage.

Trout Unlimited commissioned an economic impact assessment of the BeaMoc fishery. By analyzing the role of the BeaMoc fishery within the local economy, results from this study can increase local understanding and awareness of the economic importance of the fishery, and foster better stewardship practices. The analysis is also intended to identify opportunities for sustainable economic development surrounding the trout fishery, and in particular, angler related business opportunities.

The rest of this paper describes methods of data collection and analysis, and presents results and a discussion of implications of these results.

**DATA COLLECTION AND ANALYSIS**

This study assesses the economic impact of the trout fishery on the Lower Beaverkill and Willowemoc rivers in 1994. Both mail and intercept surveys provided data on angler expenditures and preferences for different aspects of the trout fishing experience. In addition, local businesses currently patronized by BeaMoc anglers were surveyed to verify estimates from the angler surveys, to map the flow of income in the local economy, and to determine secondary impact. All surveys were developed and modified after focus group meetings with anglers in the local area, and consultation with NYSDEC officials and Trout Unlimited. In addition, the business survey questionnaire was pretested on business proprietors who belong to the local chamber of commerce. While the mail survey instrument was field tested during the opening day of fishing season (April 1, 1994).

**Angler Surveys and Data Analysis**

Data were collected from both a mail and intercept survey. Intercept surveys were administered to anglers who fished in the public access areas during 1994. In addition, surveys were mailed to a randomly chosen sample of anglers who purchased New York State fishing licenses in 1994. The mail survey was conducted in order to ensure that survey responses were representative of general anglers.

For the most part, both the mail and intercept surveys collected the same information. The first part of both questionnaires requested information on angler demographics, experience, preferred methods of trout fishing, areas along the river fished most often and expenditures during the 1994 fishing season. In the second part of each survey, questions focused on eliciting preferences for trout fishing characteristics on these rivers and amenities in the town of Roscoe and Livingston Manor, the two centers of commerce in the local area.

Anglers who fished in this watershed in 1994 were asked to provide data on the following categories of expenditures for 1994: fishing gear and supplies purchased at local shops; guiding and fly fishing instruction; travel costs; outlays for accommodation; outlays for meals and beverages; and other expenditures made locally.

Demographic information included state of residence and zip code as well as driving time. Questions aimed at characterizing anglers included: organizational affiliation, trout fishing experience, method of fishing used most often, catch and release ethics, areas on the BeaMoc fished most often, and preference for catching hatchery-reared versus wild trout.

Statistical tests are used to determine if there are significant differences between these two groups, with regard to fishing expenditures and angler characteristics.

**Implementation of the intercept survey**

To increase awareness of the study and help boost response rates, news releases about the BeaMoc study was sent to local newspapers, and posters were displayed at several area businesses. Three sampling trips were undertaken with five trained interviewers per trip to conduct the intercept survey. In efforts to obtain a representative sample of anglers, sampling days were chosen to include both weekend and weekday
participation. Sampling days were also chosen to be compatible with the NYSDEC population estimates which were used in this study, and with peak usage throughout the fishing season. For all seven survey days, an interviewer was stationed at popular fishing pools, and a roving intercept survey method was used on other sections of these rivers.

In general, anglers fishing in the watershed were cooperative with interviewers and completed both sections of the survey instrument on site. Less than 1% of anglers intercepted refused to participate in this survey. In total, 418 questionnaires were filled out, which exceeded initial expectations.

Mail Survey of 1994 New York State Anglers

It was expected that the mail survey would reach anglers who did not currently fish on the BeAoc. A sample of 1,000 anglers who had purchased New York State freshwater fishing licenses in 1994 was chosen randomly. This sampling distribution was based on the results of a 1988 study of New York State license holders (Tyrrell et al., 1996). The mail survey was implemented following the Dillman method (Dillman, 1978). A total of 270 mail surveys were returned. As the response rate to this mail questionnaire was under 30%, a follow up telephone survey was necessary to account for non-respondent bias (Dillman, 1978). Results from this telephone non-respondent bias survey indicated that data from the mail survey were not biased by any particular demographic or motivating factor.

Population estimates

There were no direct estimates of the number of angler visits to the Willowemoc and Beaver Kill Rivers during 1994. A 1988 statewide study (Connelly et al., 1990) provided rigorous estimates of angler days for 1988. Aerial survey data from the New York State Department of Environmental Conservation (NYSDEC) indicated the trend in fishing participation from 1988 to 1994. The estimate of 1994 angler days used in this study was determined by creating a ratio of the NYSDEC angler trips for 1988 and 1994, and applying this ratio to the 1988 estimated number of fishing days on both the Beaverkill and Willowemoc rivers. However the ratio of two random variables does not have a symmetric distribution, so this ratio is generally biased downward. Therefore, to reduce this bias, both the ratio estimate and the 95% confidence interval around this estimate was calculated using a method suggested by Geary (Tyrrell et al., 1996). Using this method, the 1994 estimate of angler fishing days on the Beaverkill and Willowemoc Rivers was 90,229 ±40,926.

Total angler expenditures was calculated as the product of average daily expenditures obtained from the angler surveys and the estimate of total days. The variance on total expenditures is approximated by the formula:

\[ \text{Var}(XY) \approx X^2 \text{Var}(Y) + Y^2 \text{Var}(X). \]

Weighting the intercept survey data

Sample selection bias can also occur in intercept surveys as a result of the non-random sampling process. NYSDEC angler trip estimates for 1994, derived from angler counts, were used to adjust the intercept survey data for the distribution of anglers along the river. This ensures that intercept survey data are more representative of the population of anglers who fished the BeAoc in 1994, assuming that the distribution of fishing effort in 1994 was the same as that in 1995.

Business Survey and Data Analysis

A business survey was developed and administered to 102 commercial establishments in the Town of Rockland. Area businesses that are potentially impacted by visiting anglers were identified by the chambers of commerce. During 1994, these and other "like-businesses" in the Rockland Visitors Guide were mailed a one page survey questionnaire. Data on total revenue earned, wages, and employment, together with estimates of the percentage of the business that comes from: residents; non-residents; and anglers were used to calculate the amount of sales derived from this trout fishery, and wages that are attributable to BeAoc anglers. Other businesses in these towns may also realize secondary impacts from the trout fishery, thus data were collected on the amount businesses spent on goods and services, rent, and utilities in Rockland. Estimates of property taxes, sales tax, and other area taxes were also obtained through the survey instrument, since business taxes will impact the community through spending on school and other municipal services.

In order to estimate the magnitude of angler-related business in Rockland, relative to the size of the entire area economy, all businesses in Roscoe and Livingston Manor were identified from the "Yellow Pages" listings. A total of 268 businesses were listed. Because
surveys were sent to only select area businesses, it was not possible to identify the portion of sales attributed to this trout fishery for all 268 businesses. Thus, estimated revenues attributable to BeAMoc anglers are expected to be conservative.

U.S. Census data was used to calculate missing values for businesses which did not respond or were not interviewed. Where possible, data for Sullivan County was utilized. In other cases New York State data was used, after adjusting for the size of the Rockland economy.

RESULTS
Results from the angler study and the business study are grouped separately.

Angler Survey
In 1994, survey participants made an average of 6-8 trips per year, of a mean duration of 3 days per trip, to fish in the BeAMoc watershed. These anglers drove for an average of just over 2.5 hours. About 41% of all intercepted anglers responded that they had fished other areas while on BeAMoc fishing trips. The average time spent fishing other areas was 43% for the anglers who fished other areas. This group of anglers who fish other areas may be more inclined to shift to other rivers if fishing conditions on the BeAMoc were to become less attractive.

Expenditures by BeAMoc anglers in 1994
By necessity, the angler study has focused on 1994 angler activities and expenditures. Thus, there is the possibility of recall bias. As observed from pretesting the survey and focus group meetings, most anglers were able to approximate 1994 expenditures. Ease and reliability of recalled estimates depended on the type of expense. It appeared that anglers accurately recalled money spent on expensive items, such as rods and reels, fly fishing instruction and guiding. The least accurate recall estimates were expenditures on food and beverages, and small fishing supplies such as flies and lures.

In 1994, the average on-site annual expenditure per angler from the intercept survey ($792 ±$109) was higher than that for mail survey respondents ($524 ±$112). Total estimated expenditures in the study area ranged from $5.79 ±$3.04 million for the mail survey to $9.06 ±$4.63 million for the intercept survey. However, these two estimates were not significantly different at the 95% level. Although mail survey respondents are considered to be more representative of anglers who fish the BeAMoc, expenditure estimates obtained from the mail survey are considered less reliable given the low response rate to the mail survey. In addition, the distribution of expenditures on the intercept survey closely matched the distribution of expenditures that was estimated through the area business study.

Expenditures on accommodations, food and beverages, travel, and gear are approximately equal, ranging between 21-26% (Table 1). Only about 1% of the total was spent on instruction and guiding.

<table>
<thead>
<tr>
<th>Expenditure Category</th>
<th>% of total expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food and Beverages</td>
<td>24%</td>
</tr>
<tr>
<td>Accommodation</td>
<td>26%</td>
</tr>
<tr>
<td>Instruction &amp; Guiding</td>
<td>1%</td>
</tr>
<tr>
<td>Gear</td>
<td>26%</td>
</tr>
<tr>
<td>Travel</td>
<td>21%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
</tr>
</tbody>
</table>

Angler Characteristics
Not surprisingly, more than half (52%) of all anglers fishing the BeAMoc are New York state residents. A large percentage (31%) of BeAMoc anglers also resided in the state of New Jersey. Both mail and intercept survey respondents who fished the BeAMoc had been fishing for trout for just over 20 years. This indicates that anglers are more likely to take a fishing trip to the BeAMoc if they have had more experience fishing for trout.

Between 40% and 50% of all anglers who fished on the BeAMoc were members of a sport fishing club, and 88% of intercept survey respondents stated that they would not visit the area if the fishery did not exist. Most anglers release most of the fish they catch, even if they are above the legal size limit. Mail survey results indicate that there are a higher percentage of fly fishermen among those who fish the BeAMoc, compared to the general angler population.

Business Survey
As evidence of their dependence on visitors from out of town, many businesses in Rockland operate on a seasonal basis. In addition, even though some businesses are open year-round, seasonal fluctuations in business receipts are significant. For many establishments, this seasonal variability could be clearly attributed to visiting anglers (April 1st-November 31st). The owner of one fly tackle store reported that more than 50% of his business revenues
were usually realized between the last week of April and the 4th of July weekend. For others, some of this variability could be attributed to visitors other than anglers, such as general "off-the-road traffic", hunters, or other non-fishing Catskill vacationers.

**Rockland Revenues**

Angler impacts on Rockland businesses are estimated for 7 different business categories using survey responses and U.S. Census data. Those businesses receiving the highest proportion of angler-related spending are the area campgrounds. (Table 2). However hotels and bed and breakfasts (SIC 701) in the area received more angler-related revenues that any other business sector in Rockland.

**Table 2: Angler related revenues by sector of the economy**

<table>
<thead>
<tr>
<th>Type of Business (SIC Code)</th>
<th>Angler Related Revenue</th>
<th>% of Total Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camps not including kids camps (703)</td>
<td>$771,063</td>
<td>48.0%</td>
</tr>
<tr>
<td>Department/Specialty Sport (594)</td>
<td>$1,348,326</td>
<td>40.9%</td>
</tr>
<tr>
<td>Hotel/Bed &amp; Breakfasts (701)</td>
<td>$4,405,378</td>
<td>39.1%</td>
</tr>
<tr>
<td>Restaurants/Pubs (581)</td>
<td>$598,466</td>
<td>17.3%</td>
</tr>
<tr>
<td>Grocery/Convenience (541)</td>
<td>$121,331</td>
<td>1.2%</td>
</tr>
<tr>
<td>Other retail and Service</td>
<td>$2,861,263</td>
<td>4.5%</td>
</tr>
<tr>
<td><strong>All Other</strong></td>
<td><strong>$0</strong></td>
<td><strong>0%</strong></td>
</tr>
</tbody>
</table>

*This does not include secondary spending that remains in the town from initial angler spending.*

The hospitality and visitation industries: camps, hotels, bed and breakfasts, restaurants, and pubs comprise 20% of the 270 establishments in the study area. These businesses attributed between 17% and 50% of their revenues to visiting anglers.

Businesses not falling into any of these 6 categories, such as manufacturing or construction companies are assumed not to realize any direct sales from visiting anglers, and are classified as all other. It is estimated that total revenues received by all 268 businesses in the study region amounted to $203 million in 1994. An estimated 5% of this total, $10.1 million, was directly attributable to BeaMoc anglers. Expenditures by BeaMoc anglers made up 11% of all retail revenues in Rockland.

For those business sectors that realize a large share of their revenues from visiting anglers, a significant drop in angler visitation could result in bankruptcy. On the other hand, these are the area businesses that stand to benefit the most from improvements to the fishery that would attract more anglers.

**Rockland Jobs and Wages**

It is estimated that 1,835 jobs are supported by all businesses in the study area. Of these, 177 are generated by angler activities, 159 of which are held by residents of Rockland (Table 3). In addition, more that 30% of Rockland jobs and wages in the lodging and specialty sport shop business sectors were attributable to visiting anglers.

In 1994, the annual payroll in Rockland was $27.3 million for all businesses and $18.6 million in the retail sectors.

**Table 3: Angler related jobs and wages by sector of the economy.**

<table>
<thead>
<tr>
<th>Type of Business (SIC Code)</th>
<th>Angler Related Jobs</th>
<th>Angler Related Wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camps not including kids camps (703)</td>
<td>12</td>
<td>$156,569</td>
</tr>
<tr>
<td>Department / Specialty Sport (594)</td>
<td>18</td>
<td>$175,253</td>
</tr>
<tr>
<td>Hotel / Bed &amp; Breakfasts (701)</td>
<td>76</td>
<td>$1,258,218</td>
</tr>
<tr>
<td>Restaurants/Pubs (581)</td>
<td>17</td>
<td>$142,456</td>
</tr>
<tr>
<td>Grocery / Convenience (541)</td>
<td>1</td>
<td>$10,966</td>
</tr>
<tr>
<td>Other retail and Service</td>
<td>35</td>
<td>$515,260</td>
</tr>
<tr>
<td><strong>All Other</strong></td>
<td><strong>0</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

With 11-12% of the local retail job market dependent on angler related commerce, fluctuations in angler visitation to the BeaMoc have the potential to directly impact Rockland employment rates, especially in the lodging and specialty sport retail sectors. In fact, many of these businesses are opened exclusively for the fishing and tourist season.

The economic impacts of angler activities are felt in many formally-defined industry categories. However, the impacts of the trout fishery on the economy of Rockland are attributed not to the nature of a product, but rather to the origin of the customer. That is, anglers who visit the town from elsewhere bring new dollars into the local area. To illustrate the relative importance of the tourism component of the trout fishery to the local economy, employment dependent on visiting anglers were separated out from all SIC code categories and compared with non-angler generated employment. This revealed that employment attributable to the trout fishery ranks third among industry groups in the area. Only employment in health services (195) and lodging (192) from all non-angler visitors exceed it.
### Table 4: Summary of the Business Study Data

<table>
<thead>
<tr>
<th>Item</th>
<th>Total</th>
<th>Retail Sectors</th>
<th>Angler Related in Rockland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Businesses</td>
<td>268</td>
<td>213</td>
<td>213</td>
</tr>
<tr>
<td>Gross Revenue</td>
<td>203,018,267</td>
<td>92,557,436</td>
<td>10,105,827</td>
</tr>
<tr>
<td>Jobs</td>
<td>1,835</td>
<td>1,365</td>
<td>177</td>
</tr>
<tr>
<td>Wages</td>
<td>24,980,759</td>
<td>18,661,886</td>
<td>2,260,742</td>
</tr>
<tr>
<td>Respending in the town of Rockland</td>
<td></td>
<td></td>
<td>1,798,598</td>
</tr>
<tr>
<td>Local Taxes</td>
<td></td>
<td></td>
<td>467,231</td>
</tr>
<tr>
<td>Return on Investment</td>
<td></td>
<td></td>
<td>152,823</td>
</tr>
</tbody>
</table>

The results of the study of BeaMoc area businesses provide a second, conservative, estimate of the total impacts of visiting anglers on the region’s economy. The business survey estimate of $10.1 million of angler-related revenues strongly confirms the angler survey estimates of $8 to $12 million.

**CONCLUSION**

It was important to document this economic impact as there appeared to be some level of disagreement about the importance of the river system to the area economy. Business owners that clearly depend on visiting anglers (i.e., fly and tackle shops), and those businesses that customarily require close interaction with customers (i.e., campgrounds or motels) recognize the critical impact that the BeaMoc anglers have on the area economy. Those business owners that have less interaction with customers (i.e., grocery stores or restaurants), and those not normally directly impacted by anglers (i.e., lawyers or construction contractors) tend to dismiss angler related commerce as an insignificant contribution to the area economy.

Results from this study were distributed widely within the local community. As community leaders recognized the dependence of the local economy on the BeaMoc trout fishery, water conservation has become a critical issue by the local community. Evidence for the community’s growing concern for water conservation is the decision taken on two commercial spring water development proposals, which the local zoning board rejected.

Fisheries advocates will continue to support water conservation efforts by providing the best available data to landowners and local officials seeking to protect the resource. Community leaders are also considering actions on other development issues, sewer and septic tank permits, as well as residential and commercial zoning. Furthermore, results from this study can be applied to other social, political, and economic issues that face the BeaMoc watershed and its trout fisheries.

The participation of local businesses, community leaders, and interested citizens in these efforts is the key to effective management, as long term protection of this watershed will be in their hands. In conclusion, this project serves as a model for conservation minded watershed management that increases rural economic opportunities.

**REFERENCES**


Managing the Bridger Wilderness Fisheries; Allocating a Resource for the Users, the Ecosystem, the Future

Ron Remmick

Abstract - The Bridger Wilderness Area (BWA) provides a variety of experiences for the fishing and non-fishing public. The BWA occurs in the Wind River Mountain Range in western Wyoming. Approximately 1300 lakes occur in the BWA and 30% now have a wild trout fishery. Fishery management activities began during the early 1900's and focused on stocking. These stocking efforts created diverse fishing opportunities in waters with no existing fish populations. Little detailed information about area waters provided impetus for the Wyoming Game and Fish Department (WGFD) to conduct fish population and habitat surveys from 1969 to 1975. Current fishery management activities include stocking to maintain trout populations in 4 to 9 lakes with no natural recruitment, and fish surveys to evaluate stocking success. Four lakes are part of a joint USFS/WGFD Acid Deposition Monitoring Program, and two lakes provide refuges for Wyoming's native cutthroat trout. The WGFD has no plans to stock the remaining fishless lakes even though they may be capable of supporting a fishery. But the WGFD feels there is strong public support to maintain existing fisheries. Without this public support future political pressures from resource developers could threaten the wilderness status.

The Bridger Wilderness “A LAND OF A THOUSAND LAKES”. A unique resource for many users, known as a great place for mountain climbing, hunting, photography, hiking or camping, BUT mostly for its fishing opportunities in a multitude of lakes. And as a fishery manager my responsibility is to manage the fishery resource we inherited, for our publics (all wilderness users) without jeopardizing this pristine ecosystem.

The BWA contains an area of approximately 380,000 acres along the western half of the Wind River Range and within the USFS’s Bridger-Teton National Forest, near the town of Pinedale, Wyo. About 1300 lakes occur in the BWA ranging in size from less than 2.5 acres to 247 acres, while the average size is about 10 acres. Of these 1300 lakes about 575 (40%) have an existing fishery or have fishery potential. There are about 550 stream miles within the wilderness boundaries but 450 miles have little or no fishery potential because of a steep gradient and harsh winter conditions. All these waters flow into the Green River of the Colorado River System.

There are 3 distinct ecological zones within the wilderness area:

MONTANE
- Extends from Wilderness Boundary to 9500 feet elevation.
- Cover type predominately coniferous forest

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1 Ron Remmick, Regional Fisheries Supervisor, Wyoming Game and Fish Department, 351 Astle Street, Green River Wyoming, 82935.
• Terrain broken by deep canyons with peninsulas of rocky flats or boggy meadows
• Zone’s upper reach is “benchlike” where many lakes within this zone are situated
• Deeper lakes located in canyon areas

MIDDLE ZONE (BENCH LAND)
• 9500 feet to 10,500
• Streams generally meander between lakes before flowing into montane zone canyons
• Southern end - densely timbered
• Middle Krumholtz (dwarf, misshapen trees)
• Northern end - Zone primarily absent
• Most lake and stream fisheries in this zone

ALPINE TUNDRA
• 10,500 feet (timberline to Continental Divide)
• Bare rocks and talus slopes throughout zone
• Alpine tundra meadows dot the area
• Lakes generally sterile and often discolored by glacial flour
• Streams generally torrential

The unique geological features including steep, torrential streams in the lower end (the montane zone discussed earlier) of the wilderness drainages prevented native fish species from migrating into what is now the BWA. Early fishery management activities focused on stocking which has created the current diverse fishing opportunities. Stocking began as early as 1907 although most stocking occurred between 1924 and 1935. About 390 lakes are known to contain one or more salmonid species: Brook trout, 119; cutthroat, 84; golden, 35; rainbow, 31; brown, 7; grayling, 6; and lake trout, 4 lakes. During these early years stocking occurred primarily by horseback, hauling fish in by milk cans, changing water frequently during the trips into the more remote lakes.

Although little thought was given to inter- and intra-species competition, hybridization, and affects on other aquatic life forms, these early management efforts were still considered a wise use of the resource during that phase of conservation management.

The area was designated a Primitive Area in 1931 and became a wilderness area by the Wilderness Act of 1964. Even before included within the wilderness system this region was recognized for its diverse fishing opportunities. An issue of a 40 year old Pinedale newspaper proudly reported about a December 1955 Outdoor Life story on the unexploited fishing opportunities within the region. This popularity helped provide the public support necessary to include it within the National Wilderness System.

Because of the increased interest generated in the area after it was formally recognized wilderness, and because of the lack of information about the fisheries a detailed survey was conducted by the WGF from 1969 to 1975 to identify the biological, chemical, and physical parameters of the lakes. This information was used to modify stocking rates, stock species better adapted to a particular lake’s capabilities, and eliminate unnecessary stocking.

Current management practices include; stocking, fish sampling for stocking evaluations, fishing regulations, acid rain monitoring, and general trend data collection.

Stocking: During the mid 70’s up to 21 lakes were annually stocked. Currently this maintenance stocking occurs every two years in four to nine lakes where no natural reproduction occurs. The waters stocked are generally the popular golden trout waters. Stocking is primarily accomplished by helicopter which reduces impact to the ecosystem since we can fly over the lake, drop the fish, never touching the ground, and be out of the area in minutes. This compares to the old method of horse pack trips (last used extensively in the mid 1950’s) which could take days, decrease survival of stocked fish, and cause considerably more impact to the area than the brief appearance of a helicopter.

Besides maintenance stocking on popular lakes, stocking has occurred to provide refuges for native species. Big Sheep Mountain Lake in the northern end of the BWA was stocked with Colorado River cutthroat trout to provide a brood source for our hatchery system. Even though these cutthroat were not a true native to the lake, they are native to the
Green River drainage. When these fish became mature they were spawned and the eggs taken to the Daniel Fish Hatchery to eventually be used to restore native Colorado River cutthroat trout watersheds. Sunrise Lake, in the more southern end of the BWA was stocked in 1979 and 1987 to establish a Colorado River cutthroat trout population. Good spawning areas allowed these fish to establish naturally reproducing populations. Although not used in our fish culture program they will be available should something happen to our genetically pure populations occurring elsewhere. These lakes have become good refuges for important native trout susceptible to fishing pressure, poor habitat, and drought conditions in their native watersheds.

Stocking has been our most contentious management activity. This is not a recent issue. After the area was designated wilderness in 1964 concerns were expressed about aerial stocking by some resource users and federal agencies. This controversy even prompted a pro-stocking resolution adopted by the Colorado/Wyoming Chapter of the American Fisheries Society in 1973. This resolution generally stated the Chapter:
- opposes unqualified restriction of fish stocking activities in high mountain wilderness lakes by the United States Forest Service (USFS)
- USFS needs to recognize that stocking of some lakes by aircraft is a legitimate and necessary management tool
- USFS adopt a uniform policy of use of wilderness areas relative to fish stocking.

A revised Bridger Wilderness Fish Management Plan was developed in 1978 and signed by the WGFD director and USFS Regional Forester for the Intermountain region. Acknowledgement of fishing’s importance to many wilderness visitors was reiterated in the plan. Among the issues dealt with in the plan was aerial stocking. It was agreed to allow stocking by aircraft at those lakes that were so stocked prior to Sept, 1964. Rationale for this continued management policy included decision it would minimize impact to already heavily used trails and meadows from horse use, and it would minimize criticism from non-horse and other users because of competition for camping areas, meadows, and trail use. Although there have been varying philosophical differences concerning stocking between personnel in our department and the USFS we continue to have good working relationships with the Bridger-Teton Pinedale ranger district. We notify their office when stocking by helicopter will occur so if concerned publics call they will be able to let them know what is going on. And although we have not stocked fishless lakes in recent years (and in fact continue to reduce stocking), we will not stock new waters without going through a review process coordinated with the USFS office and the general public as outlined in the 1978 BWA fishery management plan. Most new stocking would likely be sought to provide isolated refuges for sensitive or unique species.

Fish Stocking Evaluations: In order to continue a responsible stocking program, routine gillnet sampling has occurred on stocked lakes since the 1980’s. Sampled fish were measured, and scales taken to evaluate body conditions and age-growth characteristics. This information was used to determine if stocking rates were too high or low, and if natural reproduction was occurring. Because of these efforts we have reduced our stocking from about 20 lakes stocked annually up through the 1970’s to 4 to 9 lakes stocked every other year in the 1990’s.

Fishing Regulations: regulations have always been under the general statewide restrictions which is 6 trout limit (only 1 can be over 20 inches). During the 1970’s and early 1980’s an angler could keep an additional 10 brook trout 8 inches or less in length. This was an attempt to place more pressure on lakes overpopulated with brook trout. But relatively light fishing pressure proved this extra limit ineffective. It was also noted this additional limit encouraged waste. Some anglers would harvest these fish then decide later not to pack them out, and instead throw them away. So this additional brook trout limit was eliminated in the 1990’s.

Acid Deposition Monitoring: Four study lakes are part of a joint USFS/WGFD acid deposition monitoring program initiated in 1983. This program has established baseline water chemistry, invertebrate, and fish population information. Our department’s fishery management obligation has
been to collect body condition, age-growth, and fish health data on the trout. These study lakes contain wild trout populations in the middle and south end of the BWA. These lakes were selected because they were susceptible to airborne pollutants from the larger urban areas west and south of the BWA. And by monitoring wild trout lakes, stocking does not bias fish population characteristics. Originally, fish sampling occurred every two years but sampling frequency has been reduced to every 5 to 6 years. This sampling frequency will continue unless annual water quality sampling by the USFS indicates problems beginning to occur.

**Trend Data Collection:** Routine fishery surveys will occur as budgets and time scheduling allows. We will use this information to provide our publics with current fishery resource information on the more popular fisheries whether they are stocked or wild fisheries.

Although fishing continues to provide the primary use within the BWA some publics criticize this activity since these waters were devoid of fish prior to man's stocking efforts. Some groups have even expressed a desire to see all fish removed from all lakes, returning the waters to their pristine condition.

**WE CANNOT TURN BACK THE CLOCK AND WOULD WE WANT TO IF WE COULD?**

To remove trout from these lakes would require some kind of chemical treatment and a lot of manpower and equipment. This type of effort could do much more harm to the ecosystem than just allowing them to remain as they are. What other organisms would we kill besides fish? And bringing materials and equipment to each treated lake would be a logistical nightmare. We are talking about almost 400 lakes to treat. This effort seldom produces complete kills and fish would likely return in those lakes with natural reproduction.

We have an advantage in the BWA since only 40% of the lakes have fisheries. This means there are already more than 700 lakes in their pristine state. The department has no plans to stock the remaining fishless lakes even those that could support a fishery. But the WGF feels that the current diverse fishery resource provides strong public support from a great number of people who want the area to remain wilderness. The area became a wilderness because of politically mandated legislation. Elimination of the existing wilderness fishery could create an indifference from the wilderness's most important political ally, the angler.

There are currently no known sensitive amphibians or other aquatic species in this wilderness which could be threatened by trout. During our fishery surveys it is our responsibility as management biologists to document amphibian observations. If we were to become aware of trout impacting any sensitive aquatic species we would make every effort within our abilities to protect that species in that system. But we feel this can be done without jeopardizing all the other fisheries in the BWA.

Proper fishery management using an ecosystem approach, eliminating unnecessary stocking, and maintaining public support will assure there will be waters available for the angler to catch his or her wilderness trophy, and for the naturalist to observe a system not influenced by introduced fish. We are fortunate we can have both in the BWA. Maintaining existing fisheries opportunities yet not stocking the remaining pristine waters will hopefully assure continued strong political support from all users well into the future. If this occurs, the BWA ecosystem can remain unique and free of development activities so the angler, naturalist, climber, hiker, camper, photographer, ALL resource users, can have their own wilderness experience.
California: Unparalleled Biodiversity - Unrivaled Productivity

Jim Edmondson

Abstract — Despite two centuries of unprecedented resource manipulation to accommodate immense population growth, California possesses the greatest biodiversity of native trout and steelhead of any state in the nation. Yet the state also leads the nation in the number of imperiled species. The challenge facing resource managers is to accommodate future population growth in a manner which allows for the protection and restoration of these unique trout and steelhead. This can be accomplished by taking advantage of their ecological and economic values, using them as indicators of watershed health and developing measurable population objectives.

CALIFORNIA'S UNPARALLELED TROUT BIODIVERSITY

Historically California was blessed with the most diverse native trout and steelhead fisheries in North America. Its 60 major watersheds include over 20,000 miles of rivers and streams. (FRRAP, 1988) Coldwater streams supporting trout and steelhead represent 17,635 miles of these river systems. (CFWP, 1965) These waters support nine native trout species, the majority residing in the Sierra Nevada.

Table 1.— Native trout of California

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lahontan cutthroat*</td>
<td>O. clarki henshawi</td>
</tr>
<tr>
<td>Pauite cutthroat*</td>
<td>O. clarki seleniris</td>
</tr>
<tr>
<td>Coastal cutthroat</td>
<td>O. clarki clarki</td>
</tr>
<tr>
<td>Coastal rainbow</td>
<td>O. m. irideus</td>
</tr>
<tr>
<td>Kern River rainbow*</td>
<td>O. m. gilberti</td>
</tr>
<tr>
<td>Redband rainbow</td>
<td>O. m. stonei</td>
</tr>
<tr>
<td>Eagle Lake rainbow*</td>
<td>O. m. aquilarum</td>
</tr>
<tr>
<td>Little Kern golden</td>
<td>O. m. whitei</td>
</tr>
<tr>
<td>Volcano Creek golden*</td>
<td>O. m. aguabonita</td>
</tr>
</tbody>
</table>

* Located in Sierra Nevada

California’s coastal river systems once had annual runs of adult steelhead numbering over one million. Coastal rivers spanning the state’s 1,100 mile coast line contain six evolutionary significant steelhead types which materially contribute to the species’ heritage. (Federal Register, 1996) Southern California steelhead contain the parent genetic materials for all Pacific Coast steelhead stocks, and could be the most ancient of the species. (Nielsen, 1994)

EXISTING MANAGEMENT AND STATUS OF CALIFORNIA'S TROUT

EXISTING MANAGEMENT

Of the 17,635 miles of coldwater fisheries in the state, approximately 1,200 miles are planted by the Department of Fish and Game (DFG) with hatchery-reared catchable trout. Another 1,000 miles are managed for wild fish through either a Catch and Release or a Wild Trout Program. The balance, representing more than 75% of California trout rivers and streams, are wild fisheries rarely planted with hatchery trout. These waters are generally remote wilderness fisheries that fall into state agency trout management program void.

The cost of the DFG’s catchable trout and wild trout programs are dramatically different. DFG expense to produce and stock catchable trout is at least $3.44 per pound. (Mayo Associates, 1988; Farley, 1992) Planting catchable trout in the 1,200 miles of streams requires an annual DFG expenditure ranging from $8 to $12 million, or about $6,000 to $10,000 per stream mile. The DFG’s wild trout program annual budget is less than $1 million, or approximately $1,000

1 Executive Director, California Trout, Inc. San Francisco, CA.
per stream mile. Fewer than 10% of California’s anglers purchase their sportfishing license to exclusively pursue catchable trout. (Anderson, 1990)

CURRENT STATUS

California’s trout fisheries are under siege, with annual fishing pressure exceeding 32 million angler days. (von Geldner, 1989; Lal, 1979) Even with this huge angling pressure, California’s wild trout fisheries, where managed for sustainability, are among the most productive in the Western United States.

![Ecoregion biomass from Platts and McHenry, 1988.](image)

However, two centuries of population growth and development have taken a enormous toll on these resources. Dams and diversions have been constructed in all but a dozen of the state’s major drainages. Today there are 1,200 dams exceeding 25 feet in height. (State Lands Commission, 1993) These dams have submerged rivers, blocked fish migrations, and reduced or eliminated downstream water flows essential for trout and steelhead survival. In the Sierra Nevada alone, dams have flooded 600 miles of river corridors fragmenting aquatic systems. (SNEP, 1996) Land clearing, logging and road building have caused erosion to choke spawning beds with silt and stripped streambanks of vegetation that keep water temperatures tolerable to trout and steelhead. Grazing has resulted in trampled and denuded streambanks that no longer provide cover and food for fish, and has destabilized stream channels which increases the risk of flooding. Streambank erosion is estimated to be occurring on more then 9,000 stream miles of grazed lands and 3,000 stream miles of timberlands. (FRRAP, 1988).

LEADING THE NATION IN EXTINCT AND IMPERILED AQUATIC SPECIES

California leads the nation in the number of extinct or imperiled aquatic species. (Moyle and Williams, 1991). The problems for the state’s native trout species are particularly acute in the Sierra Nevada where river systems are the most altered and impaired habitats in the range. (SNEP, 1996) The Sierra’s two cutthroat trout (Lahontan and Paiute), its unique Kern River rainbow and the Little Kern golden are all listed as threatened species under the federal Endangered Species Act. (CNDBB, 1991) Even California’s State Fish, the Volcano Creek golden trout found only in the Golden Trout Wilderness, is a candidate for the endangered species list.

Steelhead are in even worse shape. California’s steelhead populations have plummeted to less than thirteen percent of their historic numbers. Since the mid-1980’s, the decline has accelerated as steelhead numbers have dropped from approximately 250,000 adults to near 100,000. Steelhead that were once native to most major Sierra Nevada rivers are now nearly extinct. (SNEP, 1996) Sadly, 23 steelhead populations in Southern California are extinct. (Nehlsen et al, 1991) The majority of the remaining steelhead in California are scheduled for addition to the federal list of endangered, or threatened or species of special concern. (Federal Register, 1996)

With California’s population projected to grow from 33 million to over 60 million in the next century, the threats to trout and steelhead from water development and land disturbance will increase. Furthermore, the impacts of growth will not be evenly distributed throughout the state. The population of the Sierra’s will triple by 2040. (SNEP, 1996) Population growth along the coast, with its critical steelhead habitat, will also see continued population expansion.

THE CHALLENGE AND STRATEGIES

Trout managers must shape public opinion, and influence the policy choices of numerous federal, state and local agencies, so that population growth is accomplished in a manner that allows continued protection and restoration of trout and steelhead.
The salvation of future wild trout fisheries rest on the rigid protection and management of available trout habitat combined with the wise application of catch-and-release fishing. (Deinstadt, 1977) In order for these traditional conservation strategies to be successful into the next century, a new ethic of watershed management that combines ecologic and economic values will be necessary.

A range of strategies are available to meet this challenge. Generally these can be divided into two broad themes - those focused on habitat, and those focused on fishery management.

**Habitat Strategies for the 21st Century**

Any hope to pass on to future generations our natural heritage will be based on habitat protection. The underlying philosophy of future habitat stewardship should be to “protect the best and restore the rest.”

**Watershed Planning**

Watershed planning is finally starting to occur. It is happening because groups and interests concerned with a specific watershed are getting together to seek sustainable solutions to that watershed’s problems and conflicts. As California moves into this era of watershed planning, complex resource decisions will shift from regional or state authorities, to become locally based. The challenge is to provide the tools and strategies for citizens, business and government entities to achieve principled, meaningful and workable performance-based watershed plans.

**Reorganizing Fish & Game’s Boundaries**

The DFG should reorganize its administrative planning and enforcement boundaries along watershed lines utilized by the State Water Resources Control Board (SWRCB) and its nine regional water quality control subunits. Such a restructuring would pave the way for better utilization of science and effective multi-species strategies in the management of the state’s fishery resources along existing hydrologic boundaries. It also would foster stronger understanding and relationships between water and fish management agencies which are sometimes working at cross purposes.

**Restoring Water To Rivers**

A series of lawsuits and administrative proceedings has rewritten California water law. The slow, relentless destruction of Mono Lake and the trout streams that feed it was halted by California Trout, Inc. v. State Water Resources Control Board, 207 Cal.App.3d 585 [1989], and California Trout, Inc. v. Superior Court, 218 Cal.App.3d 187 [1990]. The rulings in these lawsuits established that adequate water releases from dams to protect downstream fisheries are necessary to comply with state law and the Public Trust Doctrine.

In California Trout, Inc. v. Big Bear Municipal Water District, [1995], (SWRCB Decision 95-4) the scope of these landmark “water for the environment” victories was pushed even further. The SWRCB ruled that the protection of fisheries from inadequate flows is necessary regardless of where fish live, be it in the largest navigable river or the smallest mountain stream. The ruling also determined a prior water right is not a shield for a water diverter to avoid their duty to protect fish under the Public Trust Doctrine. Fish were granted that protective right the instant California became a state in the Union.

After four decades of neglect -- and no water -- today flows have returned to the Owens River Gorge. Additional dividends from these precedent-setting cases are being witnessed elsewhere in California, and these rulings provide the opportunity to initiate new proceedings throughout the state to protect public trust resources.

**Protecting Water Quality**

The primary cause of water quality degradation in California is from non-point source pollution, which includes agriculture and forestry runoff. (California State Lands Commission, 1993). As the Sierra Nevada provides more than 50% of California surface water resources, protecting headwater’s will protect downstream water quality and fisheries. The 1996 Sierra Nevada Ecosystem Project sets the stage for comprehensive and coordinated strategies to reverse non-point pollution while restoring the region’s most imperiled species, native fish.

Due to a recent ruling by a federal court in Oregon, significant Clean Water Act (CWA) protections may be extended to the 16,000 miles of
California waters under Forest Service jurisdiction. In Oregon Natural Desert Association et al v. Thomas (CIV No. 94-522-8A (9-26-96)), the trial court ruled that livestock grazing constitutes a non-point discharge into navigable waters. Therefore Section 401 of the CWA requires the Forest Service to obtain state certification that proposed grazing would not violate water quality standards before it issues any permit for grazing on national forest lands in Oregon.

The extension of this ruling to federal grazing and logging permits in California could dramatically improve prospects for trout and steelhead.

**Hydropower Relicensing**

During this century the Federal Energy Regulatory Commission (FERC) has issued licenses to develop hydropower in virtually every major California watershed. Each license spans a 30 to 50 year term. Most were issued with little thought to the impact of water storage and diversion on the health of trout and steelhead river ecosystems. Between 1995 and 2010, 51 FERC licenses, representing 212 dams, will be up for relicensing. This renewal cycle is an unprecedented opportunity to use the best science available in determining fishery needs and establishing ecologically-based instream flow requirements. To restore ecological integrity to the rivers and their floodplains, these new flow regimes should emulate the natural hydrograph and incorporate both minimum and higher peak flows. (Hill and Platts, 1991)

The FERC relicensing process is the single greatest opportunity to restore coldwater fisheries in California over the next decade.

**Fishery Management Reforms**

**Manage by Measurable Objective**

According to Dr. Peter Drucker, Claremont University School of Business, “If it can not be measured, it can not be managed.”

During the past 25 years the DFG, and the Fish and Game Commission, have implemented the successful and popular Wild Trout Program. While the program’s goals, and its achievements are commendable, its fishery management process would benefit by adopting measurable objectives that define progress toward its goals. (Kohler and Hubert, 1993).

A fishery is shaped by geologic, chemical, physical and biological factors within and surrounding its environment. These factors translate into bio-regional density and biomass characteristics. (Platts and McHenry, 1988) With the advent of watershed planning, it will be invaluable for the DFG to develop bio-regional fishery characteristics so that measurable and accountable fish population management occurs. Platts and McHenry determined that biomass, or pounds of fish per surface acre, is superior for bio-regional fishery characterization purposes.

Fortunately the DFG has been inventorying the state’s wild trout waters for years. At the request of California Trout, the DFG has produced an initial set of bio-regional wild trout productivity standards.

![Figure 2. California wild trout ecoregion biomass.](image)

Given the controversy among fishery scientists over the legitimacy of the Instream Flow Incremental Methodology (IFIM), establishing bio-region fish population standards will be advantageous. (Castleberry et al, 1996) The IFIM process has never demonstrated a fish population response in accordance with its instream flow recommendation, and the process is used by FERC to set instream flows for long periods. Therefore, these population objectives can be utilized to calibrate IFIM hydropower releases, and promote the use of adaptive management practices, so releases achieve healthy fisheries.

**Heritage Management**

No state can compete with California’s diversity of native trout and steelhead species. By enlarging the Wild Trout Program to include a “Heritage Trout
Program” these native fish can furnish the state with both a competitive and unique opportunity to attract angler attention, and tourism income. This program would promote public awareness for unique fishery protection, and serve as a model for biodiversity aquatic management.

![Graph showing trout and steelhead biodiversity by state.](image)

**Figure 3.** Trout and steelhead biodiversity by state.

An additional benefit from this new strategy would be to provide new places for anglers to fish and appreciate the diversity of California’s native trout. Already overcrowding on existing wild trout designated waters is becoming problematic. For example, 15,000 anglers days per six month season are being extended on less then 0.9 miles of Hot Creek (Mono Co.).

**Wilderness Management**

More than 10,000 miles of trout streams in the state are not roadside fisheries, i.e. less than a half mile from a public road. (CFWP, 1965) They are rarely planted by the DFG, have self-sustaining populations of wild fish, and rely on habitat and angler harvest protection to be maintained. Presently there is no specific fishery management program for these remote fisheries.

To accommodate both future watershed planning, where wild trout can serve as an umbrella monitoring species, and continued fishing pressure growth, some fashion of wilderness fishery management is needed. Because these remote systems represent the majority of California’s trout waters, they hold the greatest hope to fill the needs of California’s continued population and fishing growth.

**Linking Trout Ecology and Economy**

Tourism and recreation are California’s largest industries. Except for its beaches, California’s rivers draw more users then any other location, and fishing is the most popular of all river recreational uses. (California State Lands Commission, 1993) Today, sportfishing generates up to $12 billion of the State’s $60 billion in tourism and recreational economic activity. (McWilliams, et al, 1994) The number of trout anglers seeking quality fishing opportunities, and businesses aiming to fill their needs, is growing. So is popular recognition of the need to manage growth in a way that preserves and restores stable natural ecosystems for the economic and environmental benefit of California’s future.

To understand and benefit from the economic contributions of wild trout angling, the DFG should expand their existing Wild Trout Program. The top five to ten existing wild trout fisheries should be incorporated into a “Blue Ribbon” or “Gold Medal” program where angler use and economics should be studied in combination with the existing biological monitoring program. If necessary, the DFG should either employ a recreational economist, or contract for these services, so the results can be used to promote the benefits of “eco-linkages.”

**CONCLUSION**

As California enters the next century, it has the opportunity to refine its trout and steelhead fishery management approaches to accommodate its impending population growth. All signals indicate that resource management in California will be by watersheds. There are no better watershed health indicator species than wild trout and steelhead. Where wild trout are protected, rivers are protected; and where rivers are protected, so are watersheds, water quality, and local economies.

**Literature Cited**


The Role Of Professional Fishing Guides and Outfitters in Wild Trout Conservation

Gerald L. Burton

Abstract – Professional fly fishing guides and outfitters have frequent contact with a segment of the public that is often interested in the conservation of wild trout. Many of these people are beginners to the art of fly fishing and are eager to learn all they can about trout. Guides and outfitters can instill in these people an ethic towards aquatic habitats that includes the conservation of wild trout resources. They can also stress that a quality fly fishing experience must include the catching and releasing of native wild trout. The guiding of fly fishermen and women must include not only instruction in the catching of fish, but must also include teaching stream ecology and trout biology. The angler should learn from the guide that wild trout need high quality habitat that includes excellent water quality and healthy riparian habitat.

When I began to gather my thoughts and ideas for this presentation, I happened across a copy of the proceedings from the first Wild Trout Management Symposium that was held in Yellowstone National Park on September 25-26, 1974. Upon reviewing the presentations made at that symposium, I reflected upon the changes that I, as a professional fisheries biologist for almost 28 years, had made since then. In 1974, I was working as a fishery biologist in Cherokee, North Carolina. I was giving technical assistance to the Eastern Band of Cherokees in conducting what was perhaps the largest catchable trout stocking program in the United States. The program was very controversial within the fly fishing community. Most of the controversy revolved around the potential impact the stocking of a ton or more of catchable size (8 inch) trout per week, in approximately 18 miles of stream, during a 30 week period would have upon the wild trout population. The name of the game in Cherokee was to stock 'em out and get 'em all caught. We prided ourselves on the fact that approximately 89 percent of the trout we stocked were creeled. While many disliked the idea of using trout in such a manner, the program did what it was designed to do; use fishing as a means of attracting people to the reservation for the purpose of having them spend money. A surprising spin-off of the program was that there were more miles of stream managed for wild trout. The reason for this was that the Cherokee program attracted the bait and keep-them anglers, and because these anglers had a place to fish, they did not fight so fiercely when the state would stop stocking streams and manage the streams as wild trout waters.

I left Cherokee in 1975 and moved to Vancouver, Washington, where I worked with anadromous species within the Columbia River Basin. This was quite a change for me, from quarter-pound stocker rainbows to 20 pound chinooks. In 1977, I left the Northwest and moved to Phoenix, Arizona, where I became involved in the Fish and Wildlife Service's endangered species program. After becoming familiar with the Endangered Species Act, I had a chilling thought one day; what if they ever start to list all those runs of Columbia River salmon and steelhead that already in the mid-70's were going downhill? Working in the Southwest gave me the opportunity to work on recovery of the endangered Gila trout and the threatened Apache trout.

In 1995 I retired from the Service and went to work as a fly fishing guide for the newly opened Orvis store

Footnote: 1Fly Fishing Guide, Albuquerque, New Mexico
in Albuquerque, New Mexico. Never in my wildest dreams back in Cherokee, would I have thought things would ever change to the point where people would pay to have someone either teach them how to fly fish or take them fly fishing. My how things have changed.

Professional guides (guides) and outfitters can play a key role in wild trout conservation. They can instill in the people they either guide or outfit an understanding and appreciation of wild trout resources and the habitat conditions that are necessary to maintain wild trout. Many people who are new to fly fishing for trout are eager to learn all they can about the fish, the equipment, and the habitats where trout are found. Often this eagerness for information causes them to hire a guide. They reason that a local guide will know the streams, which streams are best to fish under different conditions, and what fly patterns work best. Many beginners are not informed concerning trout biology or stream ecology. A guide can pass on a lot of information concerning trout biology and the need for high quality habitats to these people.

Within the past 10 years fly fishing as a whole has experienced tremendous growth. If you have fly fished for trout for more than 15 years, you have no doubt noticed that there are a lot more people fly fishing. I am not sure why more people are beginning to take up fly fishing. Some say it's because of the new rods, reels, lines, and gadgets that have been developed. Others contend that it is because of a change in values that makes it all right to catch a fish that you do not intend to eat. Many say it's because of the movie -- A River Runs Through It. They say that because of the movie, people who had never fly fished saw the grace and beauty of fly fishing and decided that they would like to give it a try. What ever the reason, the fact is that today more people are competing for the same limited resource than there was in the past.

In 1991 the U.S. Fish and Wildlife Service (Service) found during their National Survey of Fishing, Hunting, and Wildlife-Associated Recreation that 30 percent of all people who fished in freshwater in the United States fished for trout, that amounted to over 9 million people who had fished for trout. This made trout one of the most sought after freshwater fishes. While not all of these trout anglers were fly fishermen, many in the western and northeastern states, were. In a state like Montana, where 70 percent of the those who fished freshwater fished for trout, I would expect that 75 percent of those anglers were fly fishermen.

With a beginning fly fisherman, or with an experienced one, guides and outfitters can attempt to teach the customer about more than how to cast, or what flies to use, or what length rod and what weight line are best to use under what circumstances. Fly fishing guides and outfitters for the most part are experienced at locating and catching trout in a given geographic area. Because of this they are usually very knowledgeable of the area and the factors, both positive and negative, that make the area where they guide suitable for trout. They need to pass this information on to the customer. They need to attempt to make the customer an advocate for those conditions that promote healthy populations of wild trout. Sometimes these conditions are physical, such as poor water quality, and sometimes they are administrative, such as regulations that allow the overharvest of wild trout.

Guides need to make sure that the customer realizes that the waters we fish are a reflection of their watersheds. High quality wild trout streams need high quality watersheds. Streams with watersheds that are over-grazed, subjected to poorly planned and managed timber harvest, used as a dump for mining waste, or polluted with municipal or industrial waste, usually fail to produce wild trout at the capacity they would be capable of if the problems were resolved. As Aldo Leopold discussed in his conservation classic, A Sand County Almanac (1949), we need to teach a land ethic that "enlarges the boundaries of our communities to include soils, waters, plants, and animals, or collectively: the land." Guides because of the opportunity they have to be with someone for a day, or several days, are in an unique position to teach, or should I say preach, the land ethic concept to the customer.

Guides need to start at the ecosystem level, explaining how the watershed and land-use problems in the watershed effect the streams they fish. Sometimes it's as simple as responding to a customer question regarding the best time of the year to fish a given stream. While the best time may be during September or October, you can also point out that during July fishing would be great if the water was not so turbid. Then explain that the turbidity is caused by poorly constructed logging roads that erode and dump sediment into the stream when it rains in the summer.
A guide also has an opportunity to impress upon the customer the fishing quality a stream could provide if the circumstances under which it was regulated were changed. For example, in some pristine high-country streams trout growth may be limited by a short growing season. In this situation it may take a trout many years to reach 14 or 15 inches. For a quality fishery to exist under these conditions the removal of the larger trout perhaps should not be allowed. When a guide is with a customer in such a situation he or she needs to explain why the stream is full of little ones and that it would perhaps contain larger fish if the fishing were regulated differently.

To the beginning fly fisherman it may not make a difference whether the trout they catch is wild or a stocker. While conducting creel census interviews in North Carolina, I would often ask an angler if they would identify the species of trout they had caught. I found that many did not know the difference between a brook, brown, or rainbow trout. If it had spots, it was a trout, and that is all they needed to know. However, to many anglers it is important to know whether the trout they have just caught, and released, was a wild fish or a recent stocker. A guide should take the time to admire a wild trout that he or she has just netted for a customer. The features that make it recognizable as a wild stream reared fish should be noted; the perfect and delicate fins, the color and the spotting. This can be contrasted to a stocked fish which, depending upon the size at which it was stocked, may have eroded fins, a general lack of intense color, and a mixture of spotting. The guide needs to impress upon the angler that wild trout are special.

Guides and outfitters who know the streams must get involved in the regulatory process. This can be accomplished by attending and taking part in state fish and game public meetings, commission meetings, or any other meetings or hearings where regulations that will impact the wild trout resource are going to be discussed. Often guides and outfitters know the areas and the resources better than the state biologist. The biologist often can not express their opinion based upon personal experience and observation because they must be aware of and promote their departments position. Thus, if public demand is for more stocked fish, and that becomes the state game and fish departments position, there may be only a handful of anglers and guides who may question the increased stocking.

It seems that the fly fishing press tends to give the impression that quality is somehow linked to fish size. The bigger the trout the more of a trophy it becomes. While this line of reasoning may be a key part of the sport to some, most who have fly fished for trout for a long time, would say there is more to it than catching a lot of trout over 20 inches. Most would agree that catching a wild stream-reared brown of 16 inches or more, is worth much more than catching a dozen 20 inch stocked and fed rainbows in a pond. While stocking trout may be the only way acceptable fishing can be provided for the numbers of anglers a state has to provide for, a guide, if he or she has the choice, can help the wild trout cause by having anglers fish for wild fish when ever possible.

Perhaps no one person is in a better position to indoctrinate the beginner, or even the advanced fly fisherman, into the value of wild trout and the habitats that they require than a fly fishing guide. Often the customer is someone who is new to the sport and new to the area. In addition, the guide is going to be with them for a day or more. What better opportunity to preach the wild trout message than when you have a captive audience that is going to be spending the better part of the day with you. Most importantly, fly fishing guides should always try to get the customer to look at fly fishing as something more than a fish catching experience. It should be the goal of every guide to make the customer come away from a day of fishing feeling that he or she learned something about the great outdoors.

Literature Citations

Barbed Hook Restrictions in Catch-and-Release Trout Fisheries: a Social Issue

Daniel J. Schill¹, Rodney L. Scarpella²

Abstract—We summarized results of past studies that directly compared hooking mortality of resident trout caught and released with barbed or barbless hooks. Barbed hook use resulted in lower estimates of hooking mortality in two of four fly comparisons and in three of five lure comparisons. Only one of 11 comparisons resulted in statistically significant differences in hooking mortality. In this instance, use of barbless bait hooks caused significantly less mortality, but design concerns limit the utility of this finding. Mean hooking mortality rates from past lure studies were slightly higher for barbed hooks than barbless ones, but the opposite was true for flies. For flies and lures combined, mean hooking mortality was 4.5% for barbed hooks and 4.2% for barbless hooks. Combination of test statistics from individual studies by gear type via meta-analysis yielded nonsignificant results for barbed versus barbless flies, lures, or flies and lures combined. We conclude the use of barbed or barbless flies or lures plays no role in subsequent mortality of trout caught and released by anglers. Because natural mortality rates for wild trout in streams commonly range from 30% to 65% annually, a 0.3% mean difference in hooking mortality for the two hook types is irrelevant at the population level, even when fish are subjected to repeated capture. Based on existing mortality studies, there is no biological basis for barbed hook restrictions in artificial flies and lure fisheries for resident trout. Restricting barbed hooks appears to be a social issue. Managers proposing new special regulations to the angling public should consider the social costs of implementing barbed hook restrictions that produce no demonstrable biological gain.

This paper will appear in its entirety under copyright restriction in the November 1997 issue of the North American Journal of Fishery Management (Volume 17, Number 4).

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Why Wild Trout?
Why Not Wild Fish?

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Abstract — The evolution and biological organization of native trout in North America has occurred through a dynamic process, including the interaction with non-salmonid species. Because salmonids did evolve with other species, the entire native fish assemblage should be considered when developing management prescriptions. The role of non-salmonid in the evolution of native salmonid populations will be examined. We will discuss the ecological importance of the native non-salmonids, evolution and the interaction of trout with other aquatic species and with each other. We will give case-studies and draw from current literature that describes the native salmonid/non-salmonid interactions, how and why these species are beneficial to one another. We have found where the native fish assemblage was stable or restored fish populations are more vigorous and the habitats are more stable. Non-salmonid species are beneficial to salmonids even if at some life stages they appear to be in direct conflict. The non-salmonid interactions with salmonid species provide fishery managers and anglers with insight that can be used in the recovery of threatened and endangered native fish assemblages.

INTRODUCTION

In the past, state and federal fishery managers and non-governmental organizations (NGO’s) involved in fishery management and conservation of species, were very focused on key or indicator species in terms of management strategies. As fishery scientists approach the 21st Century, it is apparent that conservation of species will be most likely defined in terms of the ecosystem context in which native biodiversity is sustained. The science of conservation biology will be increasingly used to understand the effects that human development may have on species, communities and ecosystems and assist natural resource managers in developing economic and practical means to not only prevent species extinction but to reintegrate species at risk back into a properly functioning ecosystem. If the use of conservation biology is to succeed, resource managers, decision-makers and the public must understand the very basic tenets of biodiversity and watershed ecosystems.

THE AVERAGE SPORT FISHING ENTHUSIAST KNOWS BUGS, HYDROLOGY, TROUT BUT THEY DON'T KNOW FISH COMMUNITIES

Average fly anglers or sport fishermen are intimately familiar with the macroinvertebrates inhabiting the stream or water body where they are fishing. Whether by intuition, word of mouth, or careful observation, the angler uses a mimic of the prey that will catch the attention of the fish of choice. In addition, anglers are adept at ‘reading’ the water in which they are fishing. For example, articles in popular magazines abound discussing the importance of submerged features to the eventual success of reservoir anglers. And of course, ‘reading’ a stream accurately can mean the difference between catching a fish and scaring them all off for the afternoon. But, there is an area where anglers are less proficient, and that is knowing the other members of the community in which the fish - in this case trout, resides. Whether fishing for brookies in the east, or native cutthroats in the west, anglers can tie a fly to mimic a recently hatched mayfly and present it expertly under overhanging alders, but they may not be able to identify the mountain dace that is darting under the grass bank they are standing on. What's
more, they may not understand that the makeup of that fish community holds information about the quality of the habitat as well as about the quality of the fishing trip they are about to experience. Surprisingly, anglers or other persons interested in our aquatic resources, should also be interested in suckers, native suckers, as well as dace, sculpins, chubs and a host of other fish which make up the natural community of fish which evolved with the trout and salmon we so highly prize. By their very body shape they indicate the parts of the habitat that they are adapted to exploit, as well as the food resources they can best utilize and those "other species" do so in a way that divides the pie — or partitions the resource whichever way you like to say it. In an examination of the factors that affect fish distribution (Moyle 1976) and others examined the Pitt River (California) drainage with regards to zoogeographical and man-related factors. They found that the communities of fishes tend to segregate into recognizable fish zones, indicating that habitat preferences, determined largely by the physiological tolerances and body morphology of each species, were viewed as more important than biological interactions in determining native fish distribution.

**DO NATURAL RESOURCE MANAGERS REALLY RECOGNIZE THE IMPORTANCE OF THE VARIOUS AQUATIC COMMUNITIES?**

The fact that there is a community of fish represented in the stream or lake along with the trout tells us something. And the absence of the community of fish or diversity in that community tells us something too. It tells us about the history of the habitat in subtle ways. Authors such as Regier and Henderson (1973) and Gorman and Karr (1978) began to understand that the complexity of the habitat and the more natural it's condition, then the better chance that a diverse community of fish could survive and flourish there. In subsequent work (Tonn et al., 1983 for example) researchers found that habitat — natural habitat — is keyed to fish communities. The more natural and undisturbed the habitat the more likely that there are abundant and diverse fish communities to take advantage of each facet of the habitat. When systems break down, when streams are channelized, when improper road construction buries streambeds in silt, members of the community are less likely to be able to survive. The fit between fish community and habitat is like the fit between 2 strands of DNA — incredibly rich and complex and when fit together, locked in place. This is true for those natural systems still rich in diversity. But as systems decline, and diversity decreases, links in the strand are broken and the fit between fish, its community, and its habitat declines as well. The puzzle pieces no longer lock into place.

We can take this example to its ultimate conclusion after all think of examples of areas where there is heavy stocking of a single species and then consider the quality of the habitat. Chances are there has been heavy perturbations of the stream for a variety of reasons and therefore native systems have been disrupted, perhaps irrevocably. Heavy stocking of single trout species is not always the culprit in these scenarios. Many times there have been a series of seemingly insignificant incidents and bad decisions in the watershed which have led inexorably to the decline of a system. We point to the stocking truck, when many times it is ourselves and the decisions we have made over the last decades that are to blame.

Studies of the Pit River system (Moyle 1976) point out that although the fish species of the Pit River system seem to be ecologically segregated from each other, competition and predation appeared to affect the distributional patterns of a number of species present in the study systems. This was attributed to changes in fish habitat (mostly human-caused manipulation) and the introduction of 15 exotic fish species. This, the authors believe, increased the probability of competitive interaction. Introduced species tended to be most abundant in the disturbed habitats. The same concept is now being examined in the Columbia River system which involves exotic shad and salmon interactions.

Often non-salmonids are viewed as impacting salmonid populations (Moyle 1977). An excellent example of this are freshwater sculpins (genus Cottus) which are very common inhabitants of trout and salmon streams throughout the Northern hemisphere. Sculpins are efficient predators, especially on benthic invertebrates. Sculpins generally prefer habitat such has riffles. In the past, some biologists believed that sculpins might have a detrimental impact on salmonid populations through predation on eggs, fry and competition for benthic invertebrates.
Moyle found that sculpin impacted salmonids only under exceptional or artificial conditions, such as those when humans have already damaged salmonid populations through over-exploitation or habitat disturbances. More importantly, other biologists such as Dietsch (1950) thought that sculpin serve as a “buffer” prey species for brook trout by reducing brook trout predation on their own young. Its entirely possible that sculpins feeding on predacious stoneflies in a stream may increase the supply of drifting herbivorous insects for trout and even reduce stonefly predation on eggs and young of trout (Moyle 1977).

The fact that a substantial range of species coexist over tens of thousands of years suggests that when short-term environmental or habitat conditions change, it is possible that a preferred food source can become in short supply. This would result in prey-switching by one or more species.

Naturally, we humans have investigated fisheries, we have done one species at a time, since that is the simplest way to learn about something. This is true in the historical development of fisheries science in North America as well. But taken as a natural collection, a natural expression of the habitat, fish communities tell a much more compelling and complex story than the life history of a single species, that is much harder to ignore or refute. In our recent emphasis on ecosystem management and saving all the pieces, let’s begin to practice what we preach by considering a fish as a member of its community. We would argue this is an appropriate and excellent first step in the journey to understanding aquatic ecosystems and how they work and how to fix them.

Practically speaking, an understanding of the role of other species in fish communities offers fishery biologists important clues when attempting to recover species. In the McKenzie River basin, located near Eugene, Oregon, a very substantive recovery process is occurring to restore bull trout to its historical range. Other salmonids present in the basin include chinook salmon, mountain whitefish, cutthroat trout, and mottled sculpin. Based upon several years of intensive investigation through surveys and field work, USFS fishery biologists have noted that whenever they find sculpin and cutthroat in bull trout nursery streams, they find good numbers of bull trout. If one of these two other fish species are missing in the bull trout nursery stream, then the bull trout themselves are also missing (Dave Bickford personal communication). The lack of sculpin in a given stream may also provide an indication as to the historic presence or absence of bull trout in that particular stream.

There are numerous examples of the coevolution of predator-prey fish species relationships including bull trout-kokanee, bull trout-mountain whitefish, Pyramid Lake cutthroat trout-chub, the Kootenay Lake Kamloops-kokanee and the Rangely Lake (Maine) brook trout-blueback trout (relict Arctic charr) relationship described in the 19th century (Behnke 1997). In these cases, the health and population size of the preybase may be the greatest influence on the sustainability of a native salmonid population. A basic premise is that species, including endangered ones, are stabilizes (Minckley 1991).

So the challenge remains for people involved in aquatic conservation to strongly promote a better understanding of biodiversity in the context of watersheds. Even conservation groups such as Trout Unlimited, which has a principal focus on coldwater fisheries and their associated watersheds, need to reexamine the role other fish communities play in the life histories of the various salmonids and ensure that their constituent base understands this role.

The mission of Trout Unlimited (TU) is to conserve, protect, and restore North America’s coldwater fisheries and their watersheds. The long-term goal implicit in this mission statement is achieving self-sustainability of salmonid populations and species (as opposed to simple short-term enhancements of abundance) (Poff 1997). If TU’s conservation agenda is to be credible and consistent, our focus on salmonids must not be so narrow as to exclude the broader ecosystem and its constituent species (Poff 1997). Trout Unlimited recognizes natural biodiversity stewardship and ecosystem protection as essential components of our coldwater fisheries mission (Trout Unlimited 1994). In the case of salmonids, these species serve as high-quality “indicator” species. Salmonids are very sensitive to environmental quality, are positioned as top aquatic predators, and offer very high visibility to the public (Poff 1997).
In July, 1997 at the 38th Annual Trout Unlimited National Convention, Dr. Leroy Poff briefed TU leadership on a new policy statement for the organization, "Trout Unlimited’s North America Salmonid Policy: Science-based Guidance for 21st Century Conservation. This effort has been funded through the support of Trout Unlimited's Coldwater Conservation Fund and the Curtis and Edith Munson Foundation. This document charts the course for our grassroots membership, scientists and staff to follow regarding TU’s ability to use the best available scientific information incorporated into advocacy policies to guide our local and national activities. The policy discusses the importance and linkages between biodiversity and watershed ecosystems. It discusses the connections between salmonids and watershed ecology. It presents a series of fundamental principles that help define our broader efforts. It includes position statements and recommendations regarding habitat, hydropower, harvest and hatcheries.

A peer review process involving fisheries and aquatic scientists has just been completed and a final version of this document will be made available to the public soon. Contact Mr. Joseph McGurrin, Resource Director, Trout Unlimited, 1500 Wilson Blvd. #310, Arlington, VA 22209 for a copy of this document. Requests can also be forwarded through email (jmcgurrin@tu.org) or by phone (703) 284-9407.

LITERATURE CITATIONS

Native Trout of Kamchatka: A Glimpse into the Past of North America

Don S Proebstel
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Abstract--Waters of the Kamchatka peninsula, in the Russian Far East, are dominated by fishes in the family Salmonidae. Until recently, it was assumed that all of the trout in Kamchatka are coastal rainbow trout (Oncorhynchus mykiss mykiss), indistinguishable from North American coastal rainbow trout (O. m. irideus). A form of trout was collected in 1994 in the Tigil River basin of Northwestern Kamchatka with a unique spotting pattern, a cutthroat mark on the lower jaw and basibranchial teeth: all characters associated with redband rainbow (O. m. gairdneri) or cutthroat trout (O. clarki). In 1996, additional specimens were collected with these characteristics from the Sedonka River, a tributary of the Tigil River. Morphological analysis of approximately 80 specimens collected in different years finds a series of phenotypically diverse forms. While precise phylogenetic position of these various forms remains unclear, genetic analysis to date aligns these trout with the rainbow trout lineage.

"The golet shows up half way through March. Charyuss, Kunshe, Mykiss show up together half way through April. These fish remain in the rivers around Bolshoi retskoi throughout the winter. Half way through the month of May they return to the sea, and they return to the estuary of the great river in the last days of June. Chavycha usually show up in the estuary on the ninth of May, and they go away again by the middle of August. Kysusch is called lomok in Okhotsk. It comes from the sea in August and stays in the rivers till December. Otki are thrown on the beach in the estuary of the Great River. Vakhna show up in May. They do not travel far upriver and return to sea in September."

(Carl Heinrich Merck, Explorer; December 1790)

INTRODUCTION

The unique Kamchatkan peninsula, with numerous rivers draining to the Pacific Ocean basin, the Bering Sea and Sea of Okhotsk. It encompasses approximately 472,000 sq. km., or roughly the size of California and Oregon combined. In many respects, it is much the same today as it was described in 1790 by German explorer Carl Heinrich Merck. Politics and

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located between 60 and 51 degrees North Latitude, in the center of the region of extreme seismic activity associated with subduction of the Pacific plate (Figure 1). Two parallel ranges transverse the peninsula embracing the large Kamchatka River which drains to the Pacific Ocean. These ranges are replete with active and dormant volcanoes that rise from an average of 2000 meters to an elevation of 4860 meters for the Klyuchevsk volcano. Of the 28 active volcanoes, all but one are on the eastern side of the peninsula, sloping dramatically to the Pacific Ocean and the Bering Sea. Numerous hot springs warm some headwater tributaries and larger rivers.

Figure 1. The Kamchatkan peninsula in the Russian far east.

In Russian literature pertaining to fishes, Kamchatka is considered a biogeographic sub-region (Berg 1949) due to the unique character of its ichthyofauna in comparison to most of the eastern Palearctic. The ichthyofauna is dominated by the family Salmonidae, with the notable absence of genera of whitefish (Coregonus), lenok (Brachymystax) and taimen (Hucho), all of which are common throughout Eurasia. Seven species of Oncorhynchus: chum (O. keta), pink (O. gorbuscha), sockeye (O. nerka) coho (O. kisutch), chinook (O. tshawytscha), masu (O. masu) and steelhead and trout, (O. mykiss) are found on Kamchatka. Of the char, arctic (Salvelinus alpinus), dolly varden (S. malma), kundsha (S. leucomaenis) and stone char (S. albus) are represented in the rivers and lakes of Kamchatka. There is an absence of primary freshwater fishes. Only the grayling (Thymallus arcticus grubei), resident forms of anadromous trout, and two species of stickelbacks (Gasterosteus aculeatus and Pungitius pungitius) are nonmigratory permanent residents of Kamchatka's waters. Non-salmonid anadromous fishes include lamprey (Lampetra japonica), and herring (Clupea harengus).

The domination of the Kamchatka peninsula by anadromous salmonids can be easily explained from an ecological point of view. Close examination of the net primary productivity of the oceans surrounding Kamchatka shows these waters to be among the most productive anywhere (Miele 1989). Anadromy is clearly favorable from an energetic perspective. But in addition to, and perhaps support of, the anadromous steelhead salmon and char, abundant populations of resident trout and char are to be found throughout the peninsula.

**Historical Perspective:**

While much remains to be learned, our present understanding of the origin and distribution of trout of the Pacific basin show that two distinct evolutionary lines of trout, the rainbow and cutthroat, diverged from a common ancestor near the pleiocene pleistocene border, about 2 million years ago (Behnke 1992). See Behnke (1992) for proposed phylogeny of rainbow and cutthroat trout evolutionary lineages. Cutthroat trout form a complex of four major subspecies (including 10 additional minor subspecies); and rainbow trout, though somewhat more difficult to separate, form four distinct major evolutionary lines with somewhere around 10 to 15 mostly undescribed subspecies. A major distinction in evolutionary divergence between the cutthroat and rainbow trout lineages concerns the degree of geographical isolation, and resulting systematic uniqueness. In the cutthroat series, subspecies correspond to geographical isolates resulting in morphological, karyological and molecular genetic differences that are readily detectable. Two of the four lineages of rainbow trout, leading to Gila and Apache trout (O. gila sbpp.) and Mexican golden trout (O. chrysogaster) are also well isolated geographically with expected morphological and genetic differentiation. The remaining two major evolutionary lines of rainbow trout, coastal (O. m. irideus) and redband (O. m. gairdneri), are not so straightforward. In these two evolutionary lines, there is a lack of complete genetic isolation due to presumed secondary contact and mixing. Based on distribution and morphological characters, it can be assumed that redband rainbow trout are primitive, were the first to appear, and were subsequently displaced by later invasions of coastal rainbow trout. While there are broad patterns in diagnostic characters such as meristic traits, coloration and spotting (Behnke 1992), and allelic frequencies (Allendorf 1975),
there is not sufficient consistency to separate all redband rainbow trout from coastal rainbow trout on the basis of a shared primitive characters (Currens et al. 1990; Behnke 1992, 1996). This is likely an artifact of multiple invasions, and gene flow with anadromous components of the populations. Thus, morphological and molecular characteristics resulting from relatively long periods of geographic isolation, present in the cutthroat lineage and southern rainbow trout lines, are ambiguous in the primitive redband rainbow trout of North America. It is also likely that several colonizations of differentiated forms of rainbow trout has occurred, with the most recent being that of coastal rainbow. A thorough discussion of evolution and current taxonomy of western trout is given by Behnke (1992).

With the exception of a relict population discovered on the Shantar Islands, in the eastern side of the Okhotsk Sea (Alekseyev and Sviridenko 1985), indigenous rainbow trout outside of North America are confined to the Kamchatkan peninsula. Until very recently (1994), it was assumed by both Russian and American specialists that all resident trout in Kamchatka were basically the same: a subspecies of coastal rainbow trout (O. mykiss mykiss), distinguished from North American coastal rainbow trout not by morphological characters, but by geographical isolation (Behnke 1966, 1992; Savvatova 1975). In the fall of 1994, unique specimens of trout were collected from the Pervolavaya and Sedonka rivers, both tributaries of the Tigil River of northwest Kamchatka (Figure 2.).

Figure 2.—Comparison of coastal cutthroat trout of North America (top) with trout collected from the Tigil River basin in 1994 (bottom). Coastal cutthroat trout from Behnke (1992), and Tigil trout original drawing by K. Kuzlenchina.

The unexpected presence of a cutthroat mark near the branchiostegal rays, unusual spotting pattern similar to that of coastal cutthroat trout (O. clarki clarki), and basibranchial teeth in some specimens, led to the speculation that there may be cutthroat trout persisting in Kamchatka (Savvatova et al. 1995; Behnke 1996, 1977).

In the fall of 1996, under the authority of the Kamchatka Steelhead Project (KSP) (see Soverel et al. this volume), an expedition was conducted to survey the entire Sedonka River, from its source to its confluence with the Tigil River (Figure 3).

Figure 3.—Kamchatka expedition of 1996.

Participants included representatives of the World Salmonid Research Institute, the Wild Salmon Center (Soverel et al. this volume), Colorado State University, and Moscow State University. None of the specimens collected in 1996 had spotting characteristics of coastal cutthroat, but one specimen had a spotting pattern remarkably similar to California golden trout (Oncorhynchus mykiss aquabonita) or westslope cutthroat (O. c. lewisi) (Figure 4). In addition, many specimens with coloration and spotting pattern resembling redband rainbow trout were collected along with the expected Kamchatkan coastal rainbow trout (Figure 5). Trout with "redband-like" characteristics were numerous near the headwaters.
(Figure 5). Trout with "redband-like" characteristics were numerous near the headwaters.

![Figure 4. Comparasion of trout collected from the Sedonka River (bottom) with California Golden trout (top) and westslope cutthroat trout (middle). Sedonka River trout from original drawing by K. Kuzishchin and golden and westslope cutthroat trout after Behnke (1992).](image)

What seems to be evident from these recent collections is a need to reevaluate the trout of Kamchatka. Several important questions are emerging: What is the range of diversity, and are newly discovered forms relict primitive trout? How do these new forms of trout fit into our perception of the phylogeny of North American trout? What is the relationship between resident and anadromous forms in the pristine Kamchatkan environment? Where is the center of origin of Pacific basin trout?

Clearly, the greatest radiation for Pacific basin trout has occurred in North America, inferring that this is likely the center of origin, with subsequent colonization of Kamchatka [sensu Darlington (1957); Croizat et al. (1974)]. The occurrence of additional forms of trout in Kamchatka does, however, give rise to the possibility of an Asian origin followed by colonization and diversification in North America. In either case, it is obvious from the current patterns of distribution that the evolutionary history of rainbow and cutthroat trout is complex. It likely involves preglacial colonization and isolated persistence by primitive forms of trout, followed by more recent invasions of more derived (coastal) rainbow trout; all mitigated by repeated glacial advances and retreats and tectonic activity of the pleistocene and the presence of several glacial refugia (Okazaki 1984, Curens 1990, Behnke 1992, Carl et al. 1994).

**Range of Phenotypic and Genetic Diversity of Tigli River Basin Trout:**

To date, four phenotypically distinguishable forms have been collected from the Tigli River basin: 1) the expected coastal rainbow trout (Figure 5); 2) trout with outward appearance of coastal cutthroat trout (Figure 3); 3) trout with phenotypic characteristics similar to redband rainbow trout (Figure 5); and 4) one specimen with a spotting pattern similar to California golden and westslope cutthroat trout (figure 4).

![Figure 5. Trout from the Sedonka River with phenotypic similarities to redband rainbow trout (O. mykiss gairdneri) (top), and coastal rainbow trout (O. mykiss mykiss) (bottom). Illustrations from drawings made in the field by K. Kuzishchin.](image)

**1994 Collection**

Specimens resembling coastal cutthroat trout were only collected in 1994 and are described in detail by Savvaïtova et al. (1995). A general depiction is shown in Figure 3. In addition to the obvious similarity of spotting pattern to coastal cutthroat, all specimens had the red "cutthroat" mark on the underside of the jaw, and some specimens had basibranchial teeth. The latter are considered to be primitive characters found in the cutthroat lineage, and in low frequency in some redband rainbow populations. In contrast, several other diagnostic
morphological characters were all in the expected range for coastal rainbow. These include lateral series scales (range: 124-141); pyloric caeca numbers: (range: 42-57), and number of pelvic fin rays (range: 8-9) (Table 1). Other morphological characters assessed are ambiguous for differentiating between rainbow and cutthroat trout. Thus, while a general phenotypic similarity can be observed in the specimens collected in 1994 with coastal cutthroat trout, based primarily on spotting, basibranchial teeth and presence of a "cutthroat" mark, several meristic characters do not support phylogenetic affinity with coastal cutthroat trout.

Available genetic information on this collection is limited to mitochondrial DNA (mtDNA) sequence data on 188 base pairs of the D-Loop or control region including 5 base pairs of the adjacent phenylalanine tRNA gene (e.g. Nielsen et al. 1997). Screening of 6 individuals by direct sequencing of these 193 base pairs in 6 individuals found specimens to be closest to coastal rainbow (steelhead) controls when compared to coastal rainbow (steelhead) and coastal cutthroat trout collected in Washington (Paul Bentzen, University of Washington, personal communication). It is difficult to draw sound conclusions from this genetic screening, but for the individuals analyzed, affinity to rainbow trout and not coastal cutthroat trout is apparent.

1996 collection:

In 1996, 150 trout specimens were captured from the Sedenka River ranging from the source, where the river emerges from volcanic formations, to its confluence with the Tigil River. Morphometric and meristic analysis was conducted on 43 specimens in the field and at Moscow State University and osteological analysis on 20 individuals at MGU (see Soverel et al. this volume to obtain a copy of the 1996 Kuchatskaya Steelhead Project Report). Tissue samples were taken from 145 individuals, and flow tags placed in 150 for future monitoring. In addition, three small juvenile trout (total length = 7-8 cm), presumed to be young of the year, were collected in the middle reaches of the Sedenka River.

Three phenotypically different types of trout were collected, with gradation between the forms apparent (figures 4. and 5.). Typical coastal rainbow, the expected form for Kamchatka, were collected throughout the river, but were in greater concentration in the lower reaches. Some individuals from the lowest collecting sites (approximately 20 km from the river mouth) had a silvery appearance and very faint coloration in comparison to trout collected from the headwaters, suggesting that these fish had spent some time in the Tigil River estuary or Sea of Okhotsk. In the headwaters, and upper reaches of the Sedenka River, most specimens bore a strong resemblance to redband trout in coloration and spotting pattern (Figure 5.). All of these trout had the cutthroat mark (the intensity of this character was variable among the specimens), and many individuals had basibranchial teeth. As with the collection of 1994, several meristic characters were in the expected ranges of coastal rainbow trout: lateral series scales (range: 124-141, mean: 132.4); pyloric caeca: (range: 42-57, mean: 49.7), and number of pelvic fin rays: (range: 8-9, mean 8.6) (Table 1.).

The three small specimens, collected from the Sedenka River are noteworthy. The parr marks on these specimens were strongly elliptical, and secondary rows were present above and below the primary parr marks (figure 6.). This condition is assumed to be a primitive character, present in the cutthroat and redband rainbow evolutionary lines. Coastal rainbow parr marks are more rounded and supplemental rows are generally absent or strongly reduced.

Figure 6. Trout fry collected from the Sedenka River, 1996. Drawing by K. Kuziarchich.

To date, Restriction Fragment Length Polymorphism (RFLP) information generated from PCR amplifications of the cytochrome b and ND-1 mitochondrial genes from 36 individuals has been completed at Colorado State University, and PCR/RFLP data on several small regions of nuclear DNA coding for Growth hormone introns has been collected from a
small number of individuals by geneticists at the Conservation Biology Laboratories of the National Marine Fishery Service in Seattle, Washington.

Table 1.—Ranges and means for several diagnostic characters useful in differentiating between the major groups of cutthroat trout and coastal and redband rainbow trout. Data from Tigil River trout from Kamchatka, Russia are based on specimens (N= 48) collected in 1996.

<table>
<thead>
<tr>
<th>Form</th>
<th>Range &amp; Mean</th>
<th>Lateral Series Scales</th>
<th>Pyloric Caeca</th>
<th>Basibranchial Teeth</th>
<th>Vertebrete</th>
<th>Cutthroat Mark</th>
<th>Parr Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal rainbow</td>
<td>range: 120-140 (126-132)</td>
<td>40-70 (55)</td>
<td>no</td>
<td>61-65</td>
<td>no</td>
<td>derived</td>
<td></td>
</tr>
<tr>
<td>Redband rainbow</td>
<td>range: 130-170 (140-155)</td>
<td>30-50 (40)</td>
<td>rare (&lt;2%)</td>
<td>63-66</td>
<td>rare</td>
<td>primitive</td>
<td></td>
</tr>
<tr>
<td>Tigil River trout</td>
<td>range: 124-141 (132.4)</td>
<td>42-57 (49.7)</td>
<td>25%</td>
<td>60-64 (62.2)</td>
<td>75%</td>
<td>primitive ?</td>
<td></td>
</tr>
<tr>
<td>Coastal cutthroat</td>
<td>range: 120-180 (130-160)</td>
<td>25-55 (40)</td>
<td>yes</td>
<td>59-64 (61-62)</td>
<td>yes</td>
<td>primitive</td>
<td></td>
</tr>
<tr>
<td>Westslope cutthroat</td>
<td>range: 145-220 (165-180)</td>
<td>25-50 (30-40)</td>
<td>yes</td>
<td>59-63 (60-61)</td>
<td>yes</td>
<td>primitive</td>
<td></td>
</tr>
<tr>
<td>Lahontan cutthroat</td>
<td>range: 150-180 (165)</td>
<td>30-80 (55-65)</td>
<td>yes</td>
<td>60-63 (61-62)</td>
<td>yes</td>
<td>primitive</td>
<td></td>
</tr>
<tr>
<td>Yellowstone cutthroat</td>
<td>range: 165-200 (170-180)</td>
<td>25-45 (35-43)</td>
<td>yes</td>
<td>60-63 (61-62)</td>
<td>yes</td>
<td>primitive</td>
<td></td>
</tr>
</tbody>
</table>

The results of both of these analyses reveal genetic affinity of the specimens analyzed to the rainbow trout lineage. Comparison of individual and composite haplotypes of mtDNA genes with data from subspecies of interior cutthroat trout and rainbow trout of western North America clearly aligns the Sedenka River specimens with rainbow trout. There are, however, several haplotypes that appear to be unique to Kamchatka trout that have not been observed in collections analyzed to date from North America. In addition, a relatively high number of different composite haplotypes (N=7) were observed within the sample of 36 individuals, implying that the population consists of many maternal lineages, or maintains gene flow with other populations. In a typical population of cutthroat trout or rainbow trout from North America it is rare to observe more than 3 or 4 composite haplotypes (reflecting different maternal lineages) from a collection of this size (D. Proebstel unpublished data). The individual specimen that displayed some phenotypic resemblance to California golden trout or westslope cutthroat trout, primarily in spotting pattern (figure 3.), had the most common composite haplotype observed in the Sedenka River trout.

Information obtained from screening a small sample of Sedenka River trout (N=12) for genetic affinities of Growth Hormone introns supports alignment of Sedenka River trout with the rainbow lineage (Paul Moran, National Marine Fishery Service, Seattle Washington, personal communication).

CONCLUSIONS AND DISCUSSION

1. The primary conclusion concerning the trout of Kamchatka is that there is a much greater range of phenotypic variation than previously believed. Based on the limited number of collections made from Kamchatka to date, the unique "newly discovered forms" seem to be found only on the western side of the peninsula. These forms have only been collected from the Tigil River system, and the extent of their range will only be learned from future investigations. In this river system, four phenotypic variants may be considered as a series of forms: with outward resemblance to coastal rainbow trout, coastal cutthroat trout, redband rainbow trout, and interior North American cutthroat trout or California golden trout. In addition, there are transitional individuals that are difficult to clearly assign to only one of the four phenotypic variants.

There are a number of possible explanations for these findings. First, it is possible that what we have
observed in Kamchatka in a large remote river system, is merely the range natural variation in a large metapopulation of rainbow trout, which likely includes resident, adfluvial and anadromous components. In this interpretation, the presence of primitive characters such as basibranchial teeth, and cutthroat marks in a portion of the population is difficult to explain, but the previous belief that \textit{O. mykiss} \textit{mykiss} is the only trout in Kamchatka is not rejected by the data.

Another, and perhaps more plausible explanation is that there are one or more populations of a more primitive rainbow trout on the peninsula, and certainly in the Tigil River drainage. These forms could be retaining primitive characters by co-existing in sympathy with more derived coastal rainbow trout, or by persisting in relative isolation due to some physical or ecological barrier that permits some degree of gene flow. This interpretation implies an earlier colonization by a primitive rainbow trout form and subsequent invasion by coastal rainbows, much the same way patterns of distribution in North America are believed to have arisen. There is emerging evidence, that in at least some portions of Kamchatka, there are primitive, relict forms which have diverged less from each other than North American trouts. There is not enough genetic information to infer phylogenetic connections between redband rainbow of North America and Kamchatkan trout, but the possibility cannot be ruled out at this time. The evolutionary relationship between North American and Kamchatkan trout is now more intriguing, and worthy of further investigation.

2. A second conclusion, based mostly on the available molecular genetic information, is that the cutthroat trout evolutionary line does not extend to Asia. The limited molecular genetic information now available does not depict any close genetic connection with the specimens collected from the Tigil River basin and North American cutthroat trout, though the possibility of such a finding cannot be completely ruled out. This conclusion is cautionary because a large portion of the peninsula has yet to be surveyed, and important information concerning allozymes (e.g. Allendorf and Leary 1988) and karyotypes (e.g. Thorgaard 1983) is needed. While no direct genetic evidence has been found to demonstrate phylogenetic connections between trout of Kamchatka and cutthroat trout of western North America, phenotypic similarities do exist that most likely reflect shared primitive characters.

\textbf{The Prospects: A Glimpse into the past of North America.}

Regardless of the final outcome of the systematic puzzle presented here, one fact remains certain. The rivers of Kamchatka hold valuable information as to the nature of North American trout populations prior to the intervention by man. The historical diversity of western North American trouts is indeed great, and has provided an enormously rich natural resource. It is no great secret, however, that in the past century the intraspecific diversity of trouts in America has been sharply reduced, largely because of habitat degradation, economic activity, transplanting and fish hatchery operations (Behnke 1992). With minor exceptions, the trout populations of Kamchatka have been spared the above anthropogenic transformations. There is nowhere in North America where a comparable geographic area has not been subject to extreme changes. In addition to matters in the realm of systematics, there is an opportunity to gain insights into very important questions concerning ecology, population dynamics, and the all-important issue of the relationship between resident and anadromous trout (see: Nielsen et al. 1997 and references therein). With recent listing of many steelhead populations under the Endangered Species Act, it would be timely to have a clearer understanding of how much gene flow, if any, occurs between resident and anadromous \textit{O. mykiss} in an unperturbed environment, and whether or not resident trout populations are indeed capable of generating anadromous runs. Kamchatka offers a great opportunity to investigate this question, and information obtained may be critical in developing strategies to manage and recover the dwindling stocks of North American steelhead.

\textbf{Literature Citations}


Evolution and Life-history Organization of Yellowstone Cutthroat Trout

Robert E. Gresswell¹, Richard N. Williams², and Dennis K. Shiozawa³

Abstract—Life-history organization of cutthroat trout may be conceptualized in a nested hierarchy from species, subspecies, metapopulation, population, subpopulation, to individual (Gresswell et al. 1994). Each level in the hierarchy varies in spatial scale and in temporal persistence, and environment at each level is a spatial array that changes through time. Life-history components of each level continually change in concordance with alterations of the level-specific environment (Warren and Liss 1980).

Although there is some disagreement about the evolutionary history of cutthroat trout (Behnke 1992; Stearley 1992; Stearley and Smith 1993), fossil evidence suggests that cutthroat trout originated in the Miocene (Stearley and Smith 1993). Since then, cutthroat trout have diverged into fourteen subspecies (Behnke 1988). Variation in life-history characteristics (e.g., anadromy, iteroparity, and age at maturity) reflects the diverse environments and selective factors affecting the evolution of the species (Gresswell 1988).

The Yellowstone cutthroat trout is believed to be more abundant and inhabit a greater geographical range than any other subspecies of cutthroat trout except the coastal cutthroat trout (Oncorhynchus clarki clarki) (Varley and Gresswell 1988). During the Pleistocene glaciation, the Yellowstone subspecies was forced out of high-elevation environments by expanding glaciers. Toward the end of the Pleistocene when Shoshone Falls on the Snake River were formed by the Bonneville Flood (approximately 14,500 years ago; Ovitt et al. 1992), rainbow trout replaced Yellowstone cutthroat trout in most of the Columbia River Basin below the falls (Behnke 1992). The most recent invasion of Yellowstone cutthroat trout into the Yellowstone River drainage is associated with the retreat of glacial ice that occurred about 12,000 years ago (Richmond and Pierce 1972).

This set of events suggests that the range of Yellowstone cutthroat trout was greatly restricted and overall numbers were reduced during the late Pleistocene. The current genetic structure of the subspecies reflects these fluctuations in geographical range and abundance. Allozyme data support the occurrence of a geologically recent genetic bottleneck in the Yellowstone subspecies. In a survey of 10 Yellowstone cutthroat trout populations over a broad geographical range, Loudenslager and Gall (1980) reported that only 8% of the genetic diversity was due to divergence among populations. Allendorf and Leary (1988) compared divergence within eight potamodromous salmonids, and the Yellowstone cutthroat trout was the only form with low genetic divergence among local populations.

Genetic divergence of Yellowstone cutthroat trout from Sedge Creek (R. N. Williams, R. F. Leary, and D. K. Shiozawa, Clear Creek Genetics, Meridian, Idaho, unpublished data) is an exception to this generality. This population has been reproductively isolated from adjacent Yellowstone cutthroat trout populations for approximately 8,000 years, and heterozygosity and allelic diversity were substantially lower within the Sedge Creek population than in other populations of Yellowstone cutthroat trout. These data suggest a second genetic bottleneck affected the

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Sedge Creek population during the early Holocene. Samples of cutthroat trout from Sedge Creek and Yellowstone Lake indicated substantial allozyme divergence (Nei’s $D = 0.046$) compared to levels observed among other populations of Yellowstone cutthroat trout (Nei’s $D = 0.003$); however, divergence of mitochondrial DNA between Sedge Creek and Yellowstone Lake populations was not detected.

A third potential genetic bottleneck is associated with human activities in the Sedge Creek drainage between 1977 and 1982. During this period 2,380 Yellowstone cutthroat trout were removed from the drainage for transplanting into fishless streams in the headwaters of the Yellowstone River, south of Yellowstone National Park (Jones et al. 1983). Density of Yellowstone cutthroat trout declined 46% during this period (from 318 fish/km in 1978 to 173 fish/km in 1982). Decreased growth rates and shifts in length and age distributions (to smaller and younger fish) were also related to this management action.

The Yellowstone cutthroat trout from Sedge Creek provide an example of important issues in conservation biology. Our data suggest a loss of genetic diversity associated with serial founder events, isolation, and genetic bottlenecks. Increased inbreeding associated with these events would be expected to manifest itself in increased fluctuating asymmetry, increased expression of recessive lethal and sublethal alleles, and expected decrease in fitness. In contrast, the Sedge Creek cutthroat trout appear to be well adapted to life in a small headwater system. Apparently, the population has survived several instances where inbreeding depression was likely, and yet, lethal and deleterious genes are not apparent in the surviving population. If some of the resulting progeny survived and successfully reproduced, the population could pass through the inbreeding depression while losing overall genetic diversity.

**LITERATURE CITATIONS**


Genetic Diversity Of Coastal Cutthroat Trout

Thomas H. Williams¹, Kenneth P. Currens², Gordon H. Reeves³

Extended abstract—Coastal cutthroat trout (Oncorhynchus clarki clarki) are found in coastal basins from northern California to Prince William Sound, Alaska. Currently many are declining, particularly in the southern extend of their range (Hall et al. 1997). However, this may not be a recent phenomenon. In his review of the trouts of California, John Snyder (1940) observed a decline in cutthroat numbers in northern California streams since he first fished them in 1897. Was this the first observation of the current crash of coastal cutthroat trout or have these populations always cycled between periods of abundance and extinction? What do we really know about the long-term ecology of this species? Clearly, lack of a historical and ecological understanding of this subspecies hampers management and conservation.

Patterns of genetic variation may have important implications for these efforts, however, because they give us clues to the long-term dynamics of populations. Here we describe a picture taken from genetic data of 43 populations distributed across the subspecies range. This is one snapshot from our research examining how life-history characteristics and habitat diversity might affect the genetic diversity and persistence of coastal cutthroat trout. Coastal cutthroat trout have many different life-histories (Trotter 1989). For example, coastal cutthroat trout, like rainbow trout (O. mykiss) and sockeye salmon (O. nerka), may have freshwater, migratory (potamodromous) forms, which never enter saltwater. They may spawn more than once, which many ocean-going (anadromous) salmon do not do. Coastal cutthroat trout are also unique, because they can move between fresh and saltwater for purposes other than spawning (amphidromous). Although many populations may be isolated above barriers to migration, amphidromous and potamodromous populations of coastal cutthroat trout can often be found together downstream of barriers. In this analysis, we looked at genetic differences in 36 protein-coding loci from fish of various ages that were collected below migration barriers where they had opportunity to enter saltwater.

Our data suggest that compared to other species of Pacific salmon and trout, coastal cutthroat trout are characterized by many smaller, genetically more diverse local populations that act in a more independent, isolated nature over short time frames (<100 years). For example, on average approximately 19.1% of all genetic differences we observed (total gene diversity) was attributed to differences among populations (G_{st}=0.19, Nei 1977). This was much greater than that reported for other species of anadromous salmonids in western North America (see also Williams et al. 1997). Consistent differences occurred among populations from different regions (Alaska, Washington/Oregon, and California), but within regions there was less geographical structure than that observed among populations of other Pacific salmon and trout. Genetically, this can be explained by genetic drift (common in small populations), by founder effect (common in small populations in areas with dynamic habitat conditions or where species are colonizing new habitats), and by periods of low dispersal. To us, this paints a picture of coastal cutthroat trout as many small populations evolving independently in habitats that are diverse and constantly changing.

Differences in genetic population structure between coastal cutthroat trout and other Pacific salmon and trout may reflect life-history differences among species. The many migratory life-histories that coastal cutthroat trout have evolved, for example, would be advantageous in unpredictable habitats where small populations expand,
decline, or become extinct with changing conditions. Dispersals, which would be more likely with fish that migrate, might be rare or consist of only few individuals, but they may be crucial for reestablishing populations in adjacent habitat following localized extinctions or as new habitat becomes available.

In conclusion, coastal cutthroat trout appear to consist of many small, local, diverse populations that have evolved in a dynamic environment. Knowledge of life history differences adds color to this picture, but to bring it all into focus we need to also understand the habitat changes that coastal cutthroat trout have adapted to and will be faced within the future. Connectivity of biological and physical processes throughout the basin must be considered for management, conservation, and rehabilitation efforts (Reeves et al. 1995). Conservation units for coastal cutthroat trout need to reflect appropriate geographic areas based on the genetic diversity and life history variation among populations. In addition, because small populations are typically at greater risk of extinction than larger populations, conservation measures designed for other Pacific salmon and trout populations with larger, more connected populations may not be appropriate.

ACKNOWLEDGMENTS

This research was funded by the U.S. Forest Service, Pacific Northwest Research Station, and Regions 6 and 10. Electrophoretic analysis was done in the laboratories of the Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

LITERATURE CITED


The Evolutionary Significance of Southern Brook Trout Populations

Raymond P. Morgan II\textsuperscript{1} and Roy G. Danzmann\textsuperscript{2}

Abstract -- Initially, it was assumed that brook trout (Salvelinus fontinalis) populations, throughout its eastern native range, were closely related, despite the variety of life history patterns observed in this species. Electrophoretic work on brook trout from the southern extreme of its range had suggested potential subspecific differences but the entire eastern range had not been well surveyed, especially with advanced molecular techniques. The current study on southern brook trout populations was a derivative of work to determine post-Wisconsin patterns of reinvasion from a number of postulated refugia by northern brook trout. Brook trout mitochondrial DNA from liver and heart were analyzed from 17 southern populations, outside of northern glaciated regions. Results from the study identified the presence of at least six major mtDNA clades present in the native range of the brook trout, with supporting strong evidence for the distinctness of brook trout from the Great Smoky Mountains. In addition, there is a very high level of mtDNA differentiation in drainage basins of West Virginia and western Maryland, suggesting a number of evolutionarily significant units. The presence of these distinct units is critical to the conservation biology of Appalachian brook trout.

INTRODUCTION

The brook trout\textsuperscript{3}, Salvelinus fontinalis, is the native salmonid of river drainages throughout the Appalachian Mountain. Its range extends from northeastern Canada through the Smoky Mountains of Tennessee and on into northwestern Georgia (MacCrimmon and Campbell 1969). The natural history of this region reveals numerous events that could serve to isolate fish populations, including extensive glacial impoundment and stream capture. In fact, Brooks (1971) states of the Appalachian geomorphology that "there could scarcely be a set of natural circumstances more conducive to isolation, to the interruption of gene flow and to encouragement of endemism through natural selection and mutation." The natural history and zoogeography of fishes in the Appalachians is discussed at length by Hocutt et al. (1986).

Brook trout are endemic to eastern North America (Scott and Crossman 1973) and have been postulated to have recolonized northern parts of their range from a single Atlantic refugial zone (Radforth 1944) following the Wisconsinan glaciation. Surprisingly, recent work on brook trout (Salvelinus fontinalis) indicates the presence of a major sextet of mitochondrial DNA (mtDNA)

\textsuperscript{3}For this paper, we will use brook trout in the text as the common name for this species since it is the accepted common name used by the American Fisheries Society (Common and Scientific Names of Fishes, American Fisheries Society, Special Publication 20, 1991). The brook trout is a char (Morton 1980), and this common name is being used more frequently in the literature, especially in non-American journals.

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phylogenetic assemblages in eastern North America (Danzmann et al., in review).

This result is based on the examination of mtDNA variability in brook trout from 16 sampling regions comprised of 49 units (major drainages, small stream catchments, and isolated lakes) representing 175 populations in eastern North America (this is the second largest data set known on vertebrate mtDNA variation). An AMOVA indicates that the majority of the variation detected is partitioned among units (64%), i.e. drainages, and populations within drainages, as compared to within population variation (36%), thus indicating a large degree of heterogeneity in population founding events among geographic units.

Although a number of brook trout populations from non-glaciated areas were studied, there remains a definite lack of knowledge concerning the genetic status of brook trout from the Central and Southern Appalachians. Only 172 brook trout represent populations from non-glaciated areas in the Central and Southern Appalachians versus 2,201 brook trout collected from glaciated regions of eastern North America. This paper examines mtDNA diversity in wild populations of brook trout from the southern Appalachians and compares it to that extant in populations throughout the species native range of eastern North America.

**MATERIALS AND METHODS**

**Source of the Fish**

A total of 2422 fish from 175 populations of brook trout were sampled in North America for mtDNA variation (Danzmann et al., in review). Southern populations sampled are listed in Table 1. Sample sizes per population in the south consisted of 7-24 fish. Details of mtDNA variation present in several east coast populations of brook trout from the Canadian Maritimes have previously been presented by Ferguson et al. (1991), Jones (1995) and Jones et al. (1996), and for Algonquin Park, Ontario and Big Creek, Ontario populations by Danzmann and Ihssen (1995) and Danzmann et al. (1991b), respectively.

<table>
<thead>
<tr>
<th>Table 1. Collection sites for southern brook trout populations. One additional sample was collected from the Edray Hatchery, WV. (New England source).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winch Run - Principio Creek to Chesapeake Bay (WIN)</td>
</tr>
<tr>
<td>Tuscarora Creek - Monocacy River to Potomac River to</td>
</tr>
<tr>
<td>Chesapeake Bay (TUR)</td>
</tr>
<tr>
<td>Fishing Creek - Monocacy River to Potomac River to</td>
</tr>
<tr>
<td>Chesapeake Bay (FIS)</td>
</tr>
<tr>
<td>Kellogg Branch - Deer Creek to Susquehanna River to</td>
</tr>
<tr>
<td>Chesapeake Bay (KEL)</td>
</tr>
<tr>
<td>Panther Branch - Gunpowder River to Chesapeake Bay (PAN)</td>
</tr>
<tr>
<td>Timber Run - Patapsco River to Chesapeake Bay (TIM)</td>
</tr>
<tr>
<td>Bear Creek - Youghiogheny River to Monongahela River to</td>
</tr>
<tr>
<td>Ohio River (BEA)</td>
</tr>
<tr>
<td>Mill Creek - Youghiogheny River to Monongahela River to</td>
</tr>
<tr>
<td>Ohio River (MIL)</td>
</tr>
<tr>
<td>Shavers Run - Tygart River to Monongahela River to Ohio</td>
</tr>
<tr>
<td>River (SHA)</td>
</tr>
<tr>
<td>Crooked Fork - Elk River to Kanawha River to Ohio River (CRO)</td>
</tr>
<tr>
<td>Sutton Run - North Fork Deer Creek to Greenbriar River to</td>
</tr>
<tr>
<td>Kanawha River to Ohio River (SUT)</td>
</tr>
<tr>
<td>Walderman Run - Poca Run to East Fork of the Greenbriar</td>
</tr>
<tr>
<td>River to New River to Kanawha River to Ohio River (WAL)</td>
</tr>
<tr>
<td>Tetercamp Run - Big Run to North Fork of the South Branch of</td>
</tr>
<tr>
<td>the Potomac River to Chesapeake Bay (TET)</td>
</tr>
<tr>
<td>Horsecamp Run - Seneca Creek to North Fork of the South</td>
</tr>
<tr>
<td>Branch of the Potomac River to Chesapeake Bay (HOR)</td>
</tr>
<tr>
<td>Spy Run - South River to Maury River to James River to</td>
</tr>
<tr>
<td>Chesapeake Bay (SPY)</td>
</tr>
<tr>
<td>Dry Run - Disappears underground in karst area; drainage to</td>
</tr>
<tr>
<td>Chesapeake Bay (DRY)</td>
</tr>
<tr>
<td>Indian Camp Creek - Pigeon River to French Broad River to</td>
</tr>
<tr>
<td>Tennessee River to Ohio River (IND)</td>
</tr>
</tbody>
</table>

**mtDNA Preparation and Analysis**

Details of mtDNA preparation and analysis of brook trout from the Canadian Maritimes have previously been presented by Ferguson et al. (1991), Jones (1995) and Jones et al. (1996), and for Algonquin Park, Ontario and Big Creek, Ontario populations by Danzmann and Ihssen (1995) and Danzmann et al. (1991b), respectively. Basically, tissue (liver and heart) are excised from the fish and the mtDNA from these tissues is purified through a number of steps. Once purified, the mtDNA is cleaved using specific restriction endonucleases and the resulting haplotype visualized and scored. Haplotype scores for
each population and then used in the statistical analyses.

Statistical Analyses

The first analysis of molecular variation among populations followed Excoffier et al. (1992) using the program WINAMOVA. The second analysis assessed variation among drainages partitioned into 16 major geographic regions that primarily represent major present day drainage basins or post-glacial refugial/drainage zones (Danzmann et al., in review). The complete, detailed statistical analyses of the North American brook trout data set is found in Danzmann et al. (in review).

The data set was subjected to a parsimony analysis using Dollo parsimony as implemented by the program DOLLOP in PHYLIP 3.5 (Felsenstein 1989). Ancestral RFLP sites were used to root the tree if it was possible to ascertain these sites. RFLP sites that were either present in Arctic charr (Salvelinus alpinus) (Danzmann et al. 1991a, Wilson 1995) or lake charr (Salvelinus namaycush) were considered to be ancestral (Wilson 1995).

RESULTS

A total of 65 haplotypes were detected among the brook trout populations surveyed in this study, using the common set of restriction enzymes that produced RFLPs. Some of these haplotypic variants have previously been described (Danzmann et al. 1991b, Bernatchez and Danzmann 1993, Danzmann and Jhens 1995, Jones et al., 1996).

Intrabranch standard error tests among the six most common, and genetically divergent haplotypes (i.e. haplotypes 1, 6, 58, 50, 21, and 51) were all non-negative, thus supporting the existence of the six major intraspecific phylogenetic clades. These clades are designated A - F (Figure 1).

Clades A - C have previously been identified in a combined DNA sequence and RFLP analysis of northern brook trout populations (Bernatchez and Danzmann 1993). Haplotypes 64 and 65 appear to represent a distinct sub-clade characterized by two unique site losses compared to haplotype 6 (Figure 1). These phyla may represent stable sub-clades within the A assemblage. Some of the other A and some B assemblage haplotypic relationships are less definitive, however, due to the high number of homoplasy observed among these lineages. The rooted Dollo parsimony tree requiring 67 steps indicates that the C clade haplotypes (haplotypes 21 and 22) are the most ancestral haplotypes within this species.

The present sampling of mtDNA haplotypes from North American brook trout suggests that most fish belong to the A, B, and to a lesser extent, C assemblages (Danzmann et al., in review). This is most likely due to an artifact of sampling bias. Most of the populations surveyed in this study were taken from more northerly latitudes in North America. Assemblage A and B fish appear to be the predominate types that have recolonized northerly latitudes. More haplotypic variation will be found with the D, E, and F, as well as C clades, as more southerly populations are surveyed for mtDNA variability.

Six major genetic groupings are evident when the genetic distances among these drainages are compared. Two groupings, represented by fish from the Youghiogheny River drainage of the Ohio River in western Maryland and fish from Indian Camp Run of the Tennessee River, were the most genetically isolated groups sampled. Only two haplotypes (51 and 52 = Assemblage D) were found in the two Youghiogheny River populations sampled, while a single haplotype (haplotype 50 = Assemblage E) was found in the Indian Camp Run population. Interestingly, other fish from the Ohio River drainage (Shavers Run, and the three populations from the Kanawha River drainage) were more closely related to the Indian Camp Run population (possessing fish primarily from the C and F clades) than they were to Youghiogheny River populations, even though these populations were in closer geographic proximity to Youghiogheny River populations. These four populations represent a fourth genetic grouping.

A fifth genetic grouping is composed largely of drainages possessing fish with a high frequency of Assemblage A haplotypes. Many of these populations occur in the Chesapeake Bay drainage (Potomac River, Dry Run, Kellogg Branch). However, a large proportion of drainages sampled from southern and south-central Ontario are also
included in this grouping. Three populations from the Chesapeake Bay drainage did not belong to this fifth grouping. Fish from Winch Run, Timber Run, and Panther Branch, were more closely related to fish that predominate in more northerly regions. Fish from these three populations possess a high frequency of Assemblage B haplotypes. Interestingly, these three populations were the lowest elevation populations sampled from the Atlantic Piedmont plain region. The most genetically distinct fish sampled in the south-central region were from the most southerly drainages sampled from Lake Huron. This sixth genetic grouping possessed a very high frequency of clade C haplotypes.

In comparisons of the haplotypic heterogeneity among drainages it was evident that most of the northern drainages did not differ from one another in their haplotypic composition, due to the fact that most of these drainages possessed a high frequency of haplotype 1 fish. However, fish from several drainages which are genetically closely related to fish in the majority of northern drainages are, nonetheless, genetically quite distinct from one another. This is due to the fact that fish in these drainages possess one or more haplotypes in a relatively high frequency, which are not commonly found in most populations from other drainages. For example, Winch Run is fixed for haplotype 7, (one mutational step from haplotype 1) while in other populations this haplotype is absent or rare.

Comparisons among most other drainages reveals a high degree of significant interdrainage heterogeneity in the composition of mtDNA haplotypes (Danzmann et al., in review). In fact, fish from several drainages are significantly different at the P < 0.001 level from fish in all the other drainages compared. Most of these groupings are within the Ohio River drainage, and therefore, these fish would appear to be the most divergent both in terms of genetic distance, and with respect to haplotypic composition.
DISCUSSION

Brook charr populations show a large degree of intra- and inter-drainage heterogeneity in mtDNA haplotypic distributions consistent with a pattern that would be generated from small founder events followed by random lineage extinction (Avise et al. 1987). Across the entire species range, phylogeographic patterning is largely consistent with the category I patterning of Avise et al. (1987) in that clades E and F appear restricted to a far southern distribution, and clade D occupies an isolated middle-range habitat. Clades A and B show a discontinuous type II pattern, which likely results from a large degree of secondary contact among populations that may have begun to diverge during previous glacial maxima.

Clade C fish retain most of the apparent pleisomorphic characters in this species and also appear to be fairly wide-spread in the north-central portion of the species range. Certain assemblage C haplotypes are present in more than one drainage in the central Great Lakes basin and northern Great Lakes region, which suggests a more wide origin for these fish. This phylogeographic patterning appears initially consistent with that observed for assemblage A and B fish (i.e. widespread mixing of all haplotypes across regions). However, the apparent restriction of certain C assemblage haplotypes to more southern regions (Ohio River drainage = haplotypes 54 and 55) and the confinement of haplotype 67 to the extreme northern part of the distribution for this assemblage, does provide a strong phylogeographic signal for fish in this clade. Many studies of the population genetics and genetic composition of brook trout populations in these regions have been documented (Stoneking et al. 1981; Quattro et al. 1990; Bernatchez and Danzmann 1993; McCracken et al. 1993; Perkins et al. 1993; Hayes et al. 1996; Morgan and Baker, in prep.; and Danzmann et al., in review).

DIVERGENCE OF PHYLOGENETIC CLADES

Assuming a molecular clock estimate of 2% divergence/million years for vertebrate mtDNA (Brown et al. 1979) -- although rates 5 - 10x slower have been proposed for salmonids and other teleosts (Bentzen et al. 1989; Thomas and Beckenbach 1989), the two most closely related phylogenetic clades, A and B, diverged approximately 3.2 x 10^3 years ago compared to the two most distantly related clades, D and E (ca. 8.1 x 10^6 years ago). Thus, all major groupings were extant prior to the beginning of the last Wisconsinan glacial period (approximately 100,000 yBP) with possible early origins in the Pliocene, if a slower clock rate is accepted. Heterogeneity of this magnitude suggests that these lineages (with the possible exception of A and B assemblages) may be accorded subspecific status or recognized as ESUs (Moritz et al. 1995). The lack of allopatric phylogeographic structuring in the A and B assemblages makes such a designation for these two clades more ambiguous.

Support for recognizing the unique status of these lineages comes from several sources. Separate sub-specific status for brook charr from the Great Smoky Mountains region of Tennessee has previously been suggested by Stoneking et al. (1981) based upon an allozyme survey of fish in this region, and is supported by recent allozyme data (McCracken et al. 1993). Also, the present mtDNA survey indicates that fish in this region differ on average by 1.27% sequence divergence from fish with the most common haplotypes in the other clades. Phylogeographic distinctness of some of these clades is also evident. Assemblage D fish appear localized to the Youghiogheny drainage and help constitute the 1st (1.61%), 3rd (1.31%), and 4th (1.29%) o, divergent inter-assemblage relationships detected with fish from the E, F, and C assemblages, respectively. This may be due to the fact that until the late Pleistocene, the Monongahela and Youghiogheny Rivers comprised part of the drainage of the Old Lower Allegheny River which flowed northward in the Greater Laurentian River Basin (= St. Lawrence River drainage basin) (Hocutt et al. 1986). Hocutt et al. (1986) indicate that the Youghiogheny portion of the drainage was especially isolated due to high cataracts and surrounding montane conditions. Thus fish in this drainage may indeed be relicts of a very early northern invasion, as thus, may not represent Teays/Mississippian derived fish. Also,
the fact that these fish do not possess the B phenotype restriction fragment patterns at BamHI, Dral, and PvuII, that appear to characterize fish from more southerly distributions (Bernatchez and Danzmann 1993; Danzmann and Ihssen 1995; Hayes et al. 1996), suggests a more northerly origin for D clade fish. Monongahela River fish (SHA) are only represented by assemblage C haplotypes not found further north. All populations in the Kanawha River drainage possess high frequencies of F assemblage haplotypes and the only A assemblage haplotypes detected appears unique to this region. All these southern drainages are genetically distinct from each other and all the other drainages surveyed. This further supports the phylogeographic distinctness of these regions.

It is recognized that the sampling of southern populations has been less extensive than northern populations and that this bias will likely alter interpretations regarding the status of populations belonging to ESUs (Moritz et al. 1995). For example, haplotype S6 of Hayes et al. (1996) possesses the Hind III-D phenotype of assemblage F fish. This haplotype was only detected in one of the northern most populations sampled by these researchers, but suggests that fish from this phylogenetic assemblage may extent further southward than presently detected. Since assemblage E and F fish are closely related, they may have diverged in northern and southern parts of the Mississippi drainage.

In addition, future work should strongly focus on the southern Appalachians. There are a number of significant faunal breaks that have been observed for a number of species in this region (Avise 1996). Our samples from the southern end of the Appalachians are on the western side of the Great Smoky Mountains. There is a strong potential for a different brook trout clade to be present on the southern or eastern side of the Appalachians. An alternative hypothesis is the presence of different haplotypes in the southern Appalachians related to the currently observed clades.

Data on mtDNA divergence among these lineages will be insufficient to resolve questions regarding the unique status of these fish without more refined information on the physiological, ecological, behavioral, and reproductive isolation of fish in these different clades (Smith et al. 1995). While it is evident that the intraspecific differences we detected are similar to those found in other sub-species comparisons, and are in fact greater than some of the differences detected among species (Bernatchez and Osinov 1995; Bowers et al. 1994; Echelle and Dowling 1992; Wettstein et al. 1994; 1995), mtDNA divergence levels alone will not ascertain genome-wide complementation, or behavioral incompatibility. Assessment of developmental homeostasis in inter-clade crosses may provide a falsifiable test of the hypothetical genetic distinctness of these clades, but interpretation of the results from such experiments will need to consider cytonuclear interactions. Of interest will be reciprocal inter-clade crosses made in sympathy versus those made on the basis of microgeographic allopatric distributions. If incompatibilities between clades are detected and they are of similar magnitude in both sympathy and allopatry then partitioning the clades would be supported. In addition, field observations on inter-clade mate choice and mating success would be informative.

ACKNOWLEDGMENTS

A detailed list of people who assisted with the project may be found in Danzmann et al. (in review). In particular, we wish to thank Walter Holtsmaster, Michael Pinder, Katie Meagher, Matt Hall, Don Phares, Tom Oldham, Dan Duffield, Larry Mohn, Steve Owens, Steve Moore, and Bart Carter for assistance in collections of fish from southern populations. This is Scientific Contribution Number 2874 from the Appalachian Laboratory of the University of Maryland Center for Environmental Science.

REFERENCES


Genetic Variation Among Wild Lake Trout Populations: The "Wanted" and the "Unwanted"

Mary K. Burnham Curtis¹, Larry W. Kallemeyn², and Charles R. Bronte³

Abstract - In this study we examine genetic variation within and among self-sustaining lake trout populations from the Great Lakes basin, the Rainy Lake basin, and Yellowstone Lake. We used RFLP analysis and direct sequencing to examine DNA sequence variation among several mitochondrial and nuclear genes, including highly conserved loci (e.g. cytochrome b, nuclear exon regions) and highly variable loci (e.g. mitochondrial d-loop and nuclear intron regions). Native Lake Superior lake trout populations show high levels of genetic diversity, while populations from the Rainy Lake basin show little or none. The lake trout population sampled from Yellowstone Lake shows moderate genetic diversity, possibly representative of a relatively large source population closely related to lake trout from Lewis Lake, Wyoming. There has been significant social and management controversy involving these lake trout populations, particularly those that are located in National Parks. In the Great Lakes and Rainy Lake basins, the controversy involves the degree to which hatchery supplementation can contribute to or negatively impact self-sustaining populations which are highly desired by recreational and commercial fisheries. In Yellowstone Lake, the lake trout are viewed as an undesirable intruder that may interfere with resident populations of highly prized native cutthroat trout.

INTRODUCTION

The lake trout (Salvelinus namaycush Walbaum) has been highly regarded as a valuable component of sport and commercial fisheries throughout its range in North America. Fish management practices, both professional and amateur, have resulted in the expansion of the native ranges of several salmonid species across North America as well as the successful introduction of other non-native salmonids. In particular, lake trout have been successfully introduced to lakes in western North America, as well as some northern islands in Canada (Marshall and Keleher 1970, Scott and Crossman 1973). During the last century however, native lake trout populations have experienced the effects of overfishing and uncontrolled predation in both the large and small lakes that they inhabit. Today, lake trout fisheries management encompasses a wide range of activities from managing remnant and recovering stocks (Hansen et al. 1995), to restoring stocks that were decimated (Cornelius et al. 1995, Elrod et al. 1995, Holey et al. 1995), to managing transplanted or hatchery raised populations (Eshenroder et al. 1995), to eliminating unwanted populations (Kaeding et al. 1996).

Often absent from past management programs has been information about the genetic characteristics of the lake trout populations involved in transfer programs and hatchery broodstock development. Even less is known about populations which have succumbed to local extinctions. Analytical techniques for molecular biology have only recently allowed as to begin to answer some of the questions about the distribution of genetic variation
within and among lake trout populations in North America. The goal of this study is to document genetic variation and its distribution among lake trout populations from various locations in North America. Salmonid fishes have in common a tendency to evolve local adaptations in a short period of time (Behnke 1972), and each population sampled in this study has unique characteristics with regard to life history, behavior, management history, or evolutionary history.

The siscowet and humper lake trout from Lake Superior each have unique life history and morphological characteristics that are recognizable and differ from the more common lean lake trout (Eschmeyer and Phillips 1965, Rahn 1965, Burnham-Curtis 1993). These differences have affected their economic value in commercial fisheries, as well as their persistence during an era of intense exploitation and predation by the parasitic sea lamprey which rendered lean populations nearly extinct (Swanson and Swedberg 1981, Hansen et al. 1995). Lake trout stocking in Lake Superior was extensive, but concentrated mainly on the inshore lean lake trout. Broodstock was taken primarily from the Marquette area and the Apostle Islands area of Lake Superior (Hansen et al. 1995). Recently, management agencies have determined that successful natural reproduction of lean lake trout is sufficient to support self-sustaining populations. Stocking of lake trout was ceased in Lake Superior in 1996 as additional lake trout populations were deemed to be “recovered” (Hansen et al. 1994).

The lake trout from Siskiwit Lake, on Isle Royale, are native and have been isolated from the main body of Lake Superior presumably since the retreat of the Pleistocene glaciation and the recolonization of the Great Lakes basin. Siskiwit Lake is the deepest inland lake in Isle Royale National Park. Siskiwit Lake has a 0.4 km long outlet stream to Lake Superior which falls 18 m and contains several natural basalt barriers which probably restrict upstream movement of fishes and limits gene flow between the Siskiwit Lake lake trout population and the lake trout populations from Lake Superior. There is no official record of substantial lake trout stocking into Siskiwit Lake.

Native lake trout populations are believed to have existed in Cruiser Lake, Mukooda Lake, and Little Trout Lake in Voyageurs National Park, Minnesota. Supplementary stocking of lake trout, however, started in the 1940's in Cruiser and Mukooda Lakes and in 1965 in Little Trout Lake. Lake trout fingerlings were stocked biannually in all three lakes from the mid-1960's until 1988, but since then only Mukooda and Little Trout Lakes have been stocked.

Lake trout plants by the Minnesota Department of Natural Resource (MNDNR) prior to 1980 consisted almost exclusively of Marquette strain lake trout (Darryl Bathel, MNDNR, personal communication). In the 1980's the MNDNR started using two additional strains of lake trout in their stocking program. One strain originated from lake trout collected near Isle Royale in Lake Superior while the other came from a native lake trout population in Gillis Lake, a small lake also located in the Hudson Bay drainage in northeastern Minnesota. All lake trout plants in the Voyageurs National Park lakes since 1988 have been Gillis Lake fish. Cruiser Lake received its only Gillis Lake fish in 1988; it has not been stocked since.

While lake trout were officially discovered in Yellowstone Lake in Yellowstone National Park, Wyoming in 1994, the presence of several age classes in significant numbers indicated that reproduction had been occurring annually since at least 1989 (Kaeding et al. 1996). A control program has been developed in an attempt to alleviate the extreme threat that this non-native species is perceived to pose to the lake’s ecosystem. The Yellowstone cutthroat trout is native to Yellowstone Lake, and appears to be adversely affected by the presence of lake trout in the system.

Our goal in this study was to investigate variation in specific mitochondrial (mtDNA) and nuclear (nucDNA) genes using a combination of the polymerase chain reaction and restriction fragment length polymorphism analysis (PCR-RFLP). We chose to look at DNA variation because our samples could be collected non-lethally, and only small amounts of fin clip tissue were needed for adequate analysis. With this method we could also use a total genomic DNA extract for both mtDNA and nucDNA amplification. Previous studies of mitochondrial DNA variation among lake trout populations in the Great Lakes showed that at least 3 major clonal lineages were represented in populations that colonized the lakes after the last glacial retreat (Crewe and Hebert 1988). Our study documents the distribution of the 3 major lake trout clonal lineages among lakes in the Great Lakes and Hudson Bay drainage, each with a different suite of management and environmental influences.

METHODS

The 363 lake trout samples analyzed for this study came from wild caught fish from three national parks and Lake Superior (Table 1). Three hatchery lake trout broodstock strains (Lewis Lake, Seneca Lake, and Marquette strains) were also used for comparison. Lake trout from Voyageurs and Isle Royale National Parks were collected.
during spring and summer surveys in 1995 and 1996, while the trout from Yellowstone National Park were collected during gill net surveys in Yellowstone Lake in 1995. Lake Superior lake trout were collected during August 1994 and October 1995 as part of a survey foriscowet lake trout. The Lewis Lake, Seneca Lake, and Marquette Superior strain lake trout were hatchery-raised fingerlings acquired from the Jordan River National Fish Hatchery in 1993.

<table>
<thead>
<tr>
<th>Location</th>
<th>Year</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mukooda Lake, Voyageurs NP</td>
<td>1995</td>
<td>28</td>
</tr>
<tr>
<td>Little Trout Lake, Voyageurs NP</td>
<td>1995</td>
<td>15</td>
</tr>
<tr>
<td>Cruiser Lake, Voyageurs NP</td>
<td>1995</td>
<td>41</td>
</tr>
<tr>
<td>Siskiwit Lake, Isle Royale NP</td>
<td>1996</td>
<td>80</td>
</tr>
<tr>
<td>Yellowstone Lake, Yellowstone NP</td>
<td>1995</td>
<td>63</td>
</tr>
<tr>
<td>Lake Superior: siscowets</td>
<td>1899</td>
<td>35</td>
</tr>
<tr>
<td>Lake Superior: Isle Royale</td>
<td>1995</td>
<td>44</td>
</tr>
<tr>
<td>Lake Superior: Caribou Island</td>
<td>1996</td>
<td>50</td>
</tr>
<tr>
<td>Lewis/Jenny Lake strain</td>
<td>1993</td>
<td>9</td>
</tr>
<tr>
<td>Seneca Lake strain</td>
<td>1993</td>
<td>9</td>
</tr>
<tr>
<td>Superior Marquette strain</td>
<td>1993</td>
<td>9</td>
</tr>
</tbody>
</table>

Oligonucleotide primers for cytochrome b and NADH 3/4 were obtained from the Salmonid Genetics Laboratory at the University of Wisconsin-Milwaukee (Dr. R. B. Phillips, unpublished data). PCR amplified products were electrophoresed in 1% agarose gels supplemented with Synergel (Diversified Biotech) post stained with ethidium bromide, and visualized with long-wave ultraviolet light. For this study we amplified 5 mitochondrial DNA loci including the control region, cytochrome b, NADH 3/4, 16S RNA, and NADH5/6; and we amplified 1 single copy nuclear gene for prolactin.

Following amplification of specific gene products, samples were surveyed for genetic variation by digesting the DNA products with up to 18 different Type II restriction endonucleases with 4-8-base recognition sequences for each gene locus. Restriction digestion products were electrophoresed in 2-4% agarose gels supplemented with Synergel, post stained with ethidium bromide, and visualized with long-wave ultraviolet light. Restriction enzymes tested included Aat I, Acc I, Ac i I, Aku I, Bam HI, Bsa AI, Bfa I, Bst UI, Dpn II, Eco RV, Hae III, Hind III, Hin PI, Mse I, Msp I, Nco I, Nde I, Nla III, Nsi I, Psi I, Pvu II, Rsa I, Sal I, Sma I, Ssp I, Taq al, and Xba I.

Individuals were assigned haplotype designations based on differences in fragments/restriction sites, with "A" being the most common haplotype, and successively less frequent types labeled "B," "C," and so on. Composite restriction site haplotypes were used to calculate sequence divergence and estimates of nucleon diversity.

Sequence divergence was measured as Nei's D (Nei and Tajima 1983) and used as input in a UPGMA clustering algorithm. We also calculated nucleon diversity using the equation of Nei and Tajima (1981). Our goal was not to determine phylogenetic relationships among these lake trout populations, but merely present levels and distribution of genetic variation. Relationships among haplotype groups were calculated using the PHYLIP program (Felsenstein 1995).

DNA sequence information was performed at the Molecular Genetics Facility at the University of Georgia on an ABI Prism automated DNA sequencer. Sequencing was limited to only a few individuals from each population to specifically look for sequence differences that were not uncovered by RFLP analysis. Relationships among populations based on sequence data were estimated using the DNAPARS program of PHYLIP 3.5 (Felsenstein 1995).

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1 Mention of trade names does not imply U.S. Government endorsement of commercial products.
RESULTS

DNA sequence variation detected in this study was concentrated in the Cytochrome b (Cyt b) and NADH 3/4 regions of mitochondrial DNA. Cyt b and NADH 3/4 when digested with the hexameric enzyme Bam HI produces 4 different composite haplotypes which correspond to the "A," "B," "C," and "D" lake trout groups identified in previous studies (Grewe and Hebert 1989, Burnham Curtis 1993). The "A," "B," and "C" types were the only ones uncovered in this study. Restriction enzyme digestion of the mitochondrial control region with 16 different restriction enzymes did not reveal any polymorphisms, two enzymes, Nde I and Rsa I each had a polymorphism resulting from the loss of a restriction site. A total of nine different composite haplotypes were detected in this data. No polymorphic restriction sites were uncovered in nuclear intron regions examined in this study.

Calculations of genetic diversity showed that Lake Superior lake trout from the Isle Royale population had the greatest diversity, while the lake trout populations in Mukooda and Little Trout Lakes in Voyageurs National Park had the least amount of haplotype diversity (h=0, Table 2).

Table 2. Nucleon diversity (h) estimated for lake trout populations sampled.

<table>
<thead>
<tr>
<th>Location</th>
<th>N</th>
<th>Nucleon Diversity (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mukooda Lake</td>
<td>25</td>
<td>0.0000</td>
</tr>
<tr>
<td>2. Little Trout Lake</td>
<td>11</td>
<td>0.0000</td>
</tr>
<tr>
<td>3. Cruiser Lake</td>
<td>41</td>
<td>0.1162</td>
</tr>
<tr>
<td>4. Siskiwi Lake</td>
<td>80</td>
<td>0.2944</td>
</tr>
<tr>
<td>5. Yellowstone Lake</td>
<td>50</td>
<td>0.3194</td>
</tr>
<tr>
<td>6. Lake Superior siscowets</td>
<td>35</td>
<td>0.5854</td>
</tr>
<tr>
<td>7. Lake Superior: Caribou Island</td>
<td>50</td>
<td>0.6589</td>
</tr>
<tr>
<td>8. Lake Superior: Isle Royale</td>
<td>44</td>
<td>0.7775</td>
</tr>
<tr>
<td>9. Lewis/Jenny Lake strain</td>
<td>9</td>
<td>0.4975</td>
</tr>
<tr>
<td>10. Seneca Lake strain</td>
<td>9</td>
<td>0.5544</td>
</tr>
<tr>
<td>11. Superior Marquette strain</td>
<td>9</td>
<td>0.5784</td>
</tr>
</tbody>
</table>

The three major haplotype groups were distributed in varying frequencies among the sampled populations. Hatchery broodstock populations had greater genetic diversity than expected. All had the most common "A" lineage, but a second lineage (LT5 in this study) appeared in greater frequency in the Lewis Lake and Seneca Lake strains. The Marquette hatchery strain was the most diverse of the hatchery populations with 4 haplotype groups represented, 3 as individual variants. Mukooda and Little Trout Lakes in Voyageurs National Park showed the lowest haplotype diversity--these lakes were intensively stocked with hatchery raised lake trout of Lake Superior and Gillis Lake, MN origin. Previous studies have shown that the Gillis Lake population also has low genetic diversity (DeSilva 1989). Cruiser Lake samples predominantly had the common haplotype, but several individuals had the haplotype "C" that appears in greater frequency in Lake Superior.

Lake trout from the Lake Superior basin showed the greatest amount of genetic diversity, possibly because of relatively larger overall population sizes. However, the three haplotypes appeared in different frequencies among the Lake Superior samples. The lean lake trout from Isle Royale and humpers from Lake Superior had greater diversity of mtDNA haplotypes than did the siscowets and Siskiwi Lake populations, although all three major mtDNA haplotypes were represented in each of these samples.

Genetic distances for each of the 9 composite haplotypes were calculated using Nei's D (Nei et al. 1972) and compared with the RESTML program of PHYLIP 3.5 (Felsenstein 1995) to see relationships among the haplotype groups (Figure 1). Groups LT4-LT9 are each represented by 5 or fewer individuals and represent rare types defined by single restriction sites in the D-loop region. Groups 6-9 are represented by a total of six individuals, all from wile Lake Superior populations.

Results of sequence comparisons using DNAPARS in the PHYLIP 3.5 program produced an unrooted dendrogram shown in Figure 2. The sequence used was a
158-base pair sequence from the 3' end of the amplified control region. The hatchery samples clustered together in an unrooted tree based on this sequence, and the individuals from Yellowstone Lake and Cruiser Lake clustered together. Isle Royale lake trout and the Lake Superior humpner lake trout clustered with the Yellowstone and Cruiser samples, while the Lake Superior sicosowet were most unlike the rest of the samples. The data presented here are still preliminary, and additional individuals from the populations in question must be sequenced for this portion of the D-loop to provide more information about within-population variability.

**DISCUSSION**

The results of this limited analysis of mitochondrial DNA sequence variation among various populations of lake trout support the hypothesis that larger self-sustaining lake trout populations, such as those from Lake Superior, are more genetically diverse than smaller populations, such as those from Cruiser Lake and Siskiwit Lake. Populations that have experienced significant input from supplementation management practices show even lower levels of genetic diversity, due to introgression of remnant wild fish with hatchery fish, or from re-colonization by hatchery-raised fish which have limited genetic variation. As expected, the D-loop sequence provided more variable characters than the RFLP analysis. The sequencing portion of this study is ongoing, and further analyses will provide more information about the variation in the D-loop sequence and its importance in determining relationships among these lake trout populations.

Lake trout examined from Yellowstone Lake appear to have a significant amount of genetic diversity, possibly due to large population sizes. This information in combination with recent information about diverse age structure of the Yellowstone Lake trout population supports the hypothesis that this lake trout population has been resident in Yellowstone Lake for much longer than originally thought. More and more, management agencies and consortia have become increasingly interested in restoring or maintaining the natural or wild characteristics of native fish populations, especially those that have suffered severe declines just short of extinction. This shift in management focus has also spawned remediation programs in some lakes, most notably Yellowstone Lake where lake trout which once supported prized sport fisheries are being removed in favor of the native cutthroat trout.

The genetic characteristics of managed fish populations are a critical piece of information in present day management practices. For example, in National Park units, the emphasis is on preserving or restoring natural aquatic habitats and the natural abundance and distribution of native species, including fish. Fish stocking is only deemed necessary to re-establish native species in their home ranges, and must use endemic genotypes when possible. NPS guidelines also provide for management of non-natives up to and including eradication. High priority is given then, to control of non natives that will have substantial negative impact on fish and associated aquatic organisms. This highlights an interesting juxtaposition of management philosophies. Lake trout in some lakes, for example Lake Superior, Cruiser Lake, Siskiwit Lake are considered native species, and all efforts are currently focused on maintaining natural wild populations through protection and stocking. In other areas, for example Yellowstone Lake, lake trout are non-natives which were supposedly stocked sometime in the past and are currently on the list for eradication because of their negative impact on the native Yellowstone cutthroat trout.

Relative to this presentation, as a result of past fish management activities, the three National Parks represented present a complete range of challenges with regard to lake trout management. At Isle Royale, the emphasis will likely be on protecting the unaltered native stock in Siskiwit Lake and the native stocks in the Lake Superior waters of the park. At Voyageurs, the challenge for Mukooda and Little Trout lakes will be to establish self-sustaining populations. Management of the Cruiser Lake population will depend on whether the existing fish populations represent a native genotype or a mixture of strains. Fish in Cruiser Lake are reproducing successfully and appear capable of maintaining their population.
without supplementation if angler extraction is kept in check. Management of lake trout in Yellowstone Lake is based on control of the lake trout population such that cutthroat trout populations are maintained.

It is evident that more work needs to be done to answer the questions regarding stock origin of lake trout in some of these lakes. Our study will continue with an emphasis on DNA sequencing information for strain identification.

REFERENCES


Felsenstein, J. 1995. PHYLIP Phylogeny Inference Package V. 3.57C. University of Washington


ACKNOWLEDGEMENTS

The authors would like to thank J. Board for invaluable assistance in the laboratory. This study was partially funded by the National Park Service, Voyageurs National Park. This is Contribution number 991 from the USGS Great Lakes Science Center, Ann Arbor, Michigan.
Molecular Genetics and Evolutionary Status of the Trout of the Sierra Madre

Jennifer L. Nielsen

Abstract—Mitochondrial DNA D-loop sequence and 12 nuclear microsatellite loci were used to depict population genetic structure and evolutionary status of the trout of the Mexican Sierra Madre. Mexican trout from the Rio Yaqui, Rio Sinaloa, and the Culiacán drainage carried 9 unique mtDNA haplotypes. D-loop sequence found in trout from the Rio Yaqui contained a unique deletion of the putative heavy-strand promoter leading to speculation on the replication mechanism in these fish. The mtDNA phylogeny derived from our D-loop data depicted significant separation among Rio Yaqui trout (Oncorhynchus mykiss ssp.), Mexican golden trout (O. chrysoaster), California golden trout (O. m. aquabonita), and anadromous southern steelhead (O. mykiss). Nuclear microsatellite loci showed extensive allelic variation in the Mexican trout with unique size distributions at 3 loci. Analyses of genetic distance for these 12 loci indicated that trout collected east of the Continental Divide in Rio Cases Grandes are closely related to trout from nearby streams flowing west of the divide in the Rio Gavilan. Microsatellites also showed significant divergence between trout from the Rio Bavispe drainage of the Rio Yaqui and trout collected in the Rio Tutuca, a southern tributary of the Rio Yaqui.

INTRODUCTION

Mexican trout were first described in the scientific literature 101 years ago when in 1896 David Starr Jordan noted in Science Sketches “rainbow trout have been reported across the border in Mexico.” In 1964, Needham and Gard described Mexican trout from the Rio Fuerte, Culiacán and Sinaloa drainages as Mexican golden trout, Salmo chrysoaster. Other populations of Mexican trout in the Rio Yaqui and Rio Mayo were described in the 1950’s and 1960’s by R. R. Miller (Figure 1). These trout inhabit arid riverine habitats from 6,500-7,800 feet above sea level in the Sierra Madre Occidental (Figure 2). Despite these early morphological descriptions of the Mexican trout, many populations remain completely undescribed and their phylogenetic position in relation to the Pacific trout have not been analyzed at the genetic level. These preliminary data represent initial investigations into the Mexican trout using modern DNA techniques that are under development in my laboratory. Future reports will include additional populations in our phylogenetic comparisons, including fish from the Rio Mayo, Rio Verde, Rio Truchas, and Rio Del Presidio that are not yet analyzed.

MATERIAL AND METHODS

Sample Collection

Fin tissues (2mm³) were collected non-invasively from live trout at all localities using electrofishing, dip nets, beach seines, or hand capture techniques (Figure 3). Fin tissues were dried in the field, stored in individual envelopes on filter paper, and shipped directly to our laboratory. Samples taken from the Rio Yaqui were sent to our laboratory by Buddy Jensen, USFWS, Dexter, N.M. Samples from the Rio Sinaloa and Culiacán were collected by the author. Gila and Apache trout used in our phylogenetic comparisons were sent to our laboratory by A. Snyder, Museum of Southwestern Biology University of New Mexico, Albuquerque, N. M. Southern steelhead samples were collected

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Figure 1.—Photo of trout from La Presita, Rio Yaqui, Sonora Mexico (photo by B. Jensen).

Figure 2.—Arid riverine habitats by Mexican trout from 6,500 to 7,800 feet above sea level in the Sierra Madre.
by the author from coastal drainages in southern California. California golden trout samples were sent to our laboratory by the California Department of Fish and Game.

**Mitochondrial DNA**

Total genomic DNA was extracted from fin clips using Chelex-100 resin (BioRad) following the methods of Nielsen et al. (1994b). Primers used in this study (S-phe and P2) are known to amplify a highly variable segment of the mtDNA control region in salmonids (Nielsen et al. 1997b). These primers permit amplification and sequencing of a segment containing 188 bp of the *O. mykiss* mtDNA control region and 5 bp of the adjacent phenylalanine tRNA gene. See Nielsen et al. (1994b) for primer sequences, amplification and sequencing protocols, and sequence of the entire region amplified by these primers in this species.

**Microsatellites**

Twelve microsatellite loci were chosen for this study based on their level of polymorphism in *O. mykiss* (Table 1). Sequence for primers amplifying these microsatellite loci appear in the respective literature. For each locus, primer B was labeled according to protocols given in Nielsen et al. 1994a.

PCR and amplification methods followed those given in Nielsen et al. (1997a). Amplifications used three fluorescent dyes. All microsatellite gels were run on an ABI 373 (Applied Biosystems) adapted for microsatellite analysis. Gels were read using ABI Prism’s Genotyper software (1996). All loci were initially run individually as separate PCR reactions to determine allelic size distributions in rainbow trout and then multiplexed on the ABI using an adaptation of the protocols in Wenberg et al. 1996.

The allelic size reported here for each microsatellite locus was equal to the size of the total product amplified (including amplified primer sequence). Allelic size was determined by two methods: 1) reference to the ABI Genescan-500 size marker ladder and 2) known *O. mykiss* DNA samples that were rerun on each gel. Binning of alleles was performed after an analysis of variance for size distributions of each allele at each locus identified by Genotyper. To insure consistency in both PCR reactions and scoring of microsatellites, 7.8% of all samples were rerun on different gels and scored independently. Repeated runs were not included in the analysis of variance performed to establish allelic binning protocols.

**Analytical Approach**

A pairwise distance matrix was constructed for sequences from the mtDNA control region segment amplified by S-Phe and P2, based on the Kimura two-parameter model (Kimura 1980). Phylogenetic analysis was performed on the mtDNA data using the unrooted neighbor-joining (NJ) tree procedure.

**Table 1.— List of microsatellite loci and their source publications amplified from Sierra Madre trout and other *Oncorhynchus mykiss* populations, 1997.**

<table>
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<th>Locus</th>
<th>Source</th>
<th># Alleles</th>
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</tr>
<tr>
<td>Omy325</td>
<td>M. O’Connell pers. comm.</td>
<td>14</td>
</tr>
<tr>
<td>Oneu2</td>
<td>Schriner et al. 1996</td>
<td>26</td>
</tr>
<tr>
<td>Oneu8</td>
<td>Schriner et al. 1996</td>
<td>6</td>
</tr>
<tr>
<td>Oneu11</td>
<td>Schriner et al. 1996</td>
<td>6</td>
</tr>
<tr>
<td>Oneu14</td>
<td>Schriner et al. 1996</td>
<td>12</td>
</tr>
<tr>
<td>Otfs1</td>
<td>M. Banks pers. comm.</td>
<td>12</td>
</tr>
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<td>Sto8</td>
<td>Angers et al. 1995</td>
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<tr>
<td>Ssa289</td>
<td>McConnell et al. 1995</td>
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</tr>
</tbody>
</table>
from PHYLIP (Felsenstein 1993) with 1000 bootstrap replicates to assess reproducibility of the branching pattern.

A pairwise genetic distance matrix was calculated for microsatellite allelic diversity using Goldstein et al. (1995) methods for the 12 microsatellite loci combined. Goldstein et al.'s delta mu (dm²) distance measure was calculated using a program available from Dr. E. Minch, Department of Genetics, Stanford University (e-mail address - http://lotka.stanford.edu/distance.html). Delta mu maintains an estimate of the mutation process under expectation of a strict, single-step (± one repeat unit) shift for each mutation event.

Delta mu distance data were used to generate an unrooted consensus neighbor-joining tree using the NEIGHBOR81 and CONSENSE applications from PHYLIP (Felsenstein 1993) comparing microsatellite diversity among the trout populations used in this study. A 1000 replicate microsatellite distance trees were generated to obtain bootstrap estimates and assess reproducibility of branching patterns found in our dm² consensus tree.

RESULTS

Trout collected in the Rio Yaqui drainage of the Sierra Madre had 4 distinct mtDNA haplotypes when compared to other subspecies of *O. mykiss* sequenced in our laboratory (Nielsen et al. 1994a; Nielsen et al. 1997a & b). Mexican golden trout from the Rio Sinaloa and Cúlicacán carried 5 additional unique haplotypes (Table 2).

Phylogenetic analyses of mtDNA haplotypes found in the Sierra Madre in comparison to northern (MYS1) and southern (MYS5 and MYS8) California steelhead, gila trout (GIL1), Sacramento River rainbow trout (MYS3), and South Fork Kern golden trout (MSY15 and MSY16) are depicted in Figure 4.

Nuclear microsatellite loci (N=12) provided an extensive array of allelic polymorphism in the Sierra Madre trout, with the number of alleles numbering from one for Sfo8 to 18 for Onep2. Locus nucleotide repeat numbers (allele size) ranged from 104 (Omy207) - 242 (Onep2) bases. Uniquely large alleles were found in the Mexican trout for two loci (Ssa14 and Ssa85) when compared to other *O. mykiss* populations. Uniquely small alleles were found in the Mexican trout for Ssa289. Average Fst for the 12 microsatellite loci was 0.38 in southwest trout look at in this study (Rio Yaqui, gila, southern steelhead, and Mexican golden trout). Delta mu distance measures calculated among the Rio Yaqui trout populations ranged from 16.3 (between two Casas Grandes sites: Las Palmas and La Escalariado) to 376.5 between the Rio Aros (a southern tributary of the Rio Yaqui) trout and trout from the Rio Negro (tributary of the Rio Bavispe). Trout found on the eastern slopes of the Continental Divide in Rio Casas Grandes showed a close genetic relationship to trout from the Rio Gavilan, west of the Divide. A phylogenetic comparison of the Rio Yaqui trout populations using the 12 microsatellite loci combined based on dm² distance measures is given in Figure 5.

CONCLUSIONS

*Oncorhynchus chrysogaster*, the Mexican Golden trout and the trout of the Rio Yaqui drainage showed extensive divergence for both molecular markers, mtDNA and microsatellites when compared to other *O. mykiss* populations. They were also significantly different from each other. Phylogenetic associations, however, developed among the southwestern trout populations of the

<table>
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<td>MYS15</td>
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</tr>
<tr>
<td>MYS16</td>
<td>AAGGTGTTTCTAAGG</td>
</tr>
</tbody>
</table>

\*I* represents a deletion.
Figure 4.—Un rooted neighbor-joining tree based on Kimura's 2-parameter nucleotide distance measures (TS:TV = n10:1) with bootstrap values based on 1000 replicate trees.

Oncorhynchus mykiss
Oncorhynchus Apache
Oncorhynchus gilae gilae

Río Yaqui Río Bavispe El Quarteles
Río San Antonio

Río Yaqui Río Bavispe La Cueva
La Presita

Río Yaqui Río Bavispe El Arco Río Negro

Río Yaqui Río Bavispe Segundo de Mayo Río Negro

Río Yaqui Río Bavispe Las Guacamayas Río Gavilán

Río Yaqui Río Casas Grandes
Río El Álamo Las Palmas

Río Yaqui Río Casas Grandes
Río Piedras Verde La Escalariado

Río Yaqui Río Aros
Río Tutuca Arroyo El Cinco

Río Yaqui Río Aros
Río Chico Arroyo El Salto

Oncorhynchus chrysogaster

Figure 5.—Delta mu distance measures (Goldstein et al. 1995) calculated/plotted as an unrooted neighbor-joining tree depicting phylogenetic relationships among the Río Yaqui trout population.
Sierra Madre were not congruent for both molecular markers, suggesting that the different markers reflect varying degrees of resolution due to differing rates of evolution and independent evolutionary processes (Boyce et al. 1996).

It is unreasonable to assume that either or both markers reflect a composite of past evolutionary events which are necessarily consistent with recent population history for trout in the southern Sierras today. Both markers measure change on different scales of time and space. The haploid nature of mtDNA and our lack of knowledge of the molecular mechanisms leading to mutational patterns in nuclear microsatellite DNA should eliminate any expectation of deep evolutionary congruence between these markers. However, they both serve up important information on their respective scales of inference.

The loss (or lack of development) of the putative heavy strand promoter in some of the Rio Yaqui trout leads to speculation on a primitive bidirectional promoter for mtDNA in trout such as those reported in some birds and reptiles (see Nielsen et al. 1997b). Is this a primitive state? Is this promoter consistent with a pattern in the ancient development of promoter regions for vertebrate mtDNA? When did the duplication event first occur and can (did) it happen several times in the evolutionary history of the taxa? Many questions need to be addressed concerning mtDNA function and replication processes in these trout?

Microsatellites appear to reflect more recent evolutionary history with their faster mutation rates and limited biogeographic population structure (see Nielsen et al. 1997a). Microsatellites did, however, allow us to address several population genetics questions within the Rio Yaqui basin with significant rigor. And many diversity comparisons between mtDNA and microsatellites were congruent among the Sierra Madre populations.

Both mtDNA and microsatellites showed significant divergence between trout in the Rio Aroson (southern Rio Yaqui) and trout from tributaries of the Rio Bavispe in the northern Rio Yaqui drainage. Both mtDNA and microsatellites showed significant genetic similarity between adjacent trout populations east and west of the Continental Divide. Both of these findings reflect earlier conclusions drawn from morphological data concerning these fish presented by Miller, Needham and Gard in various publications and notes.

Future direction in my analyses of the Sierra Madre trout will include collecting samples from more southern drainages identified by Needham and Gard (1964). I intend to expand my microsatellite analyses to include 5 more loci known to be polymorphic in O. mykiss. I hope to develop mtDNA haploid lines in captivity reflecting the differences in the promoter region available in the Sierra Madre trout, and develop tests of mtDNA replication patterns under differing environmental conditions for the Rio Yaqui trout.

It is clear from these preliminary analyses that the trout of the Sierra Madre represent a unique and important unit in the evolutionary history of the Pacific trout, one from which we can gain significant information about evolutionary processes and adaptation in a population at the southern extent of the species range.

LITERATURE CITATIONS


The Eastern Brook Trout: Surviving in Suburbia

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ABSTRACT:

Historically, the brook trout was found throughout the Croton River watershed in Dutchess, Putnam and Westchester counties to its confluence with the Hudson River, 20 miles north of New York City. The Croton drainage basin contains twelve New York City reservoirs and numerous smaller private impoundments throughout its headwaters. Eastern brook trout are found in seven now-isolated, self-sustaining populations in the watershed. These streams are characterized by relatively low levels of development, year-round groundwater baseflow, and generally ownership by only one or two entities such as the New York City Department of Environmental Protection (NYCDEP) or private landowners. These trout reach a size of eight to ten inches and live no more than four years. Angling pressure is light due to the relative isolation of some of the streams, posting by landowners, and the small size of the fish. The principal threats to these populations are development-induced stream warming and sediment loading, summer releases of warm water from upstream impoundments, and competition with species such as brown trout, fallfish and smallmouth bass. The development of strengthened watershed regulations and an anticipated land acquisition program by the NYCDEP may offer a means of protecting several of the identified brook trout habitats.
Whirling Disease and Wild Trout Management

R. Barry Nehring¹ and David Nickum ²

Abstract—Whirling disease (caused by the myxosporean parasite *Myxobolus cerebralis*) was long considered a relatively minor threat to wild trout. New research has shown that in some situations it can have catastrophic effects, including complete loss of year classes. Many native trout species appear to be vulnerable to the disease, making the continued spread of the parasite an especially grave concern. This has forced many states to consider new approaches for containing the spread of *M. cerebralis* and for managing waters where it is already present. Strategies from Colorado, Montana, and New York are reviewed in order to better understand how whirling disease may change wild trout management in the United States.

Salmonid whirling disease is caused by a myxosporean parasite (*Myxobolus cerebralis*) that forages on the cartilaginous tissues of trout and salmon fry during the early months of life. Severity of effect on young fish depends upon the number of parasites which enter the fish while it is most vulnerable (prior to conversion of cartilage to bone). Overt symptoms of whirling disease in salmonid fry and fingerlings can include: blackening of the tail; severe bending of portions of the vertebral column (lordosis and/or scoliosis); shortened snouts and other deformities of the cranium, upper jaw, lower jaw, and orbits of the eyes (causing a bug-eyed appearance); and the erratic tail-chasing behavior for which the disease is named. These symptoms can occur in any combination, but usually begin to appear in fry or fingerling salmonid fry 60-90 days post exposure to the parasite.

The disease was first described in Europe at the dawn of the 20th century (Plehn 1904) when it was observed in cultured salmonid fishes. Pioneering work in 1984 demonstrated the parasite in fact went through a complex life cycle in which it alternates between two hosts, salmonid fish and an oligochaete worm, *Tubifex tubifex* (Wolf and Markiv 1984). A round myxospore is produced in fish and can infect worms, while a grappling-hook like triactinomyxon (TAM) spore is produced in worms and can infect fish. Since this discovery, at least 10 other diseases of fish involving myxosporean parasites have been shown to demonstrate the same life cycle pattern, alternately parasitizing fish and oligochaete worms. A brief discussion of these parasites and their alternating fish/worm hosts is given in the introduction of a paper by Kent, Whitaker, and Margolis (1993).

According to the summaries of presentations made by Dr. Glen Hoffman (Fish Pathologist, U.S. Fish and Wildlife Service) and Mr. Joe O’Grodnick (Fish Pathologist, Pennsylvania Fish Commission) at the emergency whirling disease conference held in Denver, Colorado, April 12-14, 1988, salmonid whirling disease is thought to have arrived in Pennsylvania in 1956 in frozen processed fish files from Denmark (Anonymous 1988). Until very recently the disease was considered to be of primary concern for cultured salmonids, and not thought to affect salmonid fishes in natural environments, particularly in free-flowing streams. Indeed, at the 1988 Denver conference, the consensus (but not unanimous) opinion among fish pathologists and fish health professionals was that this was a disease of no concern.

¹ Research scientist, Colorado Division of Wildlife, Montrose, Colorado.
² Regional conservation director, Trout Unlimited, Denver, Colorado.
among wild salmonid fishes (Anonymous 1988). As a result, the group recommended that whirling disease be downlisted from Prohibitive Pathogen status to the Notifiable category. The conference statement was as follows:

"The Fish Disease Subcommittee, Colorado Fish and Wildlife Council having reviewed information presented at the Whirling Disease Conference has determined that the status of the disease should be reevaluated and reassigned. The considerable expertise at the conference represented historic and current perspective pertaining to whirling disease (Myxobolus cerebralis). The Fish Disease Subcommittee recommends that whirling disease be included in the Notifiable Pathogen category of the Fish Disease Control Policy, Colorado River Fish and Wildlife Council."

However, attendees at the April 1988 conference clearly understood that virtually everything that was known about M. cerebralis was the result of observations and studies conducted either in the laboratory or on fish culture facilities. Virtually nothing was known about effects on salmonids in the wild. Indeed, the first paragraph on page 4 of the report summarizing the conference addresses this issue:

"Reported impacts on wild trout populations are thought to be minimal. However, there has been no detailed study of susceptible young fishes in areas where whirling disease has been discovered in the wild. It is important that such work be launched because the introduction of whirling disease in wild stocks represents an irreversible decision permitting environmentally persistent spores to become established in the wild. Studies should include effects on population parameters such as fecundity, growth, performance, and so on."

Unfortunately, no such studies were ever undertaken, and the fears of Mr. Dick Smith, proprietor of Lost River Trout Farm, Idaho, have come true. His facility was the first private aquaculture facility diagnosed positive for whirling disease in Idaho in 1987. In his closing remarks at the 1988 Denver conference, Mr. Smith worried that downlisting of the disease would cause further spread. Mr. Ron Goede (Fish Pathologist, Utah Division of Wildlife Resources) also expressed serious concern over the potential downlisting, stating that effects of whirling disease on free-ranging stocks has never been demonstrated and that current opinion (at the time of the conference) was based merely on the fact that no impacts had been observed. Mr. Goede recognized that the absence of evidence should not be taken as evidence of absence of such impacts.

IMPACTS OF WHIRLING DISEASE ON WILD AND NATIVE TROUT

Impacts on Wild Rainbow Trout

In the 1990s, the accepted dogma that wild trout populations would not be harmed by whirling disease was proven wrong. M. cerebralis spores were detected in feral rainbow and brown trout from several streams in Colorado in 1988, including fish from the nationally renowned segment of the South Platte River southwest of Denver (Anderson and Nehring 1984), but no population effects were detected at that time. However, free-ranging brown and rainbow trout with overt symptoms of clinical whirling disease were collected from the Fremont River in Utah in 1991 (Goede 1996).

M. cerebralis spores were first detected in wild rainbow trout in the upper Colorado River in April 1992. By the fall of 1993, an unusual size and age distribution of wild rainbow trout in the Colorado River was readily apparent. The 1991, 1992, and 1993 year classes of rainbow trout were almost totally absent from the population. It was suggested that whirling disease might be implicated in the apparent demise of year classes of wild rainbow trout in this stream (Nehring 1993). An intensive research investigation during 1994 confirmed that whirling disease was implicated as a significant factor in the disappearance of three successive year classes of wild rainbow trout in the upper Colorado River (Walker and Nehring 1995; Nehring and Walker 1996).

By 1996, whirling disease was clearly linked to the disappearance of young wild rainbow trout in five major trout streams in Colorado, including extensive segments of the Cache la Poudre, Colorado, Gunnison, Rio Grande, and South Platte rivers. In Colorado, more than 290 km of stream were showing significant to near catastrophic declines in wild rainbow trout (Nehring 1996).

Similarly, whirling disease was deemed the only plausible explanation for the dramatic declines (90%) in the wild rainbow trout population of the upper Madison River in Montana (Vincent 1996; MacConnell 1996). The decline in the wild rainbow trout population in the
upper Madison River was first noted in 1991. By 1996, *M. cerebralis* spores had been detected in free-ranging wild rainbow trout from dozens of streams throughout western Montana. The collapse of the Rock Creek rainbow trout population that began in the mid-to-late 1980s is now considered to be the result of whirling disease (Dennis Workman, fishery biologist, Montana Department of Fish, Wildlife and Parks, personal communication).

**Impacts on Native Trout**

At the end of 1996 there were no documented population level impacts of whirling disease occurring among the wild native salmonids of North America. However, there is cause for concern based on the results of sentinel fish tests used to expose several native salmonid species to ambient levels of TAM spores of *M. cerebralis* (the actinosporean stage) in Colorado and Montana during 1995 and 1996. In Colorado, young-of-the-year brown trout (*Salmo trutta*), brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), greenback cutthroat trout (*O. clarki stomias*), Rio Grande cutthroat trout (*O. c. virginalis*), Colorado River cutthroat trout (*O. c. pleuriticus*), and Snake River cutthroat trout (*O. c. bouvieri*) were exposed as sentinel fish in the summer of 1995 and/or 1996 to ambient levels of TAM spores occurring in the Colorado River (R. Barry Nehring, unpublished data). Similar tests (E. Richard Vincent, unpublished data; Beth MacConnell, unpublished data) were conducted in Montana during 1996 exposing Westslope cutthroat trout (*O. c. lewisi*), Yellowstone cutthroat trout, a subspecies derivative of the Snake River cutthroat trout - *O. c. bouvieri* (Behnke 1988), Arctic grayling (*Thymallus arcticus*), rainbow trout, and brown trout.

The results of these studies suggest that with the possible exception of the Snake River cutthroat trout, all cutthroat trout subspecies were at least as vulnerable to the ambient levels of TAM spores as similarly exposed rainbow trout, and far more vulnerable than the brown trout. Brook trout exposed to ambient levels of TAM spores in the Colorado River water in 1995 suffered severe effects of the *M. cerebralis* infection similar to that seen in the cutthroat trout. After 12 months of exposure, mortalities exceeded 90% among brook trout and cutthroat trout in sentinel fish trials in the Colorado River. In contrast, mortalities among identically exposed brown trout was less than 10% in the same experimental exposure. Only the Snake River cutthroat trout (R. Barry Nehring, unpublished data) and the Arctic grayling (Beth MacConnell, unpublished data) appeared less affected than similarly exposed rainbow trout.

These findings suggest that most cutthroat trout are vulnerable to the effects of this parasite, if the proper combinations of physical and environmental parameters occur that will result in the production and release of the TAM spores in stream segments inhabited by these fish. Sentinel fish tests conducted in Idaho during 1996 exposing rainbow trout and Westslope cutthroat trout to ambient levels of TAM spores in the Big Lost River resulted in more severe infections among the groups exposed in headwater stream areas than in those exposed at mid-drainage downstream areas (Steve Elle, unpublished data). These findings suggest that it would be unwise to assume that this parasite cannot establish itself in the higher elevation, colder stream habitats where cutthroat trout often thrive.

When results of some of the best laboratory work that has been done on the relative vulnerability of salmonids to *M. cerebralis* (O’Grodnick 1979) are put together with the recent work using sentinel fish testing in free-flowing streams (Nehring, unpublished data; Vincent unpublished data; MacConnell unpublished data; Elle unpublished data) a somewhat predictable pattern begins to emerge regarding relative vulnerability of salmonids to whirling disease. This pattern is strongly suggestive that those salmonid species or closely related species groups that occur naturally throughout the holarctic region are far more resistant to *M. cerebralis* infection than those species that occur naturally only on the North American continent. Lake trout (*Salvelina namaycush*) have a holarctic distribution and they are highly resistant to whirling disease (O’Grodnick 1979). Arctic grayling (*Thymallus arcticus*) also have a holarctic distribution and appear to be quite resistant to infection (Beth MacConnell, unpublished data).

In contrast, most of those salmonids with a biogeographical distribution restricted to the North American land mass (brook trout, rainbow trout, and cutthroat trout) have been shown through laboratory testing (O’Grodnick 1975) and sentinel fish testing in free-flowing streams to be very vulnerable to *M. cerebralis* infection and development of clinical whirling disease.
IMPACTS ON WILD TROUT MANAGEMENT

As the research described above demonstrates, whirling disease can be a major challenge to wild trout management. The severity of problems has varied from state to state, as have the management strategies to address whirling disease. Strategies from Colorado, Montana, and New York reflect this diversity in approaches to wild trout management "post-whirling disease."

Colorado

Whirling disease has been designated as the number one priority of the Aquatic Program Section of the Colorado Division of Wildlife (CDOW). The CDOW’s strategy to deal with the epidemic of whirling disease outbreaks has several components. The first is containment, and stems from the fact that *M. cerebralis* is found in most of the CDOW’s hatcheries. The CDOW hopes to minimize spread of the parasite by restricting the stocking of infected fish from most trout-bearing waters in the state. Some high-use trout waters in which *M. cerebralis* is already found may be stocked with lightly-infected fish. This containment policy has resulted in much-reduced stocking throughout Colorado’s western slope.

In conjunction with its containment strategy, the CDOW has launched an ambitious program to eradicate *M. cerebralis* from its hatcheries. In the past, Colorado’s state hatchery system has relied heavily upon surface water supplies for the raising of large numbers of catchable size trout. This made them vulnerable to infection from water-borne TAM spores. Now, most fish culture facilities test positive for *M. cerebralis*, and more than 80% of trout produced are considered exposed. A major multi-year effort to change this situation was launched in 1997. The CDOW’s multimillion dollar clean-up effort will include securing spring and well water supplies for hatcheries and rearing units and reducing or eliminating the use of surface waters. It is estimated that this task may not be complete until at least the year 2003.

Another element of CDOW’s response is the stocking of fingerling trout to replace lost year classes of wild fish. While stocked fish have been a major factor in spreading whirling disease, the CDOW is now looking at ways in which the hatchery product can be used as a tool to maintain fisheries where natural recruitment has been lost. The concept is to maintain year classes in the depleted fisheries through put-and-grow stocking of trout as fingerlings, when they are less vulnerable to whirling disease. In the Colorado River, wild rainbows have been spawned and the fertilized eggs taken to hatcheries free of whirling disease to be reared until they reach fingerling size and can be safely returned to the river. Replacement of lost year classes through fingerling stocking is also being used on the South Platte, Rio Grande, Cache la Poudre, and Gunnison Rivers.

Another key element of Colorado’s response has been an aggressive research and monitoring effort. By better understanding whirling disease, the CDOW hopes to be better able to combat it. One area of current research stems from the fingerling stocking program in the Colorado River. Sampling from these stocked fish suggest that the rainbows have acquired some level of immunity to *M. cerebralis* after being exposed to low levels of the parasite. Thus, lightly-exposed fish may then prove resistant to disease when confronted by greater numbers of the parasite. Research is underway to test this hypothesis. If it proves true, managers may use strategies (for both wild and hatchery-reared fish) through which fish are initially exposed to light levels of the parasite in order to trigger an immune response.

Montana

Montana has been exploring management strategies which would keep young, vulnerable fish removed from areas of heavy infection. The idea is to find fish with life histories which will allow them to avoid heavy exposure to *M. cerebralis* until more of their cartilage is converted to bone, making them less susceptible to disease. It appears that infectivity in streams is low until water temperatures rise in late spring, at which point fish can be exposed to a flurry of parasitic spores. Dick Vincent, whirling disease coordinator for Montana Fish, Wildlife, and Parks, is looking nationwide to see if any rainbow strains are out there which spawn early in the year -- perhaps in March -- so that young fish would be past their most vulnerable stage before encountering a heavy dose of spores.

Another intriguing effort involves the reintroduction of Westslope cutthroat trout into tributaries in the Upper
Madison River drainage. While the search for early-spawning rainbows is based on separating young trout from infection temporarily, the use of cutthroats is based on separating them physically. The hope is that tributary-spawning cutthroats will encounter fewer parasites in the tributary streams, where Tubifex worms appear to be less abundant, than in the more disrupted (and therefore more worm-friendly) habitats of the mainstem Madison River. While some adult fish would remain in the tributaries, some would also be expected to migrate downstream to the mainstem and fill in a portion of the niche left by the dramatic declines in rainbow populations. Barriers would prevent infected fish from carrying M. cerebralis back into the tributaries (and prevent non-native fish from compromising the reestablished native populations).

Like Colorado, Montana has maintained an ambitious program of research. Biologists are studying the susceptibility of different strains of fish, hoping perhaps to find those with greater resistance to whirling disease (no “bulletproof” rainbows or cutthroats have been found yet). Other research has been developed to see whether there are seasonal differences in the severity of infection (using sentinel fish placed into cages at different times during the year). Macrinovertebrate experts are working to improve our understanding of the worm host and the ecological conditions under which it thrives -- perhaps providing a basis for habitat management or biological control to limit these populations and, thereby, the disease.

**New York**

*M. cerebralis* was found in several New York hatcheries in 1994. Since that time, the state Bureau of Fisheries has focused its efforts on containing the spread of the parasite. Currently, state policy requires testing (according to the AFS Blue Book) of all lots on public and private hatcheries. Only fish coming from lots which test negative for WD can be stocked in the state. The Bureau hopes that these stocking restrictions will contain the spread of the parasite.

While *M. cerebralis* has been found in several wild populations, biologists have seen no signs of overt whirling disease in wild populations -- no clinical signs at the individual level, nor any population declines. As a result, no major changes have been made or are anticipated for wild trout management. However, the state is continuing its monitoring program. Biologists will sample wild populations to document the parasite's distribution. In addition, the Bureau hopes to have some samples from wild populations which test positive for whirling disease evaluated histologically. These fish can then be compared with fish from populations in the intermountain west where documented impacts have been far greater. This may help shed light on why whirling disease seems to be a problem in western states, but not in the east.

In short, trout managers in New York are working to contain the spread of *M. cerebralis* and are taking a “wait and see” approach in terms of impacts on wild populations. Coldwater fish chief Phil Hulbert explained, “for reasons we don’t understand, we don’t expect to see trouble.” Nonetheless, the Bureau continues to keep an eye on its wild populations in case conditions change and call for changes in management.

**CONCLUSIONS**

The rapidity with which *Myxobolus cerebralis* has spread and the devastation it has wrought among wild trout populations in Colorado and Montana has been both sobering and stunning. Clearly, this problem should be a serious wake up call to the people of the late-20th century. It is high time that we stop and take collective stock of the extent to which our activities are defiling natural ecosystems, largely as the result of unbridled growth.

The myxosporean spore of *M. cerebralis* is extremely persistent and resistant to dessication, freezing, and moderate heat. Adding its innate ability to bioreplicate at an exponential rate in both fish and worm hosts makes dealing with this parasite a formidable problem. Once established in natural ecosystems, eradication becomes an insurmountable and impossible task. Containment and control are the only logical approaches. While containment strategies are relatively evident, our understanding of how to control the parasite once it is established is in its infancy. It must be recognized that containment and control will not be effective everywhere, but in many places these approaches may work. It will not be easy. It will not be cheap. And it will (in all likelihood) never be finished. It will take a monumental cooperative effort on many fronts if there is to be any chance of success.
Of particular importance in containing whirling disease will be for both public and private aquaculture to (1) own up to their responsibility in the spread of this disease over the past two decades, particularly across the intermountain west regions of North America, and (2) begin to accept and implement the necessary restrictions on the moving fish and fish products within and across state lines. The speed, precision, and accuracy of disease testing must be dramatically improved. Severe restrictions must be placed on the use and dispersal of *M. cerebralis* exposed and infected fish products. These restrictions must be fair and equitably applied to both the public and private sectors.

Continued lack of diligence or continued denial of this problem is unacceptable if we wish to avoid further risk to our wild and native coldwater fishery resources in Western North America. The time is short and the need is urgent. Are we equal to the task?

REFERENCES


Global climate change and fragmentation of native brook trout distribution in the southern Appalachian Mountains

Patricia A. Flebbe

Abstract — Current distributions of native brook trout (Salvelinus fontinalis) in the southern Appalachians are restricted to upper elevations by multiple factors, including habitat requirements, introduced rainbow (Oncorhynchus mykiss) and brown (Salmo trutta) trout, and other human activities. Present-day distribution of brook trout habitat is already fragmented. Increased temperatures predicted by various global warming models are likely to further limit suitable brook trout habitat. Predicted changes in hydrologic cycles may exacerbate temperature effects, and hydrologic effects on trout may differ across the region. Models of present-day trout guild distribution were used in a Geographic Information System (GIS) to examine the changes in trout distribution that might occur with temperature increase. Both suitable area and stream length for trout decrease as suitable habitat is increasingly restricted to mountaintops. Furthermore, the remaining trout habitat is likely to be even more fragmented than at present. If trout habitat becomes more fragmented under warming trends, common local extinctions may become irreversible as avenues for recolonization are eliminated.

CURRENT TROUT DISTRIBUTION

The southern Appalachians represent the southern margin of trout in eastern North America. For this discussion, the southern Appalachians consists of the mountain areas of Georgia, South Carolina, North Carolina, Tennessee, and Virginia. Originally, only native brook trout (Salvelinus fontinalis) were found in this area. During the late 19th and early 20th centuries, rainbow (Oncorhynchus mykiss) and brown (Salmo trutta) trout were introduced into the region. The guild of these three species now occupies streams in about 40,700 km² of these states (Fig. 1).

Current distribution of native brook trout in the southern Appalachians is restricted to upper elevations by multiple factors, including habitat requirements, introduced rainbow and brown trout, and other human activities. Stream temperature is a basic limiting factor that defines suitable habitat for all salmonids, which require relatively low temperatures. Brook trout are found at slightly lower temperatures in field settings than are rainbow and brown trout (Eaton et al. 1995), and stream temperature generally increases with decreasing elevation in mountains. Other habitat conditions no doubt contribute to the current distribution patterns. In the early years of the 20th century, logging and conversion to homesteads, fires, overfishing, and stocking all contributed to loss of brook trout habitat as European settlement moved upward.

Historically, introduction of rainbow and brown trout certainly restricted the distribution of brook trout; many streams that now have introduced trout are known to have had brook trout at one time. But, the extent to which this replacement process continues today is unknown and some think that relative distributions of the three species have

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GLOBAL CLIMATE CHANGE THREATS

Global average air temperature has probably increased about 0.5°C over the last century and, due to increasing levels of greenhouse gases, primarily carbon dioxide, may further increase by 1.0 to 3.5 °C during the next 100 years or so (Karl et al. 1997). The amount of temperature increase is not uniform over the planet and various models predict different magnitude of temperature increase. In the Southeast, models project increases of about 3 to 4 °C (or more) with a doubling of atmospheric CO₂ (Mulholland et al. 1997). Effects of increased air temperature on water temperature will vary from site to site, depending on such factors as degree of groundwater influence, amount of shading by watershed and riparian vegetation, watershed aspect, etc.

Possible changes to the hydrologic cycle are even more complex and uncertain than temperature change. Along with increased air and stream temperature, precipitation in the Southeast is also expected to increase, especially in the summer (Mulholland et al. 1997). Models indicate that summer convection storms will become more intense and frequent, with longer dry periods between them -- a clustering effect (Mulholland et al. 1997). As a result, some small mountain streams may be more likely to dry out between storms and more intense storms may cause flash flooding and damage to streams. Evapotranspiration may or may not increase with increased carbon dioxide and warming, adding to the difficulty of predicting hydrologic changes. Experts do not agree on effects of climate change on hurricanes because processes are complex (Karl et al. 1997). Furthermore, effects of concomitant increased demand for water by humans add another source of uncertainty to predictions for hydrologic changes.

CONSEQUENCES FOR TROUT IN THE SOUTHERN APPALACHIANS

Increased temperatures and hydrologic changes predicted by various global warming models are likely to further limit suitable brook trout habitat. Many other, indirect effects of climate change on the stream environment of trout are possible, but will not be considered in this paper. For example, riparian zone vegetation may change, which in turn can alter inputs of allochthonous material and large woody debris. Changes in macroinvertebrate community structure and metabolism in response to all these changes represent changes in trout food availability.

To date, consequences of hydrologic changes have not been proposed for trout in the southern Appalachians,
largely because both the sign and magnitude of hydrologic changes is uncertain, and also because we know less about how hydrologic changes are likely to affect trout. Predicted changes in hydrologic cycles may exacerbate temperature effects and may do so differently across the region. For example, many streams in Virginia are already susceptible to drying out during the summer, and trout there are forced into small, isolated refuges in deeper pools. Prolonged concentration of trout in these refuges could lead to increased mortality. These streams already experience flashy flows during summer storms, at times scouring out the stream. To the south, however, summer flows are more reliable.

Two different kinds of consequences of temperature increases for trout have been proposed in the literature: changes in trout physiology and changes in the distribution of trout.

Physiological Responses

Increased temperatures generally increase metabolism in fish, and growth rate of fish may either increase or decrease with warming, depending on whether stream temperatures are below or above the optimum temperature, respectively. Whether food is limiting also affects the extent to which growth can increase when below-optimum temperatures increase. In a model based on streams in northern West Virginia, brook trout growth increased with modest temperature increases of 2°C, but food could become limiting if temperature increased more (Ries and Perry 1995). In the southern Appalachians, however, brook trout may already be food-limited in summer (Ensign et al. 1990), and in many streams, temperature may already be above the optimum for growth for much of the year.

Trout Distribution Changes

Greater attention has been paid to possible changes in trout distribution with a warmer climate, particularly in areas like the southern Appalachians where trout are near the southern margin of their distribution in North America. At the margin, trout are probably at or near their temperature limits, and further increases in temperature can critically increase metabolic costs or exceed thermal limits, resulting in loss of the species from a stream site.

Meisner (1990) found that minimum elevation for brook trout in the southern Appalachians now rises from about sea level near 39°N to about 640 m at about 34°40'N (the southern margin). Furthermore, using a model, he predicted that the 3.8°C increase in temperature predicted for mid-21st century by the Goddard Institute for Space Studies model would increase minimum elevation for brook trout by up to 714 m, leading to a reduction of area suitable to brook trout. Using his model and trout inventory sample data for North Carolina and Virginia, Flebbe (1993) estimated that 89% of brook trout streams in the sample would be lost. Losses would be greater in Virginia than North Carolina because Virginia has fewer high elevation refuges. Increased fragmentation of brook trout habitat is likely (Meisner 1990, Flebbe 1993).

Predictions from a GIS Model

A more detailed analysis of changes to the distribution of trout in the southern Appalachians has been produced from a model constructed in a geographic information system (GIS). The trout guild, consisting of all three trout species, was modeled because the distributions overlap and a regional distribution of individual trout species is particularly difficult to obtain (Flebbe et al. 1996).

A preliminary version of present-day potential trout habitat (Flebbe et al. 1996) was further refined by consulting coldwater fisheries experts in the region. Areas with unsuitable developed and agricultural land uses were also eliminated. An empirical model, which relates elevation to latitude at the boundary, was fitted to the boundary of current trout habitat (Fig. 1).

An empirical relation equating 189 m of elevation change to 1°C change in air temperature, based on temperature data from the southern Appalachians (Meisner 1990), was applied to the trout boundary model to estimate trout habitat area for a range of temperature increases. Rather than linking effects on trout to projections of any particular global change model, effects of 1-5°C increases on suitable trout habitat were assessed. Projected trout habitat areas were used to select blue-line streams (Flebbe et al. 1996, Hermann 1996) in the GIS and predict corresponding stream lengths for the range of temperature increases.

Projected trout habitat areas for 2°C and 4°C temperature increases are shown in figures 2 and 3, respectively, and projected changes in area and stream length are shown in table 1. Both the area and stream length suitable for trout decline with increasing temperature (Table 1). At each sequential 1°C increase in temperature, a larger proportion of the remaining area and stream length is lost. Stream length declines slightly faster than does area. In the southern Appalachians, stream density is high, and in our GIS layer, density doesn't vary greatly with elevation.
Table 1.—Projected trout habitat area and stream length, expressed as a percentage of current area and stream length, corresponding to possible changes in air temperature for the southern Appalachians.

<table>
<thead>
<tr>
<th>Temperature change (°C)</th>
<th>Area (%)</th>
<th>Stream length (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1</td>
<td>65.4</td>
<td>54.9</td>
</tr>
<tr>
<td>+2</td>
<td>31.7</td>
<td>22.1</td>
</tr>
<tr>
<td>+3</td>
<td>12.6</td>
<td>7.5</td>
</tr>
<tr>
<td>+4</td>
<td>4.2</td>
<td>2.1</td>
</tr>
<tr>
<td>+5</td>
<td>1.3</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 2.—Projected maximum trout habitat patch size and number of patches >1000 square km.

<table>
<thead>
<tr>
<th>Temperature change (°C)</th>
<th>Area of largest patch (square km)</th>
<th>Number of patches &gt;1000 square km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>27,562</td>
<td>4</td>
</tr>
<tr>
<td>+1</td>
<td>7,129</td>
<td>4</td>
</tr>
<tr>
<td>+2</td>
<td>3,469</td>
<td>2</td>
</tr>
<tr>
<td>+3</td>
<td>1,026</td>
<td>1</td>
</tr>
<tr>
<td>+4</td>
<td>572</td>
<td>0</td>
</tr>
<tr>
<td>+5</td>
<td>164</td>
<td>0</td>
</tr>
</tbody>
</table>

Suitable habitat is eliminated almost completely from Virginia at +4°C (Fig. 3). At +5°C, the largest remaining refuge is in the peaks of the Great Smoky Mountains and the Blue Ridge Mountains of North Carolina. Virtually no stream habitat remains in these high mountain enclaves.

Furthermore, the remaining trout habitat becomes even more fragmented than at present. With increasing temperature, the size of the largest trout habitat patch declines (Table 2). Presently, there are several large areas of habitat >1000 km². At increased temperatures, these large patches break up and eventually disappear. If trout habitat becomes more fragmented under warming trends, common local extinctions may become irreversible as avenues for recolonization are eliminated.

**CONCLUSION**

Effects of global climate change could be significant, both for brook trout and the trout guild in the southern Appalachians, where present-day distributions are already fragmented and restricted to higher elevations. Whether rainbow and brown trout might retreat to higher elevations, displacing brook trout as air and stream temperatures increase, or would be lost from the region before brook trout cannot be determined. Certainly, multiple factors interact to determine the final outcome. Temperature changes, if they happen, will be accompanied by hydrologic changes, riparian vegetation changes, continuing stream sedimentation and acidification, and changes in land use patterns.
ACKNOWLEDGMENTS

I thank Jennifer Bush for her hard work on all aspects of the GIS model; Randolph Wynne for his assistance with the GIS; and the 30-odd coldwater fisheries experts in the southern Appalachians who helped find the present-day boundary for the GIS model.

LITERATURE CITATIONS


Ecological Risk Analysis of a Piscivorous Fish Introduction into the Yellowstone Lake Ecosystem

Robert E. Gresswell¹, Hiram Li², and Phillipe Rossignol³

Abstract—With the recent discovery of nonnative lake trout (Salvelinus namaycush) in Yellowstone Lake, persistence of the endemic Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri) is uncertain. Available data were not sufficient for quantitative assessment of the potential effects of the lake trout introduction on the ecology of the Yellowstone cutthroat trout metapopulation, and therefore, we used loop analysis, a qualitative modeling technique, to assess post-introduction systems behavior. Food- and interaction-web diagrams were developed for 16 different scenarios ranging from the native aquatic community (no introduced fishes) to the current community that includes four introduced species. System models remained stable when either one or two nonnative fishes (regardless of species) were present. In some cases the presence of three introduced species in the system did not affect system stability, but in models where lake trout occurred in conjunction with both redside shiners and lake chub, the system was unstable. Preliminary results suggested that unconstrained increases in lake trout abundance will cause oscillations in Yellowstone Lake fish populations to become amplified and the frequency of oscillations to increase. Beyond these direct effects, the trophic web of the lake ecosystem may become irreversibly altered.

About the same time that wolves (Canis lupus) were being reintroduced to the Northern Range of Yellowstone National Park, biologists became aware of a second, more insidious, introduction of a nonnative predator, lake trout (Salvelinus namaycush), in Yellowstone Lake (Kaeding et al. 1996). Lake trout are voracious predators that have been associated with substantial declines of native cutthroat trout in other lacustrine habitats where they have become established (Marnell 1986). The consequences of this introduction may be expressed at scales never before observed in Yellowstone National Park (Varley and Schullery 1995).

Yellowstone Lake currently supports the largest remaining genetically unaltered assemblage of Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri). More specifically, Yellowstone cutthroat trout remain in about 85% of their historic range (on an areal basis) in lakes (Varley and Gresswell 1988), but Yellowstone Lake represents almost 90% of this remaining area. Furthermore, potential repercussions of this introduction extend beyond a reduction in abundance of cutthroat trout or even an alteration in aquatic community dynamics within the lake. Mammalian predators such as the

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endangered grizzly bear (*Ursus arctos*), mink (*Mustela vison*), and otters (*Lutra canadensis*) seasonally focus on Yellowstone cutthroat trout (Gresswell 1995), and piscivorous birds such as endangered bald eagles (*Haliaeetus leucocephalus*), osprey (*Pandion haliaetus*), and white pelicans (*Pelecanus occidentalis*) depend on adfluvial Yellowstone cutthroat trout spawners for a rich protein source during the annual breeding season (Davenport 1974; Swenson 1978; Swenson et al. 1986).

Unfortunately, the ability to predict effects resulting from the establishment of this introduced predator is limited because the extensive information required for quantitative models used by community and population biologists is unavailable for the Yellowstone Lake ecosystem. Furthermore, many of the more elementary quantitative models are uncoupled from the remainder of the trophic network (Li and Moyle 1981). Recent advances in the use of qualitative models (Puccia and Levins 1985), such as loop analysis, have yielded an alternative approach for evaluating the behavior of complex systems. Because loop analysis provides a prediction of system stability that results from species interactions, it may be useful for initial examination of the dynamics of the Yellowstone Lake system before and after lake trout became established.

The purpose of this paper is to examine the potential influence of the lake trout on the aquatic community of Yellowstone Lake. Using information from the published literature and unpublished data collected over the last 30 years, we attempted to answer the following questions: How will the establishment of lake trout in Yellowstone Lake affect the structure and persistence of the native cutthroat trout assemblage? What is the relationship among native and introduced fishes in the lake? What are the alternate management options for minimizing potentially negative effects of lake trout on the Yellowstone Lake ecosystem? What types of information are necessary to refine future predictions concerning the aquatic community of the lake?

**STUDY AREA**

**Physical Setting**

At an elevation of 2,357 m, Yellowstone Lake is the largest high-altitude lake (elevation > 2,000 m) in North America. Surface area is about 34,000 ha, and the shoreline length is 239 km (Kaplinski 1991). A total of 124 tributaries to Yellowstone Lake has been identified (Hoskins 1974, 1975; Jones et al. 1986, 1987), and Yellowstone cutthroat trout spawners have been observed in 68 of these streams (Jones et al. 1986). Tributaries range in size from the Yellowstone River upstream from Yellowstone Lake (110,000 ha) to small intermittent streams with drainage of only 5 ha. Pelican, Chipmunk, Beaverdam, Clear, Columbine, Sedge, Arnica, Solution, Grouse, and Cub creeks comprise 31% of the total lake drainage area. There are 81 tributaries with drainage areas < 100 ha that represent 1% of the study area (Gresswell et al. In press).

Yellowstone Lake is composed of a north-south oriented main basin and six subbasins (Kaplinski 1991). The main basin, defined by the 80-m depth contour, extends northwest from the Southeast Arm. West Thumb is the largest of the second-order subbasins. Upwelling occurs in West Thumb as a result of strong prevailing winds from the southwest that generate surface currents toward the northeastern shore and bottom currents back to the southwest (Benson 1961). The northern portion of the lake is divided into two subbasins, one south of the Yellowstone River outlet, and a second in Mary Bay. Three other subbasins, South Arm, Flat Mountain Arm, and the channel connecting West Thumb to the main lake basin, occupy areas carved by Late Pleistocene fluviatil and/or glacial activity (Kaplinski 1991).

**Fishes**

Native fishes in the Yellowstone Lake include the Yellowstone cutthroat trout and the longnose dace *Rhinichthys cataractae*. Because distribution of the longnose dace appears to be limited to the mouths of tributaries to the lake, the Yellowstone cutthroat trout is believed to have been the primary vertebrate in the lake since the retreat of Pleistocene glaciers, approximately 12,000 ago.

Most young Yellowstone cutthroat trout migrate from their natal streams into the lake within a month or two of emergence. In the lake, immature cutthroat trout occupy pelagic areas where they feed on zooplankton, primarily cladocerans and copepods. As the cutthroat trout grow and mature, they move into the littoral zone. Although they continue to feed on zooplankton, larger macroinvertebrates such as amphipods and a variety of aquatic insect larvae and adults, dominate the diet of larger cutthroat trout. There is little evidence of piscivory among cutthroat trout in the lake. Thus, the aquatic community that evolved in Yellowstone Lake was relatively simple and quite stable.

Three nonnative fishes, redside shiner *Richardsonius balteatus*, lake chub *Cernius plumbeus*, and longnose sucker *Catostomus catostomus*, have been introduced since
the 1920s (Gresswell and Varley 1988). Yellowstown cutthroat trout and longnose suckers are distributed throughout the lake basin. Redside shiners, lake chub, and longnose dace are limited to shallow areas around the shoreline; these small fishes are not found in the vicinity of the islands in the lake. Although some diet overlap has been identified, spatial interaction is low among these fishes, and there is little evidence that the introduction of the nonnative minnows and sucker has negatively affected cutthroat trout in Yellowstone Lake (Gresswell and Varley 1988).

Because of their location in a national park, Yellowstone Lake and its watershed have not been subjected to large-scale environmental degradation. During the first half of the 20th Century hatchery supplementation and excessive angler harvest led to alterations of Yellowstone cutthroat trout population structure. Hatchery operations were suspended in the mid-1950s, however, and harvest has been restricted since the early 1970s. A shift in population structure toward a greater proportion of older and larger fish has been documented since the implementation of more restrictive angling regulations (Gresswell and Varley 1988; Gresswell et al. 1994).

Lake trout were first captured in Yellowstone Lake in 1994 (Kaeding et al. 1996). Age analysis suggests that lake trout in Yellowstone Lake are over 20 years old, and they are reproducing in the lake (Mahony and Ruzyczki 1997). Lake trout are broadly distributed by water depths when the lake is not stratified, but during stratification, they are almost common below the thermocline. To date, lake trout appear to be concentrated in West Thumb and western shore of the lake; very few have been collected along the east shore or in the South or Southeast arms. Cutthroat trout have been the most common prey item in stomachs of adult lake trout examined in feeding studies (Dan Mahony, National Park Service, Personal Communication).

METHODS

We used loop analysis (Li and Moyle 1981; Puccia and Levins 1985) to evaluate potential effects of the establishment of an introduced population of lake trout in Yellowstone Lake. Food- and interaction-web diagrams were developed for 16 different scenarios. In the first case, only native species were included in the model. Subsequent scenarios all contained the native species; however, various combinations of introduced were also incorporated.

Relationships among species were expressed as signs (positive, negative, or zero) that described the type of feedback or influence between species pairs (Li and Moyle 1981). Information from the graphical models was transferred to a Jacobian matrix consisting of interactive links between species that were denoted by the symbol $q_{ij}$. Each species comprised a row and column in the matrix, and signs were recorded for interactions of the $i$th species on the $j$th species. The determinant of the Jacobian matrix was obtained through the use of software employing a symbolic processor (MathCad™).

We qualitatively analyzed individual model stability in the context of species iterations (Puccia and Levins 1985). These predicted outcomes were useful because stable systems are generally more resilient to perturbation (Li and Moyle 1981). Additionally, we attempted to determine if an individual model was stable globally (returns to equilibrium following disturbance of any magnitude) or locally (returns to equilibrium only following small disturbances) (Li and Moyle 1981).

RESULTS

Loop analysis under the initial scenario of only native species met Routh-Hurwitz stability criteria, and equilibrium would be expected to persist. System models remained stable when either one or two nonnative species (regardless of species) were added (Table 1). The introduction of three species to the system reduced stability, however, specifically when lake trout occurred in conjunction with both redside shiners and lake chub. Loop analysis also suggested that the current mix of species in the lake could potentially lead to a short-term increase in population oscillations and unpredictability. Furthermore, in the absence of management intervention, the likelihood of species extinctions and eventual simplification of the system will probably increase in the long-term.

From a mathematical perspective, remedial action with the goal of suppressing the lake trout can be interpreted in three ways:

1) Lake trout suppression is regarded as a negative input. The goal of this approach would be increasing mortality and decreasing natality in the introduced lake trout population. Given no competition for food resources between trout species, lake trout adults would decrease, but juveniles would increase. Conversely, cutthroat trout adults would increase, and juveniles would decrease.

2) Lake trout suppression is regarded as a predator-prey relationship. Lake trout in this case are linked directly to cutthroat trout; the introduced predator responds directly, and only, to the population abundance of cutthroat trout. In this case, the target species (lake trout) will not respond to inputs except those associated with management actions.
Table 1. Predicted stability (Routh-Hurwitz) for loop analysis of Yellowstone Lake system models (N = not stable; S = stable) with various combinations of introduced species (+ indicates presence and - indicates absence). Introduced taxa are lake chub Cottus gulosus, redside shiner Richardsonius balteatus, longnose sucker Catostomus catostomus, and lake trout Salvelinus namaycush. Native taxa (Daphnia siedleri, Diaptomus shoshone, Gammarus lacustris, Chironomidae, and Yellowstone cutthroat trout Oncorhynchus clarki bouvieri) were included in all models.

<table>
<thead>
<tr>
<th>Fish species</th>
<th>Presence or Absence in Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>LKC</td>
<td>+ + - - + + - - - + - - -</td>
</tr>
<tr>
<td>RSS</td>
<td>+ + + + - + + - - + - - -</td>
</tr>
<tr>
<td>LNS</td>
<td>+ - - + + + - - - + + - +</td>
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<tr>
<td>LKT</td>
<td>- + - - + - + - - + - - +</td>
</tr>
<tr>
<td>Stability</td>
<td>N N N S S S S S S S S S S S</td>
</tr>
</tbody>
</table>

LKC = lake chub; RSS = redside shiner; LNS = longnose sucker; LKT = lake trout.

3) Lake trout suppression is regarded as a "harvest", or a positive self-effect. This would occur when density independent quotas are established. Under the scenario of no competition, feedback at the higher levels would be negated, and the system would become unstable. Consequences of suppression on the abundance of adult lake trout in this case could be minimal.

**DISCUSSION**

Qualitative systems analysis, such as loop analysis, is most effective when used to make a first-order approximation of systems behavior in cases when information is limited (Li and Moyle 1981). According to Li and Moyle (1981), the greatest uncertainty in the use of loop analysis involves the estimation of interspecific interaction intensities. They concluded that systems that evolved under stable natural conditions for long periods of time, especially oligotrophic systems, may be more sensitive to environmental perturbations than other systems.

Although Yellowstone Lake may not be oligotrophic (Theriot et al. 1997), the structure of the system prior to Euroamerican settlement was quite simple (Gresswell and Varley 1988). Only two species of fish inhabited the lake drainage, and one, the longnose dace, was probably never widely dispersed within the lake itself. Our results suggest that perhaps the most important effect of the introduction of nonnative fishes has been the potential for increased variation within the system structure and a subsequent reduction in stability. Because results vary substantially depending on the specific scenario and stated assumptions, information that would provide support for one of the alternatives is critical for increasing the accuracy and precision of future predictions. Preliminary analyses with the entire community of introduced fishes suggest that further information concerning interspecific relationships is vitally important to understanding the potential effects of the introduced lake trout.

Additionally, a comprehensive understanding of food habits of lake trout in Yellowstone Lake is needed so that managers can better evaluate the direct effects of predation on cutthroat trout. It is also important to understand the dynamics of species distribution in the lake and how distribution varies spatially and temporally within the basin. For instance, preliminary results from gillnetting operations in the lake suggest that lake trout frequently move between the pelagic and littoral areas during periods when the lake is not stratified, but even during stratification some individuals move into shallow water (presumably for foraging forays). In addition, although cutthroat trout may be more numerous in shallow areas (Jones et al. 1977; Gresswell, unpublished data), they have been captured at all depths regardless of temperature gradients (Mahony and Ruzycki 1997).

**Literature Citations**


A Bioenergetics Modeling Assessment of the Lake Trout Impact in Yellowstone Lake

James R. Ruzycki¹ and David A. Beauchamp²

Abstract—The establishment of a reproducing population of non-native lake trout Salvelinus namaycush poses a potentially serious threat to the integrity of the Yellowstone Lake ecosystem, particularly to indigenous cutthroat trout Oncorhynchus clarki bouvieri. We used field data on diet, distribution, growth, and size structure of lake trout in a bioenergetics model to estimate the seasonal and size-specific loss of cutthroat trout that could be attributed to lake trout predation. Because the abundance of lake trout is currently unknown, predation was calculated as loss biomass for every 1,000 lake trout. Juvenile cutthroat trout are highly vulnerable and lake trout prey on cutthroats that are about 25% their body size. An average piscivorous lake trout (>300 mm TL) is estimated to consume 59 cutthroats each year. This analysis demonstrates the potential negative impact of an introduced predator into an ecologically isolated ecosystem.

INTRODUCTION

Yellowstone National Park (YNP) represents 91% of the current range of Yellowstone cutthroat trout Oncorhynchus clarki bouvieri and contains 85% of the historical lacustrine habitat for this subspecies (Varley and Gresswell 1988, Gresswell 1995). Yellowstone cutthroat trout are designated as a "Species of Special Concern-Class A" by the American Fisheries Society (Williams et al. 1989). The cutthroat trout population in Yellowstone Lake supports a fishery estimated to value over $36 million in 1994 (Varley and Schullery 1995). Cutthroat trout play a significant role as both predator and prey in the Yellowstone Lake ecosystem, and provide an important trophic link to the terrestrial community for up to 42 avian and mammalian predators and scavengers (Schullery and Varley 1995).

Lake trout introductions have been implicated in declines of native adfluvial cutthroat trout populations in several western North American lakes: Bear Lake, Idaho-Utah (Ruzycki and Wurtsbaugh 1995); Lake Tahoe, California-Nevada (Cordone and Frantz 1966); Heart Lake, Yellowstone National Park (Dean and Varley 1974); Jackson Lake, Grand Teton National Park (Behnke 1992); and other large deep lakes in the Rocky Mountain region. The establishment of a reproducing population of non-native lake trout Salvelinus namaycush in Yellowstone Lake poses a potentially serious threat to the integrity of this ecosystem, particularly to indigenous cutthroat trout. We used field data on diet, distribution, growth, and size structure of lake trout in a bioenergetics model to estimate the seasonal and size-specific loss of cutthroat trout that could be attributed to lake trout predation.

Bioenergetics models have been widely used to estimate salmonid impacts (e.g., Kitchell and Crowder 1986, Negus 1995). More specifically, the lake trout model of Stewart et al. (1983) has been successfully applied to a number of systems (e.g., LaBar 1993, Yule and Luecke 1993, Ruzycki and Wurtsbaugh 1995, Beauchamp 1996) to estimate their predatory impacts.

Our model results indicated that lake trout are capable of consuming large numbers of cutthroat trout with juvenile cutthroats being highly vulnerable. Currently, predatory impacts are generally limited to the West Thumb Basin (Mahoney and Ruzycki, this volume). Lake trout, however, have the potential to seriously impact the cutthroat trout population if control measures are ineffective. This analysis demonstrates the potential negative impact of an

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introduced predator into an ecologically isolated ecosystem. Further, this consumption information provides quantitative measures of the predatory impact thereby justifying the National Park Service lake trout removal program.

METHODS

Study Area

Yellowstone Lake (surface area 341 km²) is located in east-central Yellowstone National Park at an elevation of 2,356 m. The lake has a shoreline length of 239 km, mean depth of 48.5 m, and a maximum depth of 107 m (Kaplinski 1991). Ice cover typically occurs from mid-December through May, a thermocline forms in July, and hypolimnetic waters remain well-oxygenated during thermal stratification. Summer surface temperatures rarely exceed 18°C (Benson 1961).

Six species of fish are now established in the lake. Yellowstone cutthroat trout and longnose dace, *Rhinichthys cataractae*, are indigenous (Simon 1962). Longnose sucker, *Catostomus catostomus*; redside shiner, *Richardsonius balteatus*; lake chub, *Cottus plumbeus*; and lake trout have been introduced. Longnose dace, redside shiner, and lake chub inhabit littoral regions; cutthroat trout and longnose sucker are located throughout the lake (Gresswell et al. 1994). Lake trout have also been captured throughout the lake but adult fish are most abundant in the West Thumb Basin.

Age and Growth

Both age and annual growth were determined from annual growth increments of sagittal otoliths and preopercles of lake trout captured with gill nets and received from anglers. Preparation and analysis of preopercles followed Sharp and Bernard (1988). Otolith preparation followed the techniques of Secor et al. (1991) and Casselman and Gunn (1992) except that otoliths were read directly. Annual growth increments of prepared otoliths and preopercles were interpreted at 1-40 X magnification with the aid of an image analysis program (Leica Q500MC). Total length (TL) of fish at specific otolith and preopercle annuli was determined using regressions of fish TL on otolith radius and preopercle diameter. A von Bertalanffy growth curve was fit to the combined otolith and preopercle size-at-age data (Gulland 1983).

Survival Rate

Survival for adult lake trout was computed using gill net data and a catch curve technique (Van Den Avyle 1993). Size-at-age groups were developed by the von Bertalanffy growth curve as described above. We confined this preliminary analysis to sizes of fish assumed to be fully recruited to the large mesh (> 51 mm square measure) gill nets. The relative abundances of age 9-25 yr-old lake trout were determined by examining the catch rates of these cohorts in gill nets. A regression was then fit to the log transformed, exponential decline in catch rates of each age-class and an annual survival rate was calculated from the negative slope of this curve.

Feeding Habits

We examined the diets of gill-netted lake trout and cutthroat trout collected June through October 1996. Prey items were identified and separated by taxon, blotted and weighed. When possible, partially digested fish prey items were identified by external body or bone morphology. Total length at ingestion for partially digested cutthroat trout was converted from measured vertebral column length (VL), and standard length (SL) using regression equations derived from a sample of 30 preserved cutthroat trout specimens. Diet composition was calculated as aggregated percentages by wet weight. Because of an apparent ontogenetic shift in diet, lake trout were separated into three size categories as follows: < 300 mm, 300-500 mm, and > 500 mm TL.

Thermal History

The thermal history of the three modeled size groups of lake trout was partially estimated using their seasonal depth distribution as determined by their relative catches in gill nets. This depth distribution was then converted to temperature using vertical temperature profiles collected from June through September. Beginning on 17 September 1996, the epilimnion cooled to 10.5°C and lake trout were assumed to move into shallow water to spawn. After spawning, they were assumed to occupy a variety of depths throughout the winter and into spring.

Estimation of Predatory Consumption

We estimated lake trout consumption of forage fishes and invertebrates using bioenergetics modeling (Hewett and Johnson 1992). This bioenergetics model solves an energy balance equation by allowing ration levels to be constrained by the observed growth endpoints that are
specific to the population of interest (Kitchell et al. 1977; Bartell et al. 1986; Rand et al. 1993). The coefficients of Stewart et al. (1983) were used to model lake trout. To simulate spawning, 10% of individual biomass was subtracted from lake trout longer than 500 mm TL on 1 October 1996. Size-at-age, and thermal history were determined as described above. Because information was not available for energy content of several prey items, close taxonomic surrogates from the literature were used. Model runs were tabulated at 15-d intervals and summed for annual estimates of consumption by allowing for seasonal variations in thermal history.

RESULTS

Age and Growth

First year annuli deposited in preopercles were difficult to read and measure on older fish. We therefore, relied primarily on smaller (i.e. younger) fish for interpretation of the initial two annuli. Annuli became more easily distinguishable at later ages. The oldest fish aged from preopercles (age = 21 yr) measured 795 mm TL. Preopercle diameter (P₀) was positively related to lake trout TL at capture where:

\[ TL = 2.1 + 20.6(P₀), \quad r^2 = 0.97, n = 26. \]

Preliminary interpretation and measurement of annuli deposited in otoliths differed slightly from preopercles (fig. 1). Size-at-age measures were most dissimilar among otoliths and preopercles for small (annuli 1,2) and again for large (annuli 11-17) fish but were similar at intermediate annuli (3-10). Similar to preopercles, initial annuli were difficult to interpret on larger fish and annuli became more easily distinguishable at later ages. The oldest fish aged using otoliths (age = 17 yr) measured 732 mm TL. Sagittal otolith diameter (O₀) was positively related to lake trout TL at capture where:

\[ TL = -78.13 + 125.4(O₀), \quad r^2 = 0.95, n = 90. \]

The von Bertalanffy growth function (fig. 1) was fit to the combined otolith and preopercle size-at-age data as:

\[ L_t = 927(1-e^{0.103(t+0.55)}) \]

where \( L_t \) is total length (mm) at time \( t \) (expressed in years), and \( e \) is the base of the natural logarithm.

![Figure 1.—Total length of lake trout back-calculated from annuli of otoliths and preopercles. Otolith data are offset slightly for visual clarification. The von Bertalanffy growth function is also shown.](image)

Survival Rate

The catch rates of lake trout in the YNP gill nets during the 1996 field season declined with age-class (fig. 2). The slope of the least-squares fitted, exponential decay model of the semi-log transformed data indicated an average annual survival rate of 82% for lake trout ages 9-25 yrs.

Feeding Habits

Small lake trout diets were dominated by invertebrates but fish prey items became increasingly important as lake trout body size increased. Zooplankton comprised 42% and unidentified invertebrates 53% of the diets of small lake trout (150-299 mm TL, fig. 3). Intermediate-sized lake trout (300-499 mm TL), consumed proportionally more fish. Cutthroat trout and unidentified fish comprised 28 and 19% of these diets, respectively. Large lake trout (500-850 mm TL) diets were dominated by fish prey. Cutthroat trout and unidentified fish comprised 87 and 9% of these diets, respectively (fig. 3).

Many fish prey items in lake trout diets were too highly digested for complete identification. Based on vertebral inspections, fish prey species other than cutthroat trout were suggested, however, these prey taxa were unidentified. When sufficient structures remained intact, partially digested cutthroat trout prey were converted to TL
positively related to TL where:

\[ VL = 9.58 + 1.32(TL), \quad r^2 = 0.99, \quad n = 30, \]

and standard length (SL) was positively related to TL where:

\[ SL = 3.87 + 1.16(TL), \quad r^2 = 0.99, \quad n = 30. \]

Predation of cutthroat trout begins when lake trout reach lengths of approximately 300 mm TL (fig. 4) and diet evaluations indicated that lake trout prey primarily on small cutthroat trout. The largest cutthroat trout identified in lake trout diets was 299 mm TL. Total length of cutthroat trout (CT_{TL}) prey in diets of piscivorous lake trout was positively related to lake trout TL (LT_{TL}) where:

\[ CT_{TL} = 30.7 + 0.25 (LT_{TL}), \quad r^2 = 0.40, \quad p<0.001, \quad n = 74. \]

Based on this equation, lake trout typically consume cutthroat trout 25% their body length. Larger lake trout, however, consume a greater range of sizes of cutthroat trout prey than do smaller fish (fig. 4). A similar regression equation describes maximum size of cutthroat trout prey in lake trout diets where:

\[ CT_{TL} = -55.0 + 0.55 (LT_{TL}). \]

This preliminary relationship indicates that the largest cutthroat trout prey in lake trout diets approximate 55% of lake trout predator body length.

**Thermal History**

Epilimnetic temperatures exceeded 12°C on 6 July 1996 and remained warm until 16 September 1996 when the epilimnion cooled to 10.5°C. Small lake trout (150-299 mm TL) were only captured in water >30 m deep throughout the lake. In contrast, larger lake trout were captured at a variety of depths throughout June. Lake trout were captured exclusively below the epilimnion from July through 16 September. During the spawning period in late September and October, lake trout >400 mm TL were readily captured in shallow water (<3 m deep) near Carrington Island.

**Estimation of Predatory Consumption**

The bioenergetics modeling indicated that lake trout were consuming prey near their maximum possible ration. Proportion of maximum consumption (p-values) averaged 0.75 for small, 0.71 for intermediate, and 0.60 for large lake.
Otoliths are considered to be the most reliable structure for age determination in lake trout (Sharp and Bernard 1988, Casselman and Gunn 1992). Lake trout preopercle are relatively easy to prepare for aging and Sharp and Bernard (1988) found them to be a reasonable alternative to otoliths. Our otolith size-at-age data differed slightly from preopercle data. This difference is especially apparent at small and large sizes (see fig. 1). Further, given the reported reliability of otoliths and the expected overestimation of size-at-age from preopercles, the difference is in the opposite direction than expected. This may be a consequence of misinterpretation of otoliths or preopercles. It may also be an artifact of our small sample sizes and the resultant slopes and intercepts of the regression fit of TL on either otolith or preopercle measures. However, true verification of the accuracy of any calcified structure interpretation can only be accomplished by sampling known aged fish from the system of interest.

We currently have limited information on intermediate sized lake trout (~380-480 mm TL) as they were conspicuously absent from most gill net catches (Kaeeding and Boltz 1997). Based on our diet information, this size class is a significant predator of cutthroat trout. Future gill net strategies will be designed to improve our ability to capture these fish and will be essential to our understanding of the size structure of the population.

Proportion of maximum consumption estimates (p-values) from the bioenergetics simulations indicate that lake trout are consuming near their maximum ration. Typically, p-values for piscivorous lake trout rarely exceed 0.70 (e.g., Stewart et al. 1983, Yule and Luecke 1993, Negus 1995, Ruzycki and Wurtsbaugh 1995, Beauchamp 1996). The average p-value for large lake trout in Yellowstone Lake was 0.60 suggesting that they are able to easily locate and capture fish prey. Feeding at maximum ration rates is also indicative of a population that is not food limited. This apparent lack of food limitation suggests that lake trout have yet to seriously limit cutthroat trout recruitment and that the predators' population has yet to reach carrying capacity.

Few cutthroat trout are inulnerable to the largest lake trout predators in the lake. Although the average cutthroat trout consumed by lake trout was 25% the predators body length, lake trout are also capable of capturing proportionately larger prey. Our diet information indicates that lake trout are capable of ingesting prey at least half their body length. Ingestion of prey exceeding 50% of predatory lake trout body length has also been reported for other systems (e.g., Yule and Luecke 1993, Beauchamp 1996). The largest lake trout captured in Yellowstone lake exceeded 850 mm TL suggesting that they are potentially able to prey on cutthroat trout > 420 mm TL. Therefore, few
cutthroat trout have a size refuge from this predation.

Our modeling simulations indicated that predation by lake trout can substantially impact the cutthroat trout population. The 580 lake trout removed from the lake during 1996 would have consumed > 26,000 cutthroat trout if they remained in the lake for another year. Given the apparent size structure of the lake trout population as indicated by gill net catches, and the presence and size of the cutthroat trout in their diets, a population of 1,000 piscivorous lake trout (> 300 mm TL) would consume 59,000 cutthroat trout/yr. If the population were an order of magnitude greater, and if density dependence was not yet operating, the 10,000 piscivores would be consuming nearly 600,000 cutthroat trout/yr. A population size of 10,000 piscivores is not an unreasonable population size for a system the size of Yellowstone Lake. Ruzycki and Wurtsbaugh (1995) estimated a population size of 15,000 lake trout > 400 mm TL in similarly sized Bear Lake (surface area, 282 km²), Utah-Idaho. Similarly, Beauchamp (1996) estimated a population size of > 1,000 lake trout (> 400 mm TL) in Flathead Lake (surface area, 312 km²), Montana. The larger Lake Tahoe (surface area, 500 km²) also has an estimated population size of 74,000 lake trout (> 375 mm FL; D. Beauchamp, unpublished data). Moreover, lake trout were reported to have been seriously impacting the prey fish populations in each of these systems.

Large lake trout were responsible for 98% of the per capita predatory consumption. However, their actual contribution to the population-level predatory demand is dependent on the age and size structure of the population. Accurate estimation of the size structure is dependent on reliable survival rates. We estimated a preliminary annual survival rate of 82% for these large fish. Therefore, if control measures are ineffective on these large predators and if smaller cohorts continue to recruit to this size class, they will have the ability to seriously impact the cutthroat trout population. More accurate estimates of the abundance, survival, and size distribution of lake trout in Yellowstone Lake is a major objective of our research during the next two years. This additional information will allow us to estimate population-level predatory impact.

ACKNOWLEDGEMENTS

This research was supported by funding provided by the National Park Service, U.S.G.S. Dept. of Biological Resources, and the Berryman Institute. L. Kaeding and G. Bolz of the U.S. Fish and Wildlife Service and J. McIntyre, D. Mahoney, and J. Lutch of the National Park Service, Aquatic Resources Center, Yellowstone National Park, provided technical assistance. S. Troop, M. Burnett, B. Erle, D. Richards, L. Kuehn, A. Dall, V. Munford, and numerous volunteers also provided assistance.

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Status of Yellowstone Cutthroat Trout in the Upper Henrys Fork Watershed, Idaho and Wyoming

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Abstract—Concern over decline of Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri) in the Yellowstone region has prompted a comprehensive survey of streams in the Henrys Fork Snake River watershed. Historical records show that nonnative salmonids were introduced into headwater streams as early as 1891. Hybridization with rainbow trout (O. mykiss) and competition from brook trout (Salvelinus fontinalis) have contributed to loss of cutthroat populations. Cage studies in small upper watershed streams show that young-of-year cutthroat display significantly lower overwinter survival in the presence of brook trout than they do alone. The largest viable Yellowstone cutthroat population remaining in the upper watershed is the adfluvial Henrys Lake population, which utilizes several lake tributaries for spawning. This population has been influenced since 1924 by a cutthroat hatchery program at the lake. Brook trout and cutthroat-rainbow hybrids are also present in Henrys Lake. Viable resident stream cutthroat populations have been found in three streams out of over 50 surveyed. The Henry’s Fork Watershed Council, an organization of citizens, scientists and agency representatives, has appointed a subcommittee to develop a long-term cutthroat trout conservation strategy for the watershed and to implement educational and stream rehabilitation projects to promote cutthroat conservation.
The South Fork Snake River Yellowstone Cutthroat Trout Fishery: Threats and Management Options For Its Conservation

Mark Gamblin and Bill Schrader

Abstract—The South Fork Snake River in eastern Idaho supports arguably the strongest population and finest fishery for Yellowstone cutthroat trout outside of Yellowstone National Park. During the past 12 years the South Fork Snake River has become a destination fishery for anglers across the United States attracted by high catch rates for large cutthroat and brown trout. Since 1963 the Idaho Department of Fish and Game has documented a growing population of introduced wild rainbow trout, below Palisades Reservoir, that management personnel believe constitutes a serious threat to the future of this world class wild cutthroat trout fishery. The results of recent research are being used to develop conservation strategies that may be incorporated into the South Fork fish management program, if we are successful in developing public support for the necessary changes. Gaining the public support necessary to grant native cutthroat population the priority management consideration in the South Fork fishery will require a thorough understanding of the interaction between the rainbow and cutthroat populations, effective communication with the angling public, and a meaningful translation of the benefits of cutthroat trout to the average angler.

INTRODUCTION

The theme of Wild Trout VI, “Putting the Native Back in Wild Trout”, provides a timely opportunity for us to share an all too in-frequent success story about a native wild trout fishery. We’ll also discuss a growing threat to this fishery from an increasing wild rainbow trout population, and the efforts we are making to conserve the exceptional population of Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri) that is the foundation of this fishery. Our efforts are focused on (1) understanding the dynamics of this rainbow trout population and the mechanisms of its interaction with the native Yellowstone cutthroat trout population and (2) developing conservation strategies, with public support, to insure a healthy and stable Yellowstone cutthroat trout population in the South Fork.

Since the late 1980’s the South Fork of the Snake River in eastern Idaho (Figure 1) has acquired a reputation as one of the finest wild trout fisheries in North America. The South Fork is a large freestone river regulated by Palisades Reservoir, a Bureau of Reclamation irrigation and hydro-power impoundment that straddles the Idaho-Wyoming border. The demands of irrigation water storage and delivery regulates river flows in the South Fork during most of the year, except spring snow melt months. Summer flows generally range from 10,000 to 17,000 cubic feet per second (cfs). Winter flows usually vary between 1,000 and 4,000 cfs. We currently believe the majority of Yellowstone cutthroat trout production comes from four South Fork tributaries: Palisades, Rainey, Pine and Burns Creeks.

MANAGEMENT HISTORY

Historically, the South Fork was known for its Yellowstone cutthroat trout, brown trout (Salmo trutta), and mountain whitefish (Prosopium williamsoni) fishing. Rainbow trout (Oncorhynchus mykiss) have been present for many years, but until recently, wild rainbow were an insignificant portion of the South Fork fishery.

Fishing regulations have gone through three adjustments since 1984, initially intended to enhance the survival and abundance of Yellowstone cutthroat, and later all wild trout (Figure 2). Prior to
1984, the South Fork was managed under the state-
wide general fishing regulation: a six-trout possession 
limit with no gear or size restrictions. Research 
recommendations resulted in the first change in 1984 
to a slot limit regulation that reduced the possession 
limit to two cutthroat trout, none between 10 and 16 
inches with barbless hooks required. This regulation 
was based on a research finding that cutthroat in the 
South Fork are sexually mature at 10 to 12 inches in 
length and will spawn at least once, and in most cases 
twice, by the time they reach 16 inches in length. By 
protecting the sexually mature portion of the 
cutthroat population under 16 inches, both 
production and recruitment to the fishery was 
strongly enhanced. Adjustments in 1990 and 1992 
brought us to the current regulation of a possession 
limit of 2 trout ( browns and rainbows included), none 
between 8 and 16 inches in length, and no gear 
restrictions (bait and barbed hooks allowed).

RESPONSE OF THE FISHERY

The response of South Fork cutthroat trout to the 
new regulation was dramatic in the speed and 
magnitude of the increase in both the number and 
size of cutthroat in the population. The total number 
of cutthroat over 4 inches in length increased over 
400% by 1986 (Figure 2). In spite of drought effects 
during the next 10 years, which limited trout

Figure 1.—South Fork Snake River, eastern Idaho.

Figure 2.—Harvest restrictions and estimated densities of age 1 and older (>100 mm or 4 in) wild and hatchery cutthroat trout at Conant electrofishing section, South Fork Snake River, 1982-1996. Ages are approximate and were not validated. Estimates for 1982 from Moore and Schill (1984).
production, the South Fork quickly developed a reputation as one of the top destination fisheries for wild trout in the nation. Creel survey data from 1982 and 1996 highlights the growth of the fish population and the subsequent growth of the fishery (Table 1). Total effort increased 318%, total catch (all species) rose by almost 400%, the overall catch rate increased by 22% and total harvest declined by 84%.

**SUCCESS BRINGS RECOGNITION**

Although unintended, the South Fork Snake River has become a catch and release fishery. Consumptive oriented anglers have been replaced by anglers motivated more by high catch rates for large trout than harvesting a limit of trout to eat. We emphasize that the foundation of this fishery is the native Yellowstone cutthroat population. Many anglers pursue trophy brown trout in the South Fork, but the "South Fork Experience," high catch rates for quality sized wild fish, is almost entirely supported by cutthroat trout.

The South Fork has become a destination fishery for anglers from around the United States and outside of the country as well. The South Fork fishery supports an outfitting and guiding industry that includes at least six companies and provided the start-up market for one of the country's largest drift boat manufacturers. Our point is that not only does the South Fork native cutthroat trout resource provide a world-class angling experience for thousands of anglers every season, it also pumps millions of dollars into our local economy.

**RAINBOW MOVE IN**

At the same time that the South Fork cutthroat population has been prospering, we have been monitoring a growing population of wild rainbow trout that has been present in the South Fork since at least the early 1970's. Rainbow trout numbers made up less than 5% of the wild trout population in the upper South Fork until 1990 when the percentage of rainbow and hybrid rainbow/cutthroat trout in the population began to steadily increase. In our 1996 trout population estimate for the Conant Valley reach of the river, we found that rainbow and hybrid trout comprised 15% of the electrofishing catch, up from less than 1% in 1982, and the percentage of cutthroat trout declined by 13 points for the same period (Figure 3). Upstream of Conant Valley, in the reach immediately below Palisades Dam, rainbow and hybrid trout percentages have increased from about 6% in 1987 to over 33% in 1995, and the percentage of cutthroat has similarly declined. We have also seen the percentage of rainbow and hybrids in the angler catch increase from less than 1% in 1982 to 7% in 1996 (Figure 4). The smaller increase of rainbows and hybrids in the angler catch, compared to the changes

![Figure 3](image-url) - Trout species composition and relative abundance (%) at Conant electrofishing section. Results for 1996 are from MR4 database for all sizes of fish; 1982 results are from Moore and Schill (1984).

![Figure 4](image-url) - Trout catch composition (%) in the upper South Fork Snake River, opener to mid-September, 1982 and 1996. Total fish from angler interviews n= n. Results are for all sizes of fish and, for 1982, are from Moore and Schill (1984).
in our electrofishing catch, probably reflects the longer reach of river surveyed for creel statistics, greater angler difficulty catching rainbow trout, and our findings that this rainbow trout population is centered in the upper Idaho section of the South Fork. Brown trout numbers have remained comparatively stable since 1982.

There are several possible origins for this rainbow population. The Idaho Department of Fish and Game stocked hatchery catchable rainbow trout in the South Fork for years, prior to 1981. Two tributaries, Rainey Creek and Fall Creek, received hatchery rainbow trout until 1985. Rainbow trout are present in the Salt River, tributary to Palisades Reservoir. Small numbers have been documented in the Wyoming portion of the South Fork, near Jackson, for years, and rainbow or hybrids occasionally show up in the reservoir fishery. Private ponds draining into the South Fork have also flushed hatchery rainbow trout into the river in recent years. Any one or a combination of these sources could have provided the nucleus for the present rainbow population.

**STATUS OF YELLOWSTONE CUTTHROAT**

Yellowstone cutthroat, like other cutthroat sub-species, have suffered a greatly diminished range of distribution. The most current assessment of the status of Yellowstone cutthroat indicates that viable, genetically pure fluvial populations occupy only about 10% of their historic range in Montana, Wyoming and Idaho. Approximately 41% of that historic range harbors Yellowstone cutthroat, regardless of genetic purity or population viability (May, 1996). The loss or degradation of habitat and displacement by competing or hybridizing trout species has been cited as the most important factors explaining today’s remnant range of distribution (Thurow et. al., 1988; May, 1996). We consider displacement by non-native species, especially rainbow and brook (Salvelinus fontinalis) trout, to be the most important threat to remaining viable Yellowstone cutthroat populations. The recent growth of wild rainbow trout in the South Fork is a troublesome example of this trend. In Idaho, stable and viable Yellowstone cutthroat populations exist in the Blackfoot River, Willow Creek, South Fork Snake River, Teton River and Henry’s Lake. These five drainages comprise less than 40% of the historic habitat occupied by the sub-species. Among these drainages, the South Fork Snake River population is the most important and also the largest and most robust Yellowstone cutthroat population outside of Yellowstone National Park. The recent Conservation Assessment for Yellowstone cutthroat trout (May, 1996) highlights the level of concern for remaining stocks and the potential for the sub-species to be listed under the Endangered Species Act.

**PUBLIC PERCEPTIONS**

The precarious long-term viability of Yellowstone cutthroat in general, and the threat to the South Fork cutthroat trout population by rainbow trout in particular, has received much attention in the local sporting press since 1994. Editorials and articles have focused attention on this issue, advocating measures to reduce rainbow trout numbers. Local anglers have lobbied the Department of Fish and Game to liberalize rainbow trout harvest regulations to control or reduce the growth of rainbow. We share those concerns about the threat of displacement of South Fork cutthroat trout by an expanding rainbow trout population. However, there are other anglers who prefer we protect and enhance the South Fork rainbow trout population. We believe this issue requires a thorough understanding of both the cutthroat and rainbow populations and how they are interacting so we can inform the public and work with the Fish and Game Commission to develop biologically sound and socially acceptable cutthroat conservation strategies. Above all, we hope to avoid a polarized issue, pitting advocates of one species against those for another.

**DEVELOPING MANAGEMENT OPTIONS**

In 1995, we initiated a collaborative study, with Utah State University and the Bureau of Reclamation, to improve our understanding of the rainbow and hybrid trout population, and their interaction with and impact on the cutthroat trout population in the upper South Fork drainage. We developed three specific objectives for this study: 1) describe the timing of rainbow and hybrid spawning activities; 2) describe the spatial distribution of rainbow and hybrid trout spawning activities; 3) describe any overlap of rainbow and hybrid trout and cutthroat trout spawning. After two field seasons of intensive radio-telemetry and electrofishing monitoring of
rainbow, hybrid and cutthroat spawners, Utah State University graduate student Rick Henderson has provided us a new understanding of the dynamics of the South Fork rainbow and cutthroat trout populations. This information will contribute to the development of cutthroat conservation management options.

First, we have found that the four previously mentioned principal spawning and production tributaries are used almost exclusively by cutthroat. Some rainbow and hybrid spawning occurs in the lower reaches of Palisades and Pine Creeks, but for practical purposes rainbow have not pioneered into these important tributaries. Second, rainbow and hybrids are using the mainstem and side channels of the South Fork for almost all of their spawning activities, and we have documented an unexpectedly high amount of cutthroat spawning in those areas also. The timing of spawning by rainbow, hybrid and cutthroat trout is not clearly separated, but rainbow and hybrids generally are spawning earlier than cutthroat. Where cutthroat do overlap with rainbow and hybrids, we see male cutthroat spawning more often with rainbow, such that introgression may be occurring mostly from cutthroat to rainbow. The last general observation we can share is that rainbow and hybrids are spawning in a fairly narrow reach of the upper South Fork that is centered around Indian Creek and Fall Creek, where the river is heavily braided.

We currently are evaluating three alternative conservation strategies for the South Fork cutthroat trout population based on public comments, research findings, and 15 years of trout population and creel data.

Selective Removal

If rainbow and hybrid trout continue to concentrate their spawning activities in the braided Indian Creek - Fall Creek section of the South Fork, we believe we can use our river electrofishing gear to selectively remove spawning rainbow and hybrid trout for transplant to other suitable waters in the region. This would require an intensive investment in labor and equipment, and would likely be feasible only in a 2 to 3 year rotation, but we believe this option offers a reasonable chance to significantly effect the population of spawning rainbow and hybrid trout.

Modify Harvest Regulations

Including the current fishing regulations package, we will review three alternatives for consideration during the next biennial review cycle in 1999:

Option 1: Liberalize both rainbow and brown trout harvest opportunities. This would likely mean putting rainbow and brown trout back under the general 6 trout possession limit, with no size restrictions.

Option 2: Liberalize rainbow trout harvest opportunity only. Under this option, we would recommend a 6 fish possession limit for rainbow trout, with no size restrictions. Brown trout would remain in the restrictive slot limit with cutthroat.

Option 3: Make no change in the existing regulations package.

Manage Tributaries For Cutthroat Production

We will consider the feasibility of expanding our ability to manage spawning escapement from the South Fork into the four principal spawning and production tributaries, with the construction of permanent fish weirs. By 1999, we will have completed construction of fish ladder and trapping facilities at irrigation diversions on Rainey Creek and Palisades Creek that will give us the ability to block or trap and sort spawners on their way upstream. By either closing the fish ladders during the rainbow and hybrid spawning runs, when cutthroat are not spawning in significant numbers, or by trapping and allowing only cutthroat spawners to continue upstream, we would manage those tributaries solely for cutthroat production and minimize or eliminate the threat of genetic introgression by rainbow trout in those South Fork cutthroat trout stocks. As we evaluate the success of this management strategy, we will consider constructing a weir and trapping facility at the mouth of Pine Creek for the same purpose.

INTEGRATING RESOURCE POLICY

“No policy that does not rest on philosophical public opinion can succeed”

Abraham Lincoln

In addition to being biologically sound, logistically feasible and affordable, our conservation strategies will require public acceptance and support if they are to have any chance of success. This is the reason we have a
Commission based system for fish and wildlife management in Idaho, and it is this system that our conservation strategies and management recommendations for cutthroat conservation will be developed within. Briefly, any South Fork cutthroat trout conservation strategy will be developed by the following groups:

Idaho Department of Fish and Game - Technical advisor to the public and the Idaho Fish and Game Commission.

Idaho Public - The owners of the fish and wildlife resource. Working with Department of Fish and Game staff and their Commissioners, the public tells us what it wants for management of the South Fork fishery.

Idaho Fish and Game Commission - Has final responsibility for fish and wildlife management decisions. The Commission integrates recommendations from Fish and Game Department staff and public comments to make the final decision on fishing regulations and fish management changes.

Over the next two years, we will be conducting angler opinion surveys through random mailings to Idaho fishing license buyers and on-the-water interviews of South Fork anglers. We want to use these surveys to gage the importance Idaho anglers place on conserving the South Fork cutthroat trout population and their willingness to accept and support changes in the fish management program for cutthroat conservation. With our research findings and the results of the angler opinion surveys, we will go back to the public in a series of public workshops, open houses, and general meetings to develop a revised management program for the South Fork fishery that best incorporates the biological needs of the native cutthroat trout population, the desires of the Idaho angling public and the social and political realities of our commission based system of fish and wildlife management.

FINDING RELEVANCE IN NATIVE SPECIES CONSERVATION

We want to conclude this essay with a discussion of a critically important issue in native species conservation, but one which we believe gets far too little consideration in either local or national efforts to conserve fish and wildlife. We have tried to emphasize our view that fish or wildlife management programs that do not have the support of the public they are intended to benefit are at best handicapped, and at worst doomed to failure. In our deliberations of strategies to insure a stable and abundant Yellowstone cutthroat trout population in the South Fork Snake River, we have often discussed what we can do to describe the value of a native species such as cutthroat trout to the average angler who will play a key role in deciding what changes will be made to conserve that public resource. If we fail to translate the value or benefits of cutthroat trout in terms that are understandable and meaningful to the average angler, we may well fail in our responsibility to preserve, protect and perpetuate this native species for the continued use and enjoyment by South Fork anglers.

We will emphasize several points in our future discussions with the public and the Fish and Game Commission:

1) Cutthroat trout are a true Idaho native that our grandparents and great grandfathers grew up with.

2) Cutthroat trout are the state fish of Idaho. We have already designated this species to be more than just an ordinary game fish.

3) Perhaps most importantly, cutthroat trout offer more tight lines by far than any other trout species in Idaho. A fishery supported by brown trout and rainbow trout simply will not provide the 50 to 100 fish days that the South Fork has become famous for. If we lose the health and quality of the South Fork cutthroat trout population, the fishery that has become a recreational and economic boon to eastern Idaho may become “just another good place to fish”.

LITERATURE CITED


Estimating Abundances of Juvenile Salmonids in a Fourth-Order River

Matthew G. Mitro and Alexander V. Zale

Abstract — We developed a sampling methodology to obtain mark-recapture data to estimate abundances of juvenile rainbow trout in the fourth-order Henrys Fork of the Snake River, Idaho. Abundances of age-0 and age-1 salmonids can be large in such rivers, rendering capture probabilities too small to get good abundance estimates when sampling long (>1 km) river sections by electrofishing. To improve our estimates, we intensively re-sampled multiple 100-m long areas of the Henrys Fork 5 times over 10 days. We thereby captured a higher proportion of the fish in each area and increased capture probabilities. The assumptions of population closure and equal catchability of fish, which must be considered when selecting an appropriate abundance estimator, were evaluated for this sampling methodology. The representativeness of the sample areas was checked by comparing catch per unit effort from transects in a sample area to transects randomly sampled throughout the river section. Increasing the proportion of fish captured resulted in a 32% mean capture efficiency (range, 13 to 59%) and a 6% recapture probability (range, 3 to 10%).

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2 Assistant Leader, Montana Cooperative Fishery Research Unit, Department of Biology, Montana State University, Bozeman, MT.
Habitat, Water Chemistry, and Fish Populations in Five Shenandoah National Park Watersheds

C. Andrew Dolloff and Martin K. Underwood

We used basinwide estimation techniques to examine the influence of habitat quality and water chemistry on fish populations and fish communities in five small watersheds of different acid neutralizing capacity within Shenandoah National Park, Virginia. We identified differences in the depth and large woody debris loading in both pool and riffle habitat among streams. Pool to riffle ratios (P:R) ranged from 0.6 to 0.9 among streams. Fish species richness ranged from two to three species. Brook char (Salvelinus fontinalis) and blacknose dace (Rhinichthys atratus) were the only species common to all five streams. Both species used pools more than riffles. Mean density of adult brook char in pools ranged from 16.0 to 96.0 fish/100 m². Blacknose dace density in pools also varied, ranging from <1.0 to 117.0 fish/100 m². Water quality was responsible for most of the distinction among streams but habitat and water quality together provided the best means to separate streams.

Shenandoah National Park (SNP), located in the northern region of the Blue Ridge Province, has the greatest loading of sulfate of any National Park in the United States (Webb et al. 1989). As a result, stream water in some watersheds in SNP has become vulnerable to episodic and chronic acidification. Increased acidification poses a particular threat to brook trout (Salvelinus fontinalis) and a few other species such as blacknose dace (Rhinichthys atratus) that occur in acid-sensitive headwater streams of the Southern Appalachians (Neves and Pardue 1983). Individual fish and ultimately whole populations suffer when increased acid and aluminum interfere with ion balance (Rosseland et al. 1990; Bulger et al. 1993).

Except for streams where acid is present in extreme concentrations, attributing observed differences among fish communities to acidic conditions alone may be complicated by differences in habitat quantity and quality. Both terrestrial and aquatic habitats in SNP as throughout the eastern United States have been profoundly influenced by over 200 years of changing land use ranging from logging and clearing for agriculture to mining and subsistence homesteading (Doloff 1995).

The “Shenandoah National Park: Fish in Sensitive Habitats” (SNP: FISH) project was begun in 1992 to document the early negative effects of declining pH while accounting for differences in habitat among streams (Bulger et al. 1995). This comprehensive study used a nested approach to account for temporal and spatial variation among geochemical environments, fish habitats, and fish communities. One stream in each of the three major bedrock classes (siliciclastic-low pH, granitic-moderate pH, and basaltic-high pH) was studied intensively for three years. Five additional streams, three low pH and two moderate pH were sampled once in 1994.

In this paper we characterize habitat and fish populations in the five extensively sampled SNP watersheds. We used the basinwide visual estimation technique (BVET) (Hankin and Reeves 1988; Dolloff et al. 1993) to inventory habitat and fish populations in each basin from the SNP boundary to the upper extent habitable by fish (Figure 1). We combined our habitat estimates with basinwide estimates of water quality derived from synoptic water samples collected from habitats in each basin.

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METHODS

Data estimated in each habitat unit (pool and riffle) included habitat unit type (Bisson et al. 1982), length, mean wetted channel width, maximum depth, substrate composition, and number of pieces of large woody debris (LWD) in different size categories (Doloff et al. 1993).

Water chemistry was determined by the University of Virginia’s Shenandoah Watershed Study (SWAS) according to protocols outlined in Ryan et al. (1989). Water samples were taken at 10-20 sites along the length of each stream and linked to specific habitat features.

Fish populations were censused in about 20% of all pools and 15% of all riffles by divers equipped with face mask, snorkel, and writing slate. Divers carefully entered each selected habitat unit and recorded the species, numbers, and relative size (for young-of-year and adult brook trout only) of all fish observed.

After completing underwater observations, the sampling crew selected a fraction (about 10%) of the total number of units snorkeled in which to conduct a multiple-pass removal census (Zippen 1958) with a backpack electroshocker (700V AC). All fish were identified, measured (mm), and weighed (0.1 g) before being returned to their approximate location of capture.

Population estimates for each species (including age 0+ brook trout) were calculated and used to calibrate diver counts of fish by habitat types in each stream. Reach lengths used for calculating population estimates within each stream were truncated at the observed limits of fish distribution.

RESULTS AND DISCUSSION

Since abnormally high flows didn’t occur after the initial inventory of habitat features in each basin, physical habitat conditions were assumed constant for the duration of each survey.

We inventoried between 1.6 and 5.4 km of stream habitat (Table 1). Total area in riffles was greater than in pools; pool to riffle ratios (P:R) ranged from 0.6 to 0.9.

Table 1. Estimates of total habitat area for streams in five Shenandoah National Park watersheds, 95% CI in parentheses.

<table>
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<th>Habitat</th>
<th>Estimated Area</th>
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<td></td>
<td>Pools</td>
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<td>Brokenback</td>
<td>4,892.9</td>
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<td>Meadow</td>
<td>5,391.3</td>
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<td>Shaver Hollow</td>
<td>1,652.7</td>
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<tr>
<td>Twomile</td>
<td>4,161.8</td>
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<tr>
<td>White Oak</td>
<td>3,552.5</td>
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Figure 2. Box plots of maximum depths in five Shenandoah National Park, Virginia, streams. Brokenback = 1, Meadow = 2, Shaver Hollow = 3, Twomile = 4, and White Oak=5.
among streams. All streams were relatively shallow (Figure 2), with bedrock covering the bottoms of at least 22% of all habitat units (Figure 3). Large woody debris loading ranged from about 50 to nearly 200 pieces per stream kilometer (Figure 4).

Twomile and Meadow were the most severely influenced by low pH (Figure 5). Alkalinity and concentrations of calcium and most other base cations also were lowest in Twomile and Meadow.

Diversity of fish species was highest in White Oak Run, where fantail darters (*Etheostoma flabellare*) were present along with brook trout and blacknose dace (Table 2).

![Figure 3. Pie graphs of dominant (covering most of the stream bottom) substrate in habitat units of five streams in Shenandoah National Park, Virginia. Brokenback = 1, Meadow = 2, Shaver Hollow = 3, Twomile = 4, and White Oak = 5.](image)

![Figure 4. Bar graphs of LWD per stream kilometer in five Shenandoah National Park, Virginia streams. Brokenback = 1, Meadow = 2, Shaver Hollow = 3, Twomile = 4, and White Oak = 5.](image)

![Figure 5. Box plot of pH in five streams in Shenandoah National Park, Virginia. Brokenback = 1, Meadow = 2, Shaver Hollow = 3, Twomile = 4, and White Oak = 5.](image)

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<thead>
<tr>
<th>Stream</th>
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<th>BKY</th>
<th>BND</th>
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<td>180</td>
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<td></td>
<td>Riffles</td>
<td>602</td>
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<td>1,921</td>
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Adult brook trout population estimates and densities were higher in White Oak than in any of the other four basins. Blacknose dace population estimates and densities in White Oak were next to highest (Twomile Run had the highest) of the five basins. Fantail darters apparently were
confined to about 1,300 meters in the lower reaches of White Oak Run. Fantail darters were not seen by divers or captured by electrofishing above Luck Hollow (Figure 6).

![Graph showing number of fish by distance and species](image)

Figure 6. Number and approximate location of fish seen by divers in White Oak Run, Shenandoah National Park, Virginia.

About 80% of the brook trout in acid-sensitive Meadow Run were young-of-year fish, more than any of the four other basins. In contrast, only a few blacknose dace were observed by divers in Meadow Run (6 and 2 fish in different pools) and only two were captured in the electrofishing survey (both > 55 mm, total length).

No clear relationship among water chemistry, physical habitat, and fish populations emerged from our analyses. Contrary to what we expected, the population estimate for adult brook trout in White Oak Run was the highest of the five main branches. White Oak Run, Meadow Run, and Twomile Run are among the most acid sensitive watersheds in SNP (Webb et al. 1989).

To better understand the relationship of water chemistry and habitat, we considered all of the data (N=1,824) simultaneously using principal components analysis. Most of the information was contained in three principal components, which accounted for about 72% of the variance (Figure 7). The primary separation among streams occurred in PC-1, where basic water chemistry attributes including pH, alkalinity, and base cations (calcium, sodium, and potassium) explained over 46% of the variance. Factor loadings on the second component were dominated by sulfate and nitrate, both primary constituents of acid precipitation. Surface area of individual habitat units and amount of LWD comprised the most significant loading on PC-3, the "habitat axis." The relative position of Twomile, Meadow, and White Oak reflect the importance of water chemistry in distinguishing these three acid sensitive streams from Brokenback and Shaver Hollow. Differences in LWD loading and surface area help further separate among streams within these two major groupings.

![Diagram showing water chemistry and habitat](image)

Figure 7. Principal component axes for water chemistry and habitat among five streams in Shenandoah National Park, Virginia. M=moderate, H=highly sensitive to acidification.

Except in extreme situations, differences in fish populations and communities in acid sensitive watersheds cannot automatically be attributed to water chemistry alone. Information about both water chemistry and habitat is necessary to distinguish among streams and characterize the potential to support fish communities. Future research and management related to the influence of acidic precipitation on fish communities in acid-sensitive watersheds should account for differences in habitat quantity and quality.

Acknowledgements

We thank our research partners Art Bulger, Jim Galloway, Frank Deviney, and Rick Webb, Department of Environmental Sciences University of Virginia, Charlottesville for their advice and water chemistry data. We also thank John Karish, National Park Service, and the Resource Management Team of Shenandoah National Park for their support and encouragement.
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CUTT-SLAM - Wyoming's Grand Slam for Cutthroat Trout

Ron Remmick

Abstract - The Wyoming Game and Fish Department's Cutt-Slam Program is designed to encourage anglers to learn more about Wyoming's native cutthroat trout species, and develop an appreciation, acceptance, and support for the Department's cutthroat management programs. The Department is currently involved in recovery programs for the Bonneville and Colorado River cutthroat trout sub-species. In addition there has been long standing management programs for the Snake River and Yellowstone cutthroat trout. Each sub-species presents its own management problems, and the Department hopes that participation in the Cutt-Slam will make anglers more aware of the unique role cutthroat play in Wyoming fisheries. To qualify for the Cutt-Slam, anglers must catch all four cutthroat sub-species in their native range. Only photos are required for proof of catch to minimize harvest. It has been emphasized this is not a competition, and as such, there is no time limit to complete the slam. A father/daughter team were the first to complete the Cutt-Slam in 1996 and receive a certificate acknowledging their accomplishment. The father indicated their efforts were not only educational but provided an excellent family experience.
Trials and Tribulations in Brood Stock Development for Rio Grande Cutthroat Trout

William K. Stumpf¹ and David E. Cowley²

Abstract—The New Mexico Department of Game and Fish in 1993 started to develop a hatchery broodstock of Rio Grande cutthroat trout. The first step was to contract with Dr. David E. Cowley to come up with strategies to achieve the goal of developing this brood stock in such a way as to minimize genetic selection and maximize genetic variation. These efforts are intended to replace stockings of non-native trout in wilderness area waters and other sensitive waters within the native range of the Rio Grande cutthroat trout.

Since 1994, efforts have been undertaken to take spawn in the wild so as to achieve the above goal. This has occurred with mixed results. To date there are three year classes from different drainages and next spring we hope to spawn the first two year classes together.

Efforts continue to upgrade the facilities at Seven Springs State Hatchery to accommodate this broodstock and subsequent rearing of juvenile trout.

BACKGROUND

The Rio Grande cutthroat trout, the state fish of New Mexico, like many other native trout have been displaced by other trout species throughout a significant portion of their historic range. Currently the number of populations has declined to less than 7% of their historic range because of habitat degradation, genetic contamination and competition with other trout species.

In an effort to reverse this decline the New Mexico Department of Game and Fish with the help of Sport Fish Restoration Federal Aid dollars instituted a project to identify pure populations of Rio Grande cutthroat trout and restore them into their historic waters. Part of this program is to develop a brood stock of genetically pure Rio Grande cutthroat trout to augment restoration projects and replace current stocking of non native trout with native trout.

Critical information was needed to develop this broodstock. Little life history information is known about the Rio Grande cutthroat trout but it was believed to be similar to other western cutthroats. However exact spawning times, sex ratios, fecundity, age at sexual maturity, and other parameters were not know.

To begin this broodstock program, the New Mexico Department of Game and Fish in 1993 contracted with Envirosat to design a broodstock development manual with strategies that would maintain the wild characteristics of the cutthroat and optimize their genetic diversity.

Through past experiences with trying to build a broodstock of Rio Grande cutthroat trout and the experiences of other states’ efforts to build broodstock with wild trout it was decided to start with eggs taken in the wild and bring them into the hatchery.

FIELD SPAWNING PHASE I

Protocols developed for this broodstock suggested using two streams and cross fertilizing the eggs and milt from each stream. In 1994 this effort was initiated by a small crew who electrofished and collected the milt and eggs from ripe cutthroat trout, placing these in whirl packs on ice, and taking these to Seven Springs Hatchery for fertilization.
Three streams were used (Rito Cañ, Rito de las Palomas, and Río Puerco) for this first effort but not having a good feel for the spawn times resulted in mediocre number of eggs collected (4516). Of interest was the fact that most of the fish spawned over a five day period on Rito Cañ, days that the crew was not there (over Memorial day weekend). Also noted was that the males are ready about two weeks before the females are. Approximately 36% fry hatched out and none of the fry survived after a month. Water quality was suspected as being the culprit and testing showed elevated gas supersaturation as being high and a low head oxygen injection system was built for the water supply to the hatchery building.

Following the protocols set for the broodstock development proved to be difficult. Plans were changed to do stream side spawning, water harden the eggs and then transport them to the hatchery. The following year (1995) two streams were targeted (Chihuahuenos Creek and Canones Creek) which parallel each other. Due to easier access, Canones Creek was monitored till the male trout were ready. Chihuahuenos Creek was checked afterwards only to find out the water temperature was 20 degrees higher and the fish were already spawned out. Plans were changed to concentrate only on Canones Creek and alternating 100 meter stretches were electrofished and the fish placed in in-stream holding nets and spawned on site. In six days 10,172 eggs were collected and taken to Parkview State Hatchery for incubation. In an attempt to get eggs from another source, Rito de las Perchas was targeted and 3,099 eggs were collected and sent to Seven Springs Hatchery. Eye up of the eggs was around 76%. Of these two lots of eggs only 200 fish survived to date. Once the fish get to about two inches in size, mortality is negligible. Up to this point there is a chronic “drop out mortality” which reduces numbers to less than 2% of the eggs collected. Feeding regimes using both specialized commercial feed diet (Biodiet) and brine shrimp was used for initial feeding. Other agencies have used this diet on wild trout with good results but we still had high mortality till the fish reached about two inches.

FIELD SPAWNING PHASE II

Trying to follow the protocols set forth by Cowley proved to be to difficult logistically and it was decided to concentrate on only one stream per year. In 1996 the Río Las Vacas was targeted for spawning operations. Over six days from May 14 through May 24 over 20,000 eggs were collected. The first 7,000 did not survive to the hatchery due to the eggs being held over night and probably being shocked in transport to the hatchery. There was a 50% hatch out rate and another 20% loss till the fry developed good feeding habits. There is approximately 1000 fry left from this lot to date. This effort was done through the peak spawning time and it indicates that from 90+ females spawned one could expect about 20,000 eggs.

This year (1997) spawning operations targeted the Río Puerco. Heavy snow pack limited access to this stream. On June 5 fish were checked and most females were near ripe and all males were ready. A couple hundred fish were collected and transferred by pack animal to holding nets. It wasn’t till June 9 that the first fish were spawned. Over the next 9 days fish were collected and 92 females spawned resulting in 9,168 eggs being collected. Approximately 800 eggs were taken to Parkview Hatchery and only 10% hatched out. An experiment was done to determine if we could increase survival of eggs by eyeing the eggs in the stream and then transporting them to the hatchery. Approximately 1,000 eggs were left in the stream in an incubator tray but none survived to eye up. The eggs were covered with fine sediment and probably suffocated. The remainder of the eggs were sent to Seven Springs Hatchery and approximately 10% hatched out leaving about 800 fry. Due to the low number of eggs per female, we were about a week late in catching the peak of the spawn. Also the low hatch out rate is indicative of low egg and sperm quality. Figure 1 shows the comparison of eggs taken and fry hatched over the past four years.

**BROODSTOCK AT SEVEN SPRINGS STATE TROUT HATCHERY**

This spring the brood fish from the 1994 spawn were tagged with visible implant tags and checked for spawning condition. Fish were anesthetized prior to being handled and recovered in a solution of salt and Polyaqu to minimize fungus and then placed in an outside raceway. The average size of the 280 fish tagged was 210 millimeters. Of the fish tagged only eight were definite females with eggs. These were fertilized with males but none of the eggs survived. These fish were checked about ten days to
late for peak spawning time. Also two year old females may not produce viable eggs.

Four new troughs are on order to replace some of the older ones inside the hatchery building. These trough will provide better conditions for the fry after hatch out till the fish are four to five inches long. Next spring we should have three year old broodstock from Canones Creek and Rito de las Perchas to spawn with two year olds from the Rio las Vacas.

**SUMMARY**

Although the development of a Rio Grande cutthroat trout broodstock has been slow, the information gained each year about the life history of these fish has been invaluable. The size range of mature females is 107 to 261 millimeters and the mean number of eggs per female is 175. The males are ready approximately two week before the females and mature at age two. Spawn times is triggered and occurs based on day length and water temperature regardless of water volume. In 1995, fish in the Rio las Vacas spawned despite flood level flows from a late springs snow. Probably the most important lesson as far as collecting eggs in the wild is timing is everything. Rio Grande cutthroat trout will spawn over a four week period with the majority of the fish spawning within a few days. Figure 2 shows thermograph data for the spawning period this year. Once the snow melt was nearly gone then water temperatures rose fairly quickly. The fish responded to this increase and started to spawn shortly thereafter. The younger fish tend to be the first and last ones to spawn. Eggs numbers and quality decrease as the spawn goes on as does the melt from males. Partially spent female eggs and males whose melt has gotten watery are not very viable.

Wild trout fry are much more vulnerable to lower water quality as found out with gas saturation at Seven Springs Hatchery. Levels that have little effect on rainbow trout fry will kill Rio Grande cutthroat fry. Eggs just fertilized are extremely fragile and are difficult to transport even after water hardening. Wild trout fry are hard to get started on feed and as a result high drop out mortality is experienced. Once
the fry start to feed well and get above two inches long then mortality is negligible. Brood fish, especially the males, get very active prior to spawn in the raceways and tend to get bad cases of fungus.

Over the past four years of trying to take spawn in the wild we have been successful in timing it two out of four. Getting the eggs is just the beginning in trying to get these fragile creatures up to maturity to be used for brood stock. Figure 1 again shows the losses that we have encountered in our efforts. To date we have but 280 adult Rio Grande cutthroat brood which is only 2% of what we started out with. As time goes on and we develop better techniques this should improve. Each generation should be a little easier to get to survive but hopefully not at the expense of their wild characteristics.
Initial Investigations Towards the Development of a Lake Trout Removal Program in Yellowstone Lake

Daniel L. Mahony and James R. Ruzycki

Abstract—In 1994, non-indigenous lake trout (Salvelinus namaycush) were discovered in Yellowstone Lake, Yellowstone National Park, Wyoming. Unfortunately, this piscivore is a threat to the indigenous Yellowstone cutthroat trout (Oncorhynchus clarki bouvieri) and the aquatic and surrounding terrestrial ecosystem. Surveys conducted during 1996 showed the presence of multiple age-groups including mature adults >20 years old. Evidence that a major population expansion is underway included a summer gill-net catch of nearly 600 lake trout including more than 130 adults that exceeded 600 mm body length. Because of the presence of large, reproductive lake trout and the desire to minimize cutthroat trout by-catch in gill-nets, we directed our attention to the capture and destruction of spawning and pre-spawning adults. Cutthroat trout were found to be the primary prey of large lake trout. Total lake trout biomass caught in large mesh nets (>64 mm measure) exceeded 800 kg. Anglers caught and reported another 180 lake trout.

Most adults were captured in the vicinity of West Thumb, one of the hypothesized introduction sites. Radio telemetry and near-shore gill netting helped locate spawning areas. The removal of spawning fish was considerable; however, we now have to estimate the proportion of the population removed and whether a similar annual program will preserve this premier, lacustrine cutthroat trout fishery.

INTRODUCTION

Introductions of non-native fish species into native trout populations have been widespread throughout the western United States. Population and ecosystem level impacts of historical introductions are only beginning to be fully understood, but the effects on native fish communities include a spectrum of influences from a shift in diet preference to complete elimination of some local native populations (Magnuson 1976, Moyle et al. 1976). Western salmonids, including the Yellowstone cutthroat trout Oncorhynchus clarki bouvieri seem to be especially susceptible to negative interactions with introduced non-native species (Griffith 1988, Behnke 1992). Additional stresses attributed to environmental degradation, habitat fragmentation, and overfishing may increase the vulnerability of specific native populations to depression by introduced non-native species.

With the exception of angling, geographical isolation of Yellowstone National Park has excluded most human-associated impacts to Yellowstone cutthroat trout. Recognition of overharvest in Yellowstone Lake in the mid-1960's resulted in numerous regulatory protections that appeared to provide a secure status for this, the world's largest cutthroat trout population (Gresswell and Varley 1988). After lake trout Salvelinus namaycush were caught in the lake in summer 1994, however, the future of the Yellowstone Lake cutthroat trout became questionable at best.

Because lake trout become piscivorous after they mature and can grow larger than 25 kg (Scott and Crossman 1973, IGFA 1996), the National Park Service (NPS) took a position of preparing for the worst and solving the "lake trout problem" became the park's number one fishery priority. National Park Service management, in conjunction with the U.S. Fish and Wildlife Service (USFWS), decided that immediate

1 National Park Service, Aquatic Resources Center, Yellowstone National Park, WY 82190; 307/344-2285, FAX 307/344-2323.
action was needed to define the scope of potential impacts of this previously unknown introduction. A program to control lake trout numbers could prevent a significant reduction or potential elimination of the Yellowstone Lake cutthroat trout (McIntyre 1995). In spring of 1995, a group of fishery biologists indicated that, based on their experiences and case histories from the Great Lakes and other U.S. and Canadian lakes, the best techniques available for reducing lake trout populations encompass intensive gillnetting, trapping, and increased angler effort (McIntyre 1995).

The well-established biological, social, and economic value of Yellowstone cutthroat trout throughout its historical range (Loomis and White 1996) and particularly in the park generated a tremendous amount of interest from the popular press, national media, angler groups, and concerned citizens. Numerous suggestions and solutions to the as yet undefined lake trout problem were proffered. Historical data and "conventional wisdom" suggested that cutthroat trout in Yellowstone Lake are primarily a littoral species residing in water less than 20 m deep (Benson 1961), where surface water temperatures are rarely higher than 18°C. In contrast, lake trout typically reside in deep water colder than 13°C (McAlpine 1966, Martin and Oliver 1980). Thus, vertical separation of the two species should be greatest during summer lake stratification and facilitate reduction of lake trout populations with gillnetting. Preliminary netting in September and October 1994 revealed that, although their abundance declines with depth, some cutthroat trout can be found to at least 45 m in Yellowstone Lake (Kaeding et al. 1995). Thus, the vertical separation by temperature between cutthroat trout and lake trout was not as great as originally anticipated. The goal of this study is to develop a program to preserve the cutthroat trout in Yellowstone Lake basin by reducing the lake trout population to a level where negative impacts on the cutthroat trout population would be acceptable. Specific objectives necessary to achieve this goal include:

- Define the spatial, vertical, and seasonal distribution of lake trout in Yellowstone Lake
- Determine spatial, vertical, and seasonal distribution of cutthroat trout in order to minimize gillnet bycatch
- Locate lake trout spawning grounds

In addition, detection of the length when lake trout first spawn and the length when they initiate feeding on cutthroat trout could be useful for refining the long-term lake trout control program. We intend to adopt new techniques or modify present sampling schemes as we acquire better information. In this paper, we describe the evolution of our techniques and strategies used to define impacts of introduced lake trout on cutthroat trout in Yellowstone Lake.

METHODS

During the study design phase of this project, several impediments to immediate robust analyses became apparent. Because Yellowstone Lake is nearly 36,000 hectares in size, sampling a sufficient number of sites was determined to be logistically prohibitive in the short term. Secondly, nearly all of the historical studies associated with Yellowstone Lake have focused on the near shore adult portion of the cutthroat trout population. Information about juvenile cutthroat trout and population characteristics of cutthroat trout in deeper waters is extremely limited. The potentially catastrophic impact of a lake trout introduction did not allow NPS the luxury of initiating a multi-year "pre-treatment" study to correct these data shortcomings. Rather, the experimental netting program was started at the earliest possible date.

Gillnet Surveys

1994

In the initial phases of this program, USFWS biologists visually selected gillnetting locations based on site characteristics (i.e., rocky points, cold water temperature) typically classified as suitable lake trout habitat. Depth of water where nets were set gradually increased during the late fall netting effort. Nets were set overnight and retrieved the following day. Each net was 38 or 76 m long, 1.8 m wide, and consisted of a series of 7.6 m-long panels of graduated monofilament mesh ranging in size from 19 to 51 mm "bar measure" (side cf a square).

All gillnets were set on the bottom of the lake. Approximate water depth at each end of these multmesh "monitoring" nets was estimated with a portable Hummingbird sonar ("fish finder"). GPS coordinates provided approximate surface location...
to assist in net retrieval. All fish in each net were separated by species. Length, weight, and scales were collected from cutthroat and lake trout. Additionally, stomach contents were examined, and otoliths removed from lake trout for age and growth analyses. Data collection from longnose suckers *Catostomus catostomus* was restricted to length, weight, and stage of sexual maturity. Stage of maturity of salmonids was estimated visually and verified by use of the Gonadosomatic Index (GSI; weight of gonads divided by body weight).

**1995**

After the panel of experts met in 1995, the USFWS planned to gillnet a random subsample of 12 areas of Yellowstone Lake picked by lake trout biologists from Lake Superior (Figure 1). In order to elucidate preferred lake trout seasonal locations, the study plan called for sampling each selected area prior to, during, and after lake stratification. At each "monitoring" site, one 100 m-long 38 mm-mesh and one 100 m long 51-mm mesh nets were set with two 76 m-long multimesh nets. In most cases, each group of gillnets fished for three nights before they were retrieved; however, on several occasions, unsafe weather conditions or logistic constraints changed the standard netting protocol to two or four nights before the nets were pulled.

All data types collected in 1994 pertaining to net location and captured fish were also recorded in 1995. In addition to being segregated by net, fish were also sorted by mesh size to facilitate analyses of capture efficiency by mesh size. Because unequal sizes of nets were used and netting effort was not uniform among the monitoring sites, catch rate was standardized in terms of catch per 305 m/night of effort. For this study, a "meter-night" is defined as one linear meter of gill net set overnight for one night. Thus, in the standard set, one 76-m multimesh net set for three nights represented 228 m-nights of netting effort.

Lake-wide catch totals for the entire year, for each week and month and by monitoring site were examined. The difference in water depth between the shallow and deep end of any particular gillnet was less than 30 m for all but a minority of the nets set in 1995. Catch effort data were subsequently partitioned into overlapping 30 m vertical depth strata. Those few nets that encompassed more than 30 m of depth were assigned to the vertical stratum containing the deep end of that particular net. Bycatch of cutthroat trout was analyzed on annual total and on standardized effort bases. Results from 1995 were used to modify the 1996 sampling scheme.

**1996**

Because the USFWS office was scheduled to close in summer 1996, NPS fishery staff took over the gillnetting program that year. We continued to use the same groups of monitoring gillnets in 1996, but set these nets deeper in order to reduce potential cutthroat trout bycatch. The eight monitoring sites included the four sites sampled in 1995 and additional nearby "replicate" sites. This expanded sampling scheme provided for repeated netting in most of the major subbasins of Yellowstone Lake.

Most of the netting effort in 1996 focused on defining the distribution of large size classes of lake trout by sampling with larger (64 to 102 mm bar measure) "experimental control" gillnets. Each of these nets was 100 m long and consisted of a single-size mesh. Experimental control nets were set at locations that staff personnel judged to be suitable lake trout habitat based on underwater lake topography, seasonal depth of the thermocline, and areas of high angler catch rates (Figures 2 and 3). If lake trout were captured at a specific site, another set of nets was set at that site for at least one more night.
A visual survey in 1994 suggested that about 1/3 of the lake shoreline might be suitable lake trout spawning substrate (Kaeding et al. 1995). Beginning in mid-September 1996, an additional netting program was undertaken to attempt to find spawning lake trout. Ripe male lake trout were captured near Carrington Island, where several nets ranging from 51 to 102 mm bar measure were set continuously for a period of three weeks. Other nets were set simultaneously at numerous other locations (Figure 4), including some of the rocky substrate areas identified by Kaeding et al. (1995) and others (M. Maiolne, pers. comm.; C. Bronte, pers. comm.). Captured lake trout were measured, weighed, and their stomachs and otoliths were removed. Ovaries from a subsample of females were removed for fecundity estimates; however, those analyses are not yet completed.

**Angler Catch**

After lake trout were known to be in Yellowstone Lake, NPS changed the angling regulation in Yellowstone Lake to "total-kill" for lake trout. Anglers were also required to bring their catch to a local visitor center, ranger station, or the Aquatic Resources Office, where verification of catch, length,

**Figure 2.**—Map of Yellowstone Lake showing location of sites where large lake trout were sampled with large (> 51 mm mesh) nets in 1996.

**Figure 3.**—Locations of reported angler-caught lake trout, 1996.

Literature reviews and panel discussions suggested that concentrations of adult lake trout spawners would be susceptible to intensive netting when spawning began in the late fall; however, locations of verified spawning sites were unknown.

**Figure 4.**—Yellowstone Lake locations sampled for spawning lake trout.
weight, and catch location of lake trout were obtained. In many cases, weights were not obtained from angler-caught lake trout. We estimated weight of these individual fish by using the mean weight of similarly sized lake trout captured in gill nets in that particular year. These data could then be applied to length frequency and spatial distribution analyses in concert with gillnetting results.

RESULTS

1994

Pilot monitoring Study

Slightly less than 4,000 m-nights of effort during September and October yielded 492 cutthroat trout and 21 lake trout, resulting in an approximate cutthroat trout to lake trout catch ratio of 250:1 (Table 1). Detailed discussion of the cutthroat trout distribution and length structure is contained in Kaeding et al. (1995, 1996). Both lake trout were small fish (318 and 203 mm in length) captured at depths greater than 15 m. The two verified angler-caught lake trout were considerably longer (419-432 mm) and presumably older than the net-caught fish and weighed about 0.5 kg each.

1995

Monitoring Nets

Increased effort of 25,000 m-nights of netting with the “monitoring” multimesh gillnets yielded more than 1,000 cutthroat trout and 153 lake trout, resulting in an annual cutthroat trout:lake trout ratio of 7 to 1 (Table 1). Monthly catch of cutthroat decreased throughout the summer, while the lake trout catch showed the opposite trend.

The largest lake trout (527 mm) was captured in the southeastern portion of West Thumb in mid-June. Nearly all of the lake trout we captured were much smaller, however; average length of all netted lake trout was only 290 mm. Mean weight of these fish was 254 g. Estimated total biomass of lake trout removed from Yellowstone Lake during the 1995 monitoring program approached 40 kg.

None of the lake trout captured in 1995 appeared to be active spawners, i.e. “ripe” fish. Only two of the lake trout (both males) had a GSI greater than 1%, a value commonly associated with spawning male lake trout (Martin and Olver 1980).

Cutthroat trout were often caught in the same nets with lake trout down to depths as great as 60 m. This overlap in vertical distribution compromised the program objective of minimizing cutthroat trout bycatch during the gill net operations. When data for the entire 1995 gill net season was partitioned into overlapping 30-m strata, however, the cutthroat trout:lake trout catch ratio was greater than 50:1 in the shallowest stratum, but decreased to 1.5:1 between 30 and 60 m depth (Table 2).

A positive relationship commonly observed between gillnet mesh size and length of captured trout (Hamley 1975) appeared to apply to netting

Table 1.—Results of gillnetting surveys from Yellowstone Lake, 1994-1996. Effort (total) is expressed in linear meters of net times number of nights set. Capture rate is defined as number of fish caught per 305 m-nights of netting effort.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort</td>
<td>3915</td>
<td>24957</td>
<td>23592</td>
<td>80109</td>
<td>15403</td>
</tr>
<tr>
<td>Number of cutthroat trout caught</td>
<td>492</td>
<td>1033</td>
<td>439</td>
<td>294</td>
<td>128</td>
</tr>
<tr>
<td>Cutthroat trout capture rate</td>
<td>37.8</td>
<td>12.6</td>
<td>5.7</td>
<td>1.1</td>
<td>2.53</td>
</tr>
<tr>
<td>Number of lake trout caught</td>
<td>2</td>
<td>153</td>
<td>193</td>
<td>186</td>
<td>153</td>
</tr>
<tr>
<td>Lake trout capture rate</td>
<td>0.2</td>
<td>1.9</td>
<td>2.5</td>
<td>0.6</td>
<td>3.01</td>
</tr>
<tr>
<td>Number of longnose suckers caught</td>
<td>88</td>
<td>74</td>
<td>70</td>
<td>6</td>
<td>84</td>
</tr>
<tr>
<td>Longnose sucker capture rate</td>
<td>6.8</td>
<td>0.9</td>
<td>0.9</td>
<td>0.02</td>
<td>1.7</td>
</tr>
<tr>
<td>Cutthroat trout - lake trout capture ratio</td>
<td>252:1</td>
<td>6.6:1</td>
<td>2.3:1</td>
<td>1:8.1</td>
<td>0:6:1</td>
</tr>
</tbody>
</table>

Table 2.—Number of fish caught per 305 linear meters of gillnet per night, Yellowstone Lake, 1995. Effort is annual total of m-nights for all nets set within the specified depth range.

<table>
<thead>
<tr>
<th>Depth set (m)</th>
<th>Effort</th>
<th>Cutthroat trout</th>
<th>Longnose suckers</th>
<th>Lake trout</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 30</td>
<td>4650</td>
<td>37.64</td>
<td>3.02</td>
<td>0.66</td>
</tr>
<tr>
<td>15 - 45</td>
<td>4930</td>
<td>12.18</td>
<td>0.87</td>
<td>1.05</td>
</tr>
<tr>
<td>30 - 60</td>
<td>10810</td>
<td>4.74</td>
<td>0.14</td>
<td>3.53</td>
</tr>
<tr>
<td>45 - 75</td>
<td>4570</td>
<td>6.80</td>
<td>0.60</td>
<td>0.53</td>
</tr>
</tbody>
</table>

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Similar to cutthroat catch results, males outnumbered females by 2 to 1. These sex ratios were relatively constant throughout the field season. Females were larger by an average of 1.5 cm and about one-third kg. Similar to cutthroat trout results, 76-mm mesh was most effective for catching large lake trout (2.7 lake trout/305 m-nights of effort).

**Spawner Nets**

When surface water temperatures began to decrease in mid-September, shallow-water nets were set to detect potential locations of prespawning lake trout. During the next three weeks, 28 different locations ranging from 0.6 to 40 m depth were sampled (Figure 4). After a ripe male lake trout was captured near Carrington Island on Sept. 19, intensive netting and electrofishing efforts commenced. To ensure that the smaller spawning lake trout were caught, about 20% of the netting effort consisted of 51-mm mesh nets. A total of 178 lake trout were captured in the area. An additional immature lake trout was also captured at sites near Grant village and in Breeze channel. No evidence of spawning lake trout was found at any location in the lake other than Carrington Island.

Average length of spawning lake trout was about 2 cm shorter than the fish captured in the experimental control nets, but the longest lake trout of the year (89 cm) was captured during the spawning season. Three quarters of the spawning fish were identified as males. Females were generally larger by about 0.75 kg. Combined biomass of all spawning lake trout removed was just under 425 kg. The three smallest mesh sizes were effective in capturing at least 3.5 lake trout spawners/305 m-nights at Carrington Island.

This spawning survey was the only netting program where fewer cutthroat trout than lake trout were captured. Length distribution, average size, and sex ratios of cutthroat trout captured in the spawner nets was similar to that observed from the experimental control nets. Slightly less than one-third of the cutthroat trout captured during the spawner survey were caught at Carrington Island. Total biomass of cutthroat captured from all areas surveyed was 73.2 kg.

The spawning survey was also the only netting effort where longnose suckers constituted more than 20% of the total catch. The highest catches came from the eastern side of West Thumb, but only two longnose suckers were caught at the spawning ground by Carrington Island. Although males and females were similarly sized (47.5 cm long and 1.3 kg), females outnumbered males by about 50% in these shallow water sets. Total biomass of suckers removed during the spawning survey was 110.9 kg.

**Angler Catch**

In 1996, distribution and length data were also obtained from 168 angler-caught lake trout. Average length was 513 mm and average weight was 1170 g. Although the largest lake trout of the year was an 84-cm female weighing nearly 9.5 kg captured near Carrington Island, 90% of the angler-caught lake trout were less than 56 cm in length (Figure 6). Estimated total biomass of these 168 lake trout was 198.3 kg.

Expansion of this biomass to the estimated total angler catch of 602 lake trout suggests that anglers may have removed more than 700 kg of lake trout from Yellowstone Lake in 1996.

**DISCUSSION AND CONCLUSIONS**

The initial three years of gill netting in Yellowstone Lake indicate that the lake trout population is composed of numerous size classes that include mature spawners in addition to immature fish. Length structure and preliminary age analyses of the population suggest that some of the lake trout may have lived in Yellowstone Lake for more than 20 years. Distribution of lake trout >600 mm appears to be limited to the West Thumb area, but smaller lake trout are found in most areas except the arms in the southern part of the lake. Vertical distribution of larger lake trout appears to be restricted primarily to depths < 30 m.

A major shortcoming of our current understanding of the effects of the lake trout introduction on the indigenous cutthroat trout is the lack of an accurate population estimate for lake trout. Assuming that gillnet catch rates provide an indirect estimate of lake trout abundance, similar catch rates between 1996 and early 1997 suggest that the current experimental control program may be effective in removing large lake trout from Yellowstone Lake. Catch rates in the control nets in 1996 did not vary substantially throughout the sampling period.

In contrast, the catch rate for lake trout in smaller mesh monitoring nets fluctuated on a seasonal basis. In the vertically partitioned data from 1995 (Table 1),
the relatively equal catch rate observed between lake trout and cutthroat trout was heavily skewed toward smaller lake trout. Similar results were observed in 1996 when most of the monitoring nets were set in deeper water. Inconsistent catches together with the highest lake trout catch per effort suggest that smaller lake trout constitute most of the existing population. The increase in total numbers of lake trout captured is expected to continue for the foreseeable future. When the smaller lake trout mature and begin eating cutthroat trout in the next several years, impacts to the cutthroat trout population are expected to increase significantly.

The most efficient mesh sizes for removing the small lake trout are also those that are highly effective on cutthroat trout. Despite our intention to minimize cutthroat trout bycatch, we captured twice as many cutthroat trout as lake trout during 1996. Cutthroat trout appeared to be vulnerable to almost all mesh sizes. Modifications in netting techniques, such as pulling gillnets daily, may help to further minimize cutthroat trout mortality.

Comparison of length frequency distributions among the various netting surveys in 1996 revealed a scarcity of lake trout between 450 to 550 mm (Figure 6). This could be due, in part, to use of improper mesh size for these particular sized lake trout, or this size group comprised a minor proportion of the population. The latter is probably false because most of lake trout caught by anglers in 1996 were in this size range. A more likely explanation is our sampling scheme. To minimize cutthroat bycatch, we intentionally avoided netting in shallow water (<7.5 m) throughout the year. Most of the angler catch was reported from 3-5 m deep, which suggests some spatial separation of 450 to 550 mm lake trout from other size groups.

Conversely, length-frequency distributions of lake trout in the experimental control nets and the spawner nets were similar. Analyses of GSI are not complete at this time; however, visual examination of gonads of lake trout captured in the control nets suggested that more than 90% of those fish would have spawned in 1996. Thus, the current netting program can be viewed as a two part effort to remove spawning lake trout not only at the spawning grounds but throughout the field season.

Development of a removal program for lake trout contains numerous uncertainties, but it is not unprecedented. The dramatic decline of lake trout populations in the Great Lakes earlier this century has been partially attributed to commercial scale gillnetting. A program similar to the one we are undertaking has been in effect at Lake Annsjon in Sweden (Paulrod and Redin 1996), where an unofficial introduction of lake trout threatened the persistence of the native Arctic char (Salvelinus alpinus) in that lake. A program of lake trout “population reduction fishing” was initiated in 1991. Similar to our efforts, their study focuses on reducing the number of spawning lake trout and monitoring long-term trends in abundance and size structure of the spawning population.

Preservation of the cutthroat trout in Yellowstone Lake will require a permanent commitment by NPS to remove lake trout. Refinements to our netting protocol will undoubtedly be necessary in order to focus on specific size groups of lake trout and further reduce cutthroat trout bycatch. As our experimental netting program continues during the next few years, we hope not only to reduce lake trout impacts on the cutthroat trout population, but also to increase our understanding of interactions of these two species.

ACKNOWLEDGMENTS

As with any project of this magnitude, numerous individuals have contributed to the field effort, particularly National Park Service fishery personnel including J. Lutch, M. Burnett, K. Coffin, B. Ertel, J. Shaeffer, and S. Troop. Initial sampling and study design were developed in conjunction with G. Boltz, D. Cart, and L. Kaeding of the U.S. Fish and Wildlife Service. M. Maiolie of Idaho Game and Fish Department provided preliminary lake trout population assessments and D. Beauchamp of Utah State University participated in study design discussions. C. Bronte (BRD—USGS, Ashland, Wisconsin) demonstrated commercial netting techniques applicable to our field studies. J. D. McIntyre reviewed the initial draft of this paper and suggested many helpful changes.
LITERATURE CITED


Application of Two Habitat Evaluation Frameworks for Management, Protection, and Rehabilitation of Wild Trout Habitat in Watershed Planning

J.G. Imhof¹, J.E. FitzGibbon², J. Scott³, and C.N. Blackwell⁴

Abstract—Two different habitat evaluation frameworks are applied to evaluate the data collected for three subwatershed plans recently completed in southern Ontario. These two frameworks address various data needs for: specific species habitat requirements at three geographic scales; and habitat/channel morphology management and design at the same three scales for management, design and rehabilitation.

A comparison between the two frameworks and the watershed studies provides an assessment of the present utility of Watershed/Subwatershed Planning as a tool in wild trout habitat management. The comparison also notes changes and modifications that need to be made both to the frameworks and to the watershed planning process to ensure that Watershed Planning collects relevant information for managers of wild trout populations.

INTRODUCTION

There is a strong and growing trend towards watershed planning in North America (USEPA 1996; OMOEE/OMNR 1993a,b,c), England (e.g. Gardiner 1988, 1990) and Australia (e.g. Mitchell 1987). This change from site or local-based planning and management has occurred because of the realization that in order to protect, manage and enhance landscapes cause:effect relationships within logical, ecological units of landscape must be examined. Where water and the resources dependent upon water are concerned, the fundamental geographic unit of analysis and management appears to be the watershed.

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The approach to Watershed Management and Planning (WMP) varies from country to country, State or Province. In some jurisdictions it is a community-based initiative relying upon basic information and interpretation to determine courses of action for protection and restoration of lands and waters. In other jurisdictions it is driven by agencies with cooperation and participation of citizen groups and other stakeholders. Whatever approach is taken biologists, foresters, planners, engineers, interest groups and politicians are now endorsing a watershed approach to the management of landscapes.

In Ontario, Canada there was an evolution in water-based analysis and management over the last 20 years from studies exclusively examining flooding, water quality, erosion and servicing considerations to full-scale watershed and subwatershed studies that began in the early 1990’s. Present watershed plans are cooperative efforts of stakeholders, municipalities and government agencies to create a management plan for resources within the watershed. The goal of watershed planning is “to provide a framework to protect, maintain and restore a healthy natural watershed system, balancing environmental, social
and economic needs. Four major reasons have been put forward for the initiation of WMP in Ontario (OMNR/CVC 1995):

1. Environmental Resource Management

Plans are developed to emphasize environmental protection and management.

2. Land Use Changes and Environmental Management

Environmental and land use strategy studies determine where land use changes can be allowed in urbanizing watersheds. The studies focus on avoiding, mitigating or at worst minimizing harmful impacts on the environment.

3. Land Use Management

Watershed Planning is used in areas where there is no change in use, but a new approach to land management is needed to protect or improve environmental resources (e.g. agricultural lands).

4. Redevelopment and restoration

Watershed plans are intended to provide information and a plan to guide management of land and water interactions in order to protect the health of the watershed ecosystem. These plans are intended to recommend how water resources are to be protected and improved as land uses or land management changes. In addition, these broad-scale plans set the stage for smaller, more specific subwatershed or site management plans. Subwatershed plans reflect the goals of the watershed plan and are tailored to the needs and issues related to sub-basin within the overall watershed. They tend to be more detailed.

Objectives of Watershed/subwatershed planning can include (but not be limited to):
• Protection of natural resources, including water supply;
• Protection, enhancement and restoration of fisheries and aquatic resources;
• Protection of water quantity and quality;
• Preparation of land management and infrastructure plans;
• Identification of future development and economic opportunities;
• Reduction of remediation costs;
• Protection of natural resources from inappropriate land use change;
• Reduction of barriers to development and stream lining of approval processes.

In Ontario between 1990 - 1995, 87 watershed/subwatershed plans have been initiated, and 57 have been completed (OMOE/OMNR 1997). Approximately 21 of the 57 completed plans are basins that contain healthy, degraded or (in one basin) extirpated wild trout populations. Prior to settlement these 21 watersheds historically contained wild brook trout (Salvelinus fontinalis) populations. Most now sustain a mixed population of self-reproducing brook trout, brown trout (Salmo trutta) and rainbow trout (Oncorhyncus mykiss) populations.

River systems and their valleys are products of watersheds and subwatersheds. Concurrent with the development of the watershed approach to planning and management in Ontario, was an interest in creating an integrated approach to the management of stream channels, their riparian/floodplain zones and the aquatic and terrestrial life found in these areas of the watershed. To that end in 1991, Ontario began an initiative entitled the Natural Channel Systems (NCS) initiative. The Natural Channel System initiative endeavour to protect, manage, design and restore stream channels and their associated riparian zone, floodplain and valley so that they are naturally functional, dynamically stable, healthy, productive, and sustainable (OMNR 1994). The Natural Channel System initiative recognizes three major scales of analysis and planning: watershed; reach and site. The watershed scale relates to the same scale of planning as the Watershed/subwatershed planning processes. A reach is defined as a homogeneous unit of channel and valley exhibiting a similar channel form, valley gradient and width and general soils and can be as short as 2 meander wavelengths or may continue for many kilometres. A site is defined as a riffle or pool within a reach (see definition in OMNR 1994; Imhof et al. 1996). Objectives of the Natural Channel System initiative can include (but not be limited to):
• Protection, maintenance and enhancement of aquatic habitat;
• Management and protection of riparian/floodplain wetlands;
• Management and protection of riparian zones and floodplains for wildlife;
• Conveyance and storage of sediments;
• Conveyance and storage of floodwaters within an active floodplain.
- Improvement of water quality;
- Design or maintenance of a functional dynamically stable channel form in concert with other uses (e.g. agricultural drainage urban drainage);
- Reduction of long-term channel and floodplain maintenance costs.

NCS and WMP have evolved somewhat together because of the realization of river degradation in the face of landuse management and landuse change and the need for sound information for long-term planning and environmental protection and restoration in the face of competing resource and land use interests. Both are ecosystem-based in approach in that the unit of management and measurement is a geographically definable unit and the management prescriptions are developed by examining the functional relationships between the living and non-living systems with these units. Both initiatives exhibit parallel hierarchical analytical and management structures (e.g. watershed, subwatershed, site and watershed, reach and site) with NCS using homogeneous valley/stream reach as the focus of analysis and management (with regard for watershed context) and WMP using Subwatershed as focus for major implementation and planning direction.

In general the NCS approach acts as an implementation process for stream corridor management in subwatershed and watershed implementation strategies. However, the NCS can be undertaken in the absence of Watershed or Subwatershed planning although this entails much more watershed level data collections.

The overall management objective of watershed planning is to provide decision-makers with a broad understanding of ecosystem function and status, and to develop recommendations for appropriate resource management in the watershed. In Ontario a variety of issues have been addressed by watershed/subwatershed studies (Table 1).

As can be seen from Table 1, almost all of the 87 studies address aquatic life/fisheries issues and most are concerned with stream flows, flooding and channel structure in one way or the other. Therefore the output of WMP should be development implementation strategies to address the major issues and where appropriate to support restoration and habitat protection projects and support of monitoring and reporting strategies. Of the 57 completed plans, 57 have completed implementation strategies, 39 of these are being implemented, 26 have monitoring strategies and 19 of these are actually being monitored (OMOE/OMNR 1997).

With the release of guidelines for the Natural Channel Systems approach (OMNR 1994) numerous projects have been initiated in Ontario to rehabilitate and design degraded channels into more functional forms. Given the issues and monies involved in these WMP studies and NCS undertakings, it is imperative that before it proceeds too far, we should ensure the data collected in both these initiatives provides us with a strong basis for protection, management and restoration especially for wild salmonid habitat management.

This paper is a preliminary evaluation of two frameworks and three watershed studies in terms of utility of information collection for protection and restoration of wild salmonid populations and habitat. As managers, we must ask the question, do these plans provide sufficient information to generate a reasonable level of management support? The paper examines in detail the linkage between three watershed plans and trout habitat requirements in terms of suitability of information for protection and

<table>
<thead>
<tr>
<th>No. of Projects</th>
<th>Study Issue</th>
<th>No. of Projects</th>
<th>Study Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>74</td>
<td>Surface water-flooding</td>
<td>29</td>
<td>Agriculture</td>
</tr>
<tr>
<td>74</td>
<td>Aquatic life/fisheries</td>
<td>22</td>
<td>Transportation</td>
</tr>
<tr>
<td>73</td>
<td>Surface water quality</td>
<td>18</td>
<td>Aggregates</td>
</tr>
<tr>
<td>71</td>
<td>Surface water-stormwater</td>
<td>13</td>
<td>Municipal water</td>
</tr>
<tr>
<td>58</td>
<td>Surface water-low flow</td>
<td>13</td>
<td>Municipal sewage</td>
</tr>
<tr>
<td>57</td>
<td>Stream channel/buffers</td>
<td>11</td>
<td>Private/communal water</td>
</tr>
<tr>
<td>44</td>
<td>Groundwater quality</td>
<td>10</td>
<td>Private/communal sewage</td>
</tr>
<tr>
<td>43</td>
<td>Wetlands/Areas of Natural &amp; Scientific Interest</td>
<td>1</td>
<td>Waste disposal</td>
</tr>
<tr>
<td>39</td>
<td>Groundwater quantity</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
rehabilitation programs and projects. Conclusions and recommendations are presented on ways to improve relevant data collection for use in managing populations of wild trout. Often these types of evaluations are not carried out early in a new process, thereby allowing inefficiencies to occur in data collection or perpetuating inappropriate, wasteful or useless information for management.

THE APPROACH

We selected three completed subwatershed studies undertaken in Ontario between 1991 and 1997 (Table 2) for analysis. Each of these subwatersheds presently contain wild resident brook and/or brown trout populations in various levels of health. We employed two different evaluative frameworks developed in Ontario that identify potential types of variables required to diagnose and manage stream environments for aquatic habitat (Imhof et al. 1996; OMNR 1997). This is not to say that other evaluation frameworks or approaches could not be used (eg. see review by Fausch et al. 1988).

Imhof et al. (1996) provide a hierarchical evaluation system at three scales (watershed, reach, site) with a suggested list of attributes and variables at each scale. They also describe a format for structuring habitat information for different life stages or states of a particular species. This format is used to define the habitat requirements of two trout species in the region using an extensive literature review and consultation with experts. The format identifies the dynamic and static habitat attributes required at each stage or state of two these trout species.

OMNR (1997) identifies a hierarchical planning and design approach for the Natural Channel Systems initiative which uses the same hierarchy as that proposed by Imhof et al. (1996) and the WMP process. The NCS planning and design approach identifies nine basic analytical/design steps and the types of data required and recommended analytical approaches for three major disciplines involved in NCS management: biology/ ecology; engineering; and geomorphology.

Using the hierarchical watershed and reach cause:response format defined in Imhof et al. (1996), key state variables, process variables, response variables and habitat variables defined by the evaluation approaches of Imhof et al. (1996) and OMNR (1997) were collated. For each of the three subwatershed studies, variables used in each study were identified as present and grouped according to where they provided information (i.e. watershed analysis or reach analysis). From each subwatershed study, the variables used were assessed as to their utility for use in diagnosing habitat condition and quality for brook trout and or brown trout. A utility ranking of 1 to 3 was assessed for each variable used depending upon the nature and type data collected, whether it is descriptive, numeric or graphical and the degree to which the variable used is defined in the actual study: rank 1 indicates the variable is explicitly represented in numerical form in a measurable unit (e.g. km2 or m sec-2); rank 2 indicates the variable can likely be calculated or interpolated from other quantitative or mapped information but is not itself specifically presented in quantitative or measurable format; rank 3 indicates that the variable is assessed by purely qualitative means.

The scale at which the data was collection for each variable was also noted and the stage in the watershed process the variable was or can be used. Scale of data collection was identified as either: basin wide (BW); sub-basin (SB); reach (RE); and/or site (SI). While there might be a tendency to regard data obtained at a basin scale as being of less utility than that measured or obtained at a reach or site scale, this is not necessarily true. Utility of the data is related to the stage of management for which the data is to be used, these being: scoping or problem identification; screening or identification of variables for specific causal relationships; modelling or prediction of effects; and management or definition of appropriate interventions for problem resolution.

Based on the results of this analysis, we then examined the species habitat tables to determine whether or not the information provided by each study could be used to provide guidance for wild trout habitat management and to develop management and rehabilitation prescriptions.

RESULTS

As seen from Table 3, a total of 192 variables are identified for watershed and reach level analyses by both evaluative frameworks (watershed 76; reach 120). Of these, only 21 are common to both evaluative frameworks for the watershed analyses and 48 are common to both at the reach scale of analysis. This
Table 2.—Summary of background information for the three subwatershed studies analyzed (from OMOEE/OMNR 1997). Date of completion of plan identified in brackets e.g. Subwatershed Study (1996).

<table>
<thead>
<tr>
<th>VARIABLES</th>
<th>MILL CREEK</th>
<th>SUBWATERSHED</th>
<th>LAUREL CREEK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population:</td>
<td>25000</td>
<td>15000</td>
<td>250000</td>
</tr>
<tr>
<td>Size (km²):</td>
<td>104</td>
<td>60</td>
<td>74</td>
</tr>
<tr>
<td>Landuse:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Developed:</td>
<td>10</td>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>% Agricultural:</td>
<td>40</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>% Open:</td>
<td>30</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>% Forest:</td>
<td>20</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>Study Issues:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Water - Flooding</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Surface Water - Low Flow</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Water - Stormwater</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ground Water Quantity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Water Quality</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Ground Water Quality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aquatic Life/Fisheries</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Wetland/ANSIs</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Municipal Water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Municipal Sewage</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stream Channel/Buffer</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private/Communal Water</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private/Communal Sewage</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregates</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transportation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger and Other Issues:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Future development, sensitive ecosystems and water taking ponds.</td>
<td>New development, need for environmental protection.</td>
<td></td>
</tr>
</tbody>
</table>

PLAN COMPLETION & IMPLEMENTATION

<table>
<thead>
<tr>
<th>Study Status</th>
<th>Completed</th>
<th>Ongoing</th>
<th>Completed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Data Available?</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Implementation Strategy Prepared?</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Plan Being Implemented?</td>
<td>X</td>
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<td>X</td>
</tr>
<tr>
<td>Monitoring Strategy Prepared?</td>
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<tr>
<td>Monitoring Underway?</td>
<td></td>
<td></td>
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FINANCIAL INFORMATION

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<th>Total Cost</th>
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<th>$350,000.00</th>
<th>$840,000.00</th>
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</thead>
<tbody>
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<td>Data Inventory/Analysis</td>
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<td>$275,000.00</td>
<td>$460,000.00</td>
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<td>Hydrology/flood/erosion</td>
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<td>$60,000.00</td>
<td>$55,000.00</td>
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<td>Hydrogeology</td>
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<td>$100,000.00</td>
<td>$110,000.00</td>
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<td>Water Quality</td>
<td>$20,000.00</td>
<td>$20,000.00</td>
<td>$120,000.00</td>
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<tr>
<td>Aquatic Resources</td>
<td>$20,000.00</td>
<td>$25,000.00</td>
<td>$50,000.00</td>
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<tr>
<td>Stream Morphology</td>
<td>$10,000.00</td>
<td>$25,000.00</td>
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<tr>
<td>Terrestrial Resources</td>
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<td>$20,000.00</td>
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<td>Mapping/Data Management</td>
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<td>Plan Formulation/Evaluation</td>
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<td>$215,000.00</td>
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<td>Reports/Meetings</td>
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<td>$25,000.00</td>
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<tr>
<td>Contributors:</td>
<td>MNR 50%; Municipalities 50%</td>
<td>MNR 50%; Town of Orangeville 21%; MMA 12%, grant</td>
<td>MNR 55%; Reg Mns of Waterloo 35%; Grand River Mns 10%</td>
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</tbody>
</table>

167
suggested a need to integrate the different approaches to assessment of stream systems. This would facilitate the development of shared models and management approaches to aquatic environments.

Table 4 and Table 5 summarize the major numbers of variables used by sector (e.g. Watershed scale: climatic; landform; landcover) and their dominant utility, scale of collection and stage of management for which the data is to be used. Table 4 which summarizes the watershed level of analyses suggests that the utility of the data collected varied by both sector and for each study. The general trend towards optimum utility goes from the Laurel Creek study to the Mill to Subwatershed 19 on the upper Credit River. Subwatershed 19 appears to have the most useful data for all sectors. These data were collected predominantly at the sub-basin or basin-wide scale for climatic information, reach and site for landform data and basin wide and reach for landcover. In some instances, such as on Laurel Creek, utility of the data varied in part because much of the data collected was used for broad-scale modeling which in some cases did not require detailed site or reach measurements.

Results from the Reach level of analysis are more consistent between the three studies (Table 5). Although the utility of the information for the four sectors varies both within and between the three studies, they are all equally poor at collecting quantitative data at the reach level for use in wild trouts habitat diagnosis. Perhaps the highest utility occurs with runoff analyses. This is not surprising given the long history of hydrologic and hydraulic analysis of rivers and their flow regimes. The lack of utility of data from the other sectors would suggest a need for better guidelines and methods of analyses for these sectors, especially those variables that define sediment transport and processes and the role of vegetation in channel and habitat management.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Source of Variables</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watershed</td>
<td>EVA</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>NCS</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>21</td>
</tr>
<tr>
<td>Total Variables</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>Reach</td>
<td>EVA</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>NCS</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>Both</td>
<td>48</td>
</tr>
<tr>
<td>Total Variables</td>
<td>120</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.—Watershed level summary of analysis of data from the three subwatershed studies, summarizing dominant trends in the utility, scale and scope of information collected. The column "variables" refers to the number of variables used for the particular sector compared to the number identified as useful by both the Evaluative Framework and the Natural Channel Systems approach.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mill Creek</th>
<th>Subwatershed 19-Credit River</th>
<th>Laurel Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>Scale</td>
<td>Scope</td>
<td>Variables</td>
</tr>
<tr>
<td>Climate</td>
<td>2</td>
<td>SB,BW</td>
<td>SC</td>
</tr>
<tr>
<td>Landform</td>
<td>1,2</td>
<td>RE,SB</td>
<td>SC/MD</td>
</tr>
<tr>
<td>Landcover</td>
<td>2,3</td>
<td>RE</td>
<td>SC/MD</td>
</tr>
</tbody>
</table>

Table 5.—Reach level summary of analysis of data from the three subwatershed studies, summarizing dominant trends in the utility, scale and scope of information collected. The column "variables" refers to the number of variables used for the particular sector compared to the number identified as useful by both the Evaluative Framework and the Natural Channel Systems approach.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Mill Creek</th>
<th>Subwatershed 19</th>
<th>Laurel Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility</td>
<td>Scale</td>
<td>Stage</td>
<td>Variables</td>
</tr>
<tr>
<td>Runoff</td>
<td>2</td>
<td>RE,SI</td>
<td>SC,SR</td>
</tr>
<tr>
<td>Slopes</td>
<td>2,3</td>
<td>SI,RE</td>
<td>SC</td>
</tr>
<tr>
<td>Sediments</td>
<td>3,2</td>
<td>SI,RE</td>
<td>SC</td>
</tr>
<tr>
<td>Vegetation</td>
<td>2,3</td>
<td>SI,RE</td>
<td>SC,MD</td>
</tr>
</tbody>
</table>
Scale of data collection in the reach level of analyses occurred predominantly at the reach and site level. The predominant stage of management was scoping and screening although the Laurel Creek study, as in the Watershed level of analyses, relied heavily on modelling as well. The emphasis in modelling is likely reflected in the cost of the study as well (see Table 2).

Table 6 is reproduced from the OMOE/OMNR (1997) inventory of watershed management projects in Ontario. The issue of cost also may explain the variability in the utility of some information pertaining to stream morphology and aquatic resources (which would encompass both habitat and population information) as well as terrestrial information such as riparian zone characteristics. This is evident in Table 6. The relatively high costs associated with hydrologic and hydrogeologic components of the studies in general also reflect the traditional focus on these areas and the reliance within these components of data collections and modelling. When comparing the costs of the various scientific components outlined in Table 6 versus the quality and utility of the data from the sectors in the watershed and reach level analyses it appears that, in general, the quality of the data for watershed analyses for all three studies reflects the costs incurred (e.g. hydrology/hydrogeology). The relatively poor utility of variables in the sectors within the Reach level may be as much a result of the relative proportion of monies allocated to variables for this level of development as the level of technical guidance for data collection and analyses.

### DISCUSSION AND CONCLUSIONS

#### General Considerations

A major strength of watershed management plans is the establishment of a baseline condition. It appears that data is collected predominantly for screening purposes to assess the state-of-the-environment and as a reference point for ongoing monitoring. However, data which is descriptive should not be discounted out-of-hand because in some instances it may be sufficient at a watershed scale of analysis for diagnosing environmental functions and malfunctions. Although the same types of variables were collected in each of the three studies, the qualitative nature of some of this data is of little value unless it was collected by at least some standardized method. In addition, reports do not identify what the stream conditions were when data was collected, making it difficult to place these variables in context with those collected at other times.

In order to be able to compare variables within a study and in some instances develop new understandings by comparing other watersheds, it is imperative that watershed reports document how the data are collected and which methods were used. The reports reviewed did not document the method used to collect the variable.

Although the most detailed information was collected at the reach and site scales, the greatest use of this information appeared to be through aggregation for analysis of watershed condition.

#### Frameworks for Analysis

Managers have traditionally taken approaches for analysis such as IBI (e.g. Karr) or HSI (e.g.) or other indices and classification systems based on animal species or communities, or habitat typology. On the other hand, geomorphologists and engineers have used systems of physical measures with only a few biotically based variables and are only now considering physical classification systems (e.g. Rosgen 1996). The result is that depending on the expertise initiating the watershed plan or channel design we have different information collected and potentially different results. There is a need to integrate these approaches in order to achieve a truly ecologically based management process. It must
begin with integration of the biological and physical understanding of the watershed and stream system. This should result in more appropriate interventions which provide for a fit between the physical environment developed and the plant and animal communities which we hope will utilize these environments for habitat.

Classification systems while they vary in their structure and content are generally based on an analysis of the important functions as well as structural attributes of a system. The results of classification provide both taxonomic classification and in the case of ecosystems, they also provide a means of assessing the habitat system and relating it to a healthy taxonomic type. A lack of fit between present conditions and expected conditions based on taxonomic type indicates a deviation from the healthy state. This provides a means of diagnosing the problems of the system (lmhof et al. 1996).

The use of classification systems in a diagnostic process is valid as long as the classification includes a functional analysis. The complexity of the system is thus reduced to a set of typologies which can be used to identity problems or circumstances. This is similar to the use of classification systems to identify species, or conditions such as soil type and formation.

Watershed Plans and Natural Channel Design

Watershed plans in Ontario were initially carried out for small watersheds and were based on intensive data collection for almost every aspect of the environment. This is not unlike the early environmental impact assessments which were long on data and short on understanding. As we have progressed and adopted the ecosystem approach we have moved from a detailed measurement based plan in which modelling and prediction of impacts of development were the focus to one in which strategic plans for measurement are developed to provide a diagnostic approach for potential impacts. This has resulted in a reduction of costs and time required for the watershed studies (compare costs of Laurel Creek study completed in 1993 to Subwatershed 19 completed in 1997 Table 2). It has also resulted in the loss of the ability to provide the detailed modelling which is necessary for Natural Channel System initiative. Not all reaches within a watershed or subwatershed will require this level of detail.

Watershed scale studies are tools for area planning and are effective at providing the screening and scoping necessary for development of design. Therefore, it is probably appropriate that we reduce our expectation that watershed plans can provide the entire basis for Natural Channel System management and design. In addition, NCS information although strong in the two more recent studies (i.e. Mill Creek and Subwatershed 19), are weak in linking processes and habitat variables and are weak in linking information to higher scales such as the watershed. Furthermore, while there is comprehensive data collection, the implications of the information are not readily discussed. For example, Mill Creek and Subwatershed 19 adopt the Rosgen (1995, 1997) classification system. There is little discussion within the reports of why is it being used and what value the undertaking of stream classification has with respect to the overall objectives of the plans.

RECOMMENDATIONS

Strong efforts need to be made to improve our understanding of the linkages both qualitatively and quantitatively between physical processes and responses and the formulation of habitat for fish and how fish communities and fish species respond to these changes in physical processes.

Watershed plans should provide an appendix of all variables/information collected, how the data are collected, which variables were derived from modelling and at what scale. In addition, strong efforts should be made to standardize the types of variables and their methods of collection and analyses.

When considering the management of wild and native trout populations, there is a need for watershed plans to provide the strategic plan for trout habitat development but there is also a need for the NCS study to generate the operational plans and designs necessary for appropriate restoration and rehabilitation projects in strategic and sensitive reaches identified through the watershed/subwatershed planning process.

If these two tools are integrated then it is clear that the watershed planning process can be more effective in providing the scoping and screening necessary as a basis for the more detailed reach and site scale protection, management, and restoration programs.
LITERATURE CITED


A Landscape Perspective on Habitat Needed for Long-term Persistence of Native Cutthroat Trout in Colorado

Amy L. Harig\(^1\) and Kurt D. Fausch\(^2\)

Native cutthroat trout in Colorado have been reduced to less than 5% of their historic habitat, primarily due to interactions with nonnative salmonids and habitat degradation. The primary management strategy for recovering interior subspecies of cutthroat trout has been to isolate pure populations above barriers that prevent invasion by nonnative salmonids. We assembled data on translocations of greenback cutthroat trout (Oncorhynchus clarki stomias) and Rio Grande cutthroat trout (O. c. virginalis) in Colorado to analyze the success of this strategy. Of 21 streams to which greenback cutthroat were transplanted, only 5 (24%) have produced stable populations, whereas 6 died out or are unstable due to unknown habitat problems and 10 were affected by brook trout or heavy metals. Similarly, only 9 of 22 (41%) Rio Grande cutthroat translocations have produced stable populations, and most of the others are considered unstable due to unknown problems with habitat.

We also measured characteristics of their small enclaves of habitat at both the map scale using a Geographic Information System and in the field, to assess what features are associated with success or failure of translocations. Map scale analysis revealed that most remaining populations of greenback, Rio Grande, and Colorado River cutthroat (O. c. pleuriticus) in Colorado are isolated in small, high elevation streams or lakes. Over half of the remaining Rio Grande cutthroat trout populations are present in streams <4 km long and above 3000 m elevation. Ongoing field work indicates that habitat for many populations is highly restricted by lack of large, complex pools and harsh thermal conditions, especially during winter. Successful restoration efforts will need to consider the dual risks of invasion by nonnative salmonids and stochastic environmental events (fire, drought, flood) that may occur synchronously across regions in such small isolated habitats.

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Watershed Associations: Effective Tools for Achieving Ecological Integrity

Jill C. Silvey¹

Abstract—Ecological integrity of landscapes is declining throughout the west. The significance of watershed degradation is that many of these ecosystems are reaching a crucial point, no longer able to sustain a traditional economy or way of life. I will present a model for watershed restoration using an ecosystem approach and watershed association groups. I have found that Watershed Associations are an effective tool in watershed restoration. There are several factors that are necessary for a watershed group to be effective and successful. I will discuss these elements as gathered through literature review and case studies. Through the use of Watershed Associations and Ecosystem Management we can accomplish watershed restoration.

INTRODUCTION

The West has suffered from great ecological decline over the past century, to the point that many landowners and land managers are now facing tough choices regarding management of local landscapes. Past management actions that professional scientists once thought were ecologically benign or even positive have turned out to have negative impacts on long-term ecological sustainability.

The social and political structures have also changed over the centuries and decades. The decision-making era of Thomas Jefferson is long past, replaced by the “iron triangle.” The iron triangle is a three-way interaction among elected members of Congress, particularly key committee and subcommittee chairpersons; career bureaucrats, particularly agency heads or senior staffers; and special interest lobbies, particularly powerful lobbies in specialized fields such as health, welfare, education, ranching and defense. From this closed triad of interests, governmental policies emerge from members of Congress writing and passing legislation favorable to special interest groups, bureaucrats implementing these congressional mandates in return for bigger budgets, and special-interest groups backing, with re-election monies and other support, the helpful members of Congress. In all, it is a tidy and closed relationship (Stillman, 1992).

Trying to implement a multitude of laws and regulations has given land management agencies a personality complex; agencies are expected to be all things to all people, without a clear vision of desired future condition. Additionally, there has not been a process to balance the conflicting values imposed by public demands and enacted legislation. All of these factors combined have left involved parties frustrated, while the ecosystem unravels. The entire social, political and ecological system is in chaos.

Now for the good news: from chaos, a new and better system will arise (Wheatley, 1992). That system is Ecosystem Management through Watershed Associations.

DISCUSSION

There are many definitions of Ecosystem Management. I prefer that of R. Edward Grumbine, 1994.

Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and value framework toward the general goal of protecting native ecosystem integrity over the long term.

Another term that requires definition for this discussion is "Watershed Association." I searched for a definition and could not find one. "The Watershed Source Book," (1996) from the University of Colorado, noted six attributes of Watershed Associations:

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1) focus on one or more resource management problems
2) defined geographic area
3) active inclusion of interested members of the local community
4) agencies involved work with each other in a coordinated and cooperative fashion
5) the agencies, non-governmental groups and citizens jointly propose plans
6) broader, systems view of resource problems in the watershed

This term is used rather broadly to include any group of people working together to improve land use within a defined geographic area. I prefer the term watershed association, but frequently they are called coalitions or councils; there is not a distinction between the three, only a word preference.

Through my review of existing literature regarding organizational effectiveness, patterns emerged. Steve McMullin (1993) developed twenty-two key factors to agency effectiveness. Among the twenty-two key factors listed are: openness of agency to public input; ability to resolve issues before conflicts arise; amount, diversity and stability of agency funding; and status of animal populations and habitat.

Compare these effectiveness factors with the advice offered from watershed association participants in Ecosystem Management in the United States (Yaffee et. al, 1996):

1) Early involvement of all stakeholders
2) Clarify goals, objectives, and responsibilities
3) Use a collaborative process; build consensus and trust
4) Ensure adequate resources
5) Secure agency and political support
6) Use broad, flexible land management strategies
7) Make science part of decision making
8) Understand local community needs
9) Educate the public about the project

From this literature review and my own experience I have developed a list of key elements that are necessary for a watershed association to be successful. These key elements are: spark plug; defined geographic area; involve all interested parties; begin with a realistic, accomplishable project; someone to serve as a keeper of the process; focus on common goals; funding; collaborative process; and scientifically sound.

**Spark Plug**

The first key element is someone to act as a spark plug, to get the entire project off the ground. Successful watershed associations are like a chemistry experiment. In order to have a chemical reaction there first must be the specific elements in a particular environment. Many times the chemical reaction needs a catalyst, such as a flame or an additional element, to jump start the chemical reaction. Most successful partnerships or associations began with someone who had a crazy idea, then talked others into joining the dream until it became everyone’s dream.

**Defined Geographic Area**

A defined geographic area is absolutely necessary. The area must be defined in order to identify whom to include. There is not a right or wrong size, but I would recommend a moderate geographical area, something that is workable. Several associations started out trying to encompass too large of a geographic area, and the entire project dragged along with an unmanageable payload until the organization could no longer function, finally collapsing under its own weight.

**Involve All Stakeholders**

There might be some resistance to this, since it is always so much easier to include only like-minded people. The problem with including only people who think alike is that the group develops single-minded solutions. Welcoming differing interest groups and different types of personalities will result in more creative, non-liner solutions.

**Start Small, Think Big**

In many projects, the initial interest was lacking, with perhaps only two or three people thinking the projects worthwhile, while others did not trust the system or agencies enough to feel comfortable joining the effort. Undaunted, the project originators continued on and experienced a series of small successes and continued to build upon those
Obtain Adequate Funding

Successful watershed associations do not see funding as a limiting factor. Rather, they see funding as plentiful. It is just a matter of developing the right marketing strategies to sell their program to agencies and grant-making organizations. Successful marketing strategies mean involving local partners and land owners to invest some amount of money, then developing a well-written proposal and submitting the proposal to as many people as possible, who will match the committed dollars. Focus on the association’s successes, regardless of the size, and give a grantmaker assurances that the watershed association is capable of wisely using dollars invested in it.

Many successful watershed associations have been funded through federal, state, local or grant-making organizations. Some of the programs that these organizations have taken advantage of include, but are not limited to, Bring Back the Natives, Partners for Wildlife, grants through EPA, Oregon’s Governors Watershed Enhancement Board, Embrace a Stream, Save our Southern Rivers, to name a few.

Focus on Common Goals

The Watershed Source Book (1996) reports “individuals and organizations often participate in watershed groups expecting to address difficult and controversial issues not resolved by traditional resource management agencies and processes. However, many participants in these efforts recommended avoiding controversy during the early stages of the effort so that common goals and interests can be established among the members.”

There are four basic steps to any planning system: inventory, goal setting, operational planning, and evaluation (Crow, 1983 and Bryson, 1988). There is logic to this system, beginning with a complete inventory, determining the current ecological and social status, then setting goals. However, this may prove to be too divisive and controversial for an association just getting started. If the issues are too difficult and tension is high, it is best to focus on the common ground and resolve “how to deal” with the perceived impediments at a later date. There are plenty of examples of successful watershed associations that began with goal setting, or visioning. The group developed a “dream” that all participants could buy into and believe in.

Collaborative Process

In a 1996 study, when Yaffee asked respondents to offer advice to other watershed associations, twenty-six percent of respondents advised, “Use a collaborative process; build consensus and trust.” My own experience agrees with the study’s findings. Nearly all of the projects I have visited feature, in some form or fashion, the process of collaboration, on two levels.

The first level is consensus building, developing trust with all of the involved parties, and making decisions that everyone can live with and support. The second level of collaboration is idea development, taking a good idea and making it great. Everyone in the process has the opportunity to add in one little twist or additional item. This way it is not one person’s idea, but the group’s idea, and all can buy into the project plan.

Scientifically Sound

The previous eight steps all focus on group process, or the social and political factors for a successful watershed association. Just because scientific soundness is the last on the list of key
factors, it does not diminish its importance. If all other eight steps are done correctly, but this step is overlooked, the association is destined for failure. The literature is replete with information regarding landscape ecology and watershed approaches to management. In fact the May issue of “Fisheries” magazine, the monthly publication of the American Fisheries Society, is dedicated to this topic. The BLM and U. S. Forest Service joined forces this year to developed an interagency Riparian Team designed specifically to assist associations in developing good, flexible and economical management systems.

CONCLUSION

Osborne and Gaebler in 1988 wrote about how to transform government from a mega-bureaucracy to a functional organization that works, discussing ten different models. I am astounded that watershed associations naturally incorporate elements from most of the models. For example, in Chapter 1 the authors discuss that the role of government should be one of “steering” rather than “roweing,” or government should guide public policy and assist people in implementing programs, rather than government implementing programs. Watershed associations are a perfect model of this philosophy; government agencies are just another voice at the decision making table, offering professional expertise, but the decisions are still up to the group as a whole.

In conclusion, the social, political and ecological system is in chaos and does not work. Watershed associations are functional social, political and ecological organizations that are slowly replacing the old systems. But how does this tie to ecological integrity? Watershed associations are more capable than any other organization that I know of at dealing with the complex social, political and ecological issues. Associations are consistently successful at making the sound choices that the local region is facing. Associations are a vehicle to work through conflicting values, making decisions between development and preservation, or even better, both!

I am reminded specifically of the example on the Coos Watershed Association in Oregon, where local fishermen were forced out of work due to salmon decline. Through a state-sponsored program, those out-of-work commercial fishermen are working on private and public land, within the watershed, to restore salmon habitat. The most remarkable part is that these fishermen really understand how the landscape is connected, and how what happens in the headwaters of the watershed affects their livelihood. I was also struck at their commitment to the entire project. They frequently went above and beyond the call of duty, inventing new ways to accomplish more work faster and easier, even taking an active role in recruiting new land owners to the project.

I don’t mean to give the impression that watershed associations are a panacea, but they can come close. The incidence of a watershed association implementing a project that is ecologically detrimental is minuscule. In general, associations make good land management decisions. The associations make good decisions because the social and political system that they are working with is a functional system.

LITERATURE CITED

Construction of a Spawning Stream to Increase Recruitment of Wild Klamath Lake Redband Trout

J. Scott Davis

Abstract -- To increase recruitment of wild, native, Klamath Lake redband trout, we constructed a 2,000-foot spawning stream designed to carry 8 to 15 cfs. We designed and built the stream to use a water right previously used to irrigate pasture along Crooked Creek, tributary to the Wood River, a major tributary to Agency Lake (adjacent to Upper Klamath Lake). Spawning substrate in Crooked Creek and the Wood River consists of pumice, ash, and sand, possibly limiting recruitment of trout into the extremely productive lake. The spawning stream was designed and built across and perpendicular to the floodplain of Crooked Creek. We armored the channel with gravel from an outside source to prevent erosion. Cover was added primarily as woody debris. During the first year after construction, the natural-looking stream produced an estimated 3,000 to 5,000 juvenile redband trout.

Introduction

Upper Klamath Lake in southern Oregon is home to a unique strain of redband rainbow trout (Oncorhynchus mykiss newberrit). The rainbow trout isolated in this system represent a significant unit of diversity among redband trout (Behnke 1992). Well adapted to their eutrophic environment and prized as sport fish, these native trout typically weigh one to five kilograms and are known to grow much larger. Two major spring-fed tributaries are used for spawning, the Williamson and Wood Rivers.

Crooked Creek is an extremely low gradient, highly sinuous spring creek that joins the Wood River just upstream of Agency Lake (the northern portion of Upper Klamath Lake). Crooked Creek ranges in discharge from 90 to 110 cubic feet per second year-round and serves as a spawning and rearing stream for the unique trout. Although adult trout have been observed spawning in Crooked Creek, the main channel substrate may drastically limit spawning success and recruitment, consisting primarily of pumice, ash, and sand. Rearing habitat has been reduced by grazing and development over the years, but remains abundant, mainly in the forms of dense aquatic vegetation, undercut banks, and shoreline vegetation.

A tributary of Crooked Creek that once served as a spawning stream for these native trout has been made inaccessible. A dam impounding a recreational pond was constructed on Agency Creek around 1920, blocking 1700 feet of natal stream. Large trout can be observed annually spawning in the lower section of this small stream where spawning habitat is marginal. The inaccessible upper reach is of higher gradient and has better substrate for spawning. A hatchery constructed at the headwaters of Crooked Creek has also eliminated access to some spawning areas. These activities, in combination with other human

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influences, have likely decreased total recruitment to the Klamath Lake system.

In an effort to increase recruitment of juvenile trout into Crooked Creek and Upper Klamath Lake, we constructed a 2,000-foot spawning stream capable of carrying 8 to 15 cubic feet per second. A water right of 15 cfs, used previously to irrigate cattle pasture, was transferred to provide water for the stream.

**Stream Construction**

Because the terrain along Crooked Creek is so flat (Figure 1), we had to design the spawning stream perpendicular to the Crooked Creek floodplain.

![Figure 1. Designed stream location (typical) prior to construction. July 1996.](image)

By doing this, we sacrificed stream length to maximize gradient and spawning success. Our designed stream gradient averaged 1.1%. After our stream location was surveyed, the stream was designed for an expected discharge of 8 to 15 cfs. Channel widths were designed with reference to stream gradient and desired depth at each location. Slow water (pool) habitats were designed to range from two to five feet deep.

To begin the stream building process it was necessary to over-excavate the channel to provide space for material that would armor the channel (Figures 2a and 2b). The existing substrate was highly erodible pumice sand that would float in water until saturated. We used “pit run” gravel that ranged in diameter from two to eight inches to armor the sub-excavated channel.

![Figure 2a. Sub-excavated stream channel before placement of gravel and woody debris.](image)

![Figure 2b. Finished stream section (as seen in figure 2a), June 1997.](image)

Riffles were armored with a minimum of 1.5 feet and 1.0 feet of gravel was used to cover the pumice in pools. In pool tailouts and other selected fast water habitats, spawning gravel screened specifically to maximize spawning success was added. In choosing the size of the spawning gravel, we also considered the flow regime in the stream and future maintenance requirements. We did not want to use gravel sizes that would mobilize at our designed discharge.

Natural looking rock weirs were constructed at the heads of all deep pools. The weirs are placed to cause water to drop into the pool, thereby scouring and helping to maintain pool depth. We used boulders ranging in
diameter from 12 to 24 inches for these structures (Figures 3a and 3b).

The intended function of the woody debris is to provide complex cover for rearing juveniles. Root wads were secured with rocks, with the most complex portions of the root wads protruding from the stream banks (Figures 4a and 4b).

Root wads were primarily used in pools and deeper runs where they could be completely submerged. We also placed logs in pools. Boulders were used primarily in shallower, fast-water areas.

Following placement of habitat features, and replacement of sod on the stream banks, the new riparian area was planted with native trees and shrubs. Many areas along the stream banks were designed as expansive shallow water wetlands and planted with native grasses and sedges. These areas, ranging in depth from 0.1 to 0.4 feet, provide habitat for age 0+ trout as well as larval Lost River and shortnose suckers.

After the stream was built, a 36" headgate was installed at the diversion site so that we could control the amount of water entering the stream at any time. The water used in the stream is pure spring water with virtually no influence from storm events. Because the stream typically carries almost no suspended sediment, we designed the stream to be virtually maintenance free. We expect that little maintenance will be required to maintain pool depth and keep tailouts free of sediment. We completed

Figure 3b. Boulder weir functioning at 10 cfs. This is the same pool as seen in Figure 3a.

Figure 4a. Placement of root wads along the right bank of a corner pool (October 1996).

Figure 4b. The same pool as shown in Figure 4a after construction (June 1997)
construction of the stream in October, 1996.

**Preliminary Results**

We revisited the stream in June of 1997 and were surprised to find more young-of-the-year trout than we expected. Although no quantitative data were gathered, visual observation revealed that each of the 19 large pools in the stream held at least 100 young trout. Of 60 fish sampled, all were juvenile redband trout (Figure 5). We plan to perform a population estimate via direct observation (i.e., mask and snorkel) for all year classes during the fall of 1997.

![Figure 5. Age 0+ Klamath Lake redband trout collected in new stream (June 1997).](image)

We were also amazed to find an incredible abundance and diversity of aquatic insects in the stream only eight months following construction. We feel that the results of the stream construction have so far been positive. We expect that adult trout will continue to migrate into the new stream and spawn and that egg survival will far exceed that of redds in Crooked Creek, thereby increasing average annual recruitment into the Upper Klamath Lake redband trout fishery.

**References Cited**


**Acknowledgments**

Jim and Valerie Root of the Sabroso Company in Medford, Oregon for funding and initiating this project.

Justin Devers of Devers Excavation in Dillon, Montana for his unparalleled artistic use of a tracked excavator.

Bob Ferguson of Chiloquin, Oregon for his persistent support in resource and equipment acquisition.

Steve Potter, Landscape Architect, of Medford, Oregon for his assistance in revegetation with native plant species.

Joseph Urbani & Associates, Inc. of Bozeman, Montana for designing and supervising this project. Major contributors include Clint Campbell, William Gavin, Elizabeth Payson, and Joe Urbani.
Removal or Suppression of Introduced Fish to Aid in Bull Trout Recovery

Chris Clancy², Chris Frissell³, and Tom Weaver²

Abstract—Introduced brook, brown and lake trout have contributed to the decline of bull trout (Salvelinus confluentus) in Montana. Removal or suppression of these introduced species may play a role in recovery of bull trout in some circumstances. This paper discusses the removal or suppression of introduced fish as one aspect of the recovery process for bull trout in Montana.

INTRODUCTION

In January, 1994, the governor of Montana established a Bull Trout Restoration Team to develop a restoration plan for bull trout (Salvelinus confluentus) in Montana. The Restoration Team created a Scientific Group to provide guidance on technical issues related to the restoration of this fish. The Scientific Group recognized a need for technical reports on three of the most significant issues in bull trout restoration: 1) land use impacts, 2) the use of fish stocking, and 3) the suppression or removal of introduced species. This paper summarizes a report on the role of suppression or removal of introduced species in bull trout recovery.

Introduced species of fish are one of the most commonly cited factors for extinction or the imperiled status of native fishes in North America (Lassuy 1994, Miller et al. 1989). Several species of introduced fish are believed to contribute to the decline of bull trout in Montana. Removal or suppression of these introduced species may play a role in recovery of bull trout in some locations. This paper is not meant as a review of methods or how to specifically go about removing or suppressing a target species; there are many site specific considerations for each project and other sources are available for that information. Rather, it is meant as a general guideline to illustrate which methods have been successful and under what conditions removal or suppression should be used for bull trout recovery.

Potential for Species Conflict and Reasons for Control

The introduced species addressed in this paper are brook trout (Salvelinus fontinalis), lake trout (Salvelinus namaycush) and brown trout (Salmo trutta). Conflict between introduced species and bull trout is often implied by the absence of bull trout in waters where they historically occurred, or the existence of fish populations where introduced species predominate over bull trout. The species mechanisms creating a survival advantage for the introduced species, leading to the replacement of bull trout, are not well understood. At the present time, a prudent step would be to discontinue the stocking of introduced species in all core areas and nodal habitats of bull trout. Furthermore, brown, brook, and lake trout and predatory species that have unknown impacts on bull trout should not be stocked within western Montana without an environmental assessment. Private ponds are growing in number and are a potential source for introducing nonnative species into bull trout waters. The private pond problems will be difficult to control. Strong education efforts are needed to discourage the illegal introduction of nonnative species into bull trout waters.

¹This paper summarizes a more detailed report, “Removal or suppression of introduced fish to aid in bull trout recovery,” submitted to The Montana Bull Trout Restoration by the Montana Bull Trout Scientific Group in March 1996. Available from Montana Fish, Wildlife and Parks, Helena, MT.
²Montana Fish, Wildlife and Parks.
³Flathead Lake Biological Station, University of Montana.
Developing Goals for Removal/Suppression Programs

Before any effort is undertaken to remove or suppress a population of adversely interacting fish, it is important to identify factors responsible for the decline of bull trout. After the ecological and social considerations have been reviewed (see Table 1), a long term goal should be formulated and a commitment made to carry it out.

The effect that the introduced species is having on bull trout should be examined. Large removal projects have not always had a positive effect, because it was not clear that the target species was competing with the species that was supposed to benefit from its removal (Moyle et al. 1983). Also, removal of adversely interacting species may be treating a symptom rather than the cause of bull trout decline, the ultimate cause may often be habitat degradation (Platts and Rinne 1985, Maugham and Nelson 1980). Bull trout populations can be seriously impacted by land management practices (USFWS 1997). Often, however, introduced species are also likely adversely interacting with bull trout (Clancy 1993, Ratliff and Howell 1992, Washington Department of Wildlife 1992).

When removal or suppression efforts are anticipated, it would be reasonable to use a habitat ranking system to prioritize the streams on which to work. Streams with the highest quality bull trout habitat should have a high priority, because the bull trout populations should be more likely to respond positively (Jeffrey Dambacher, Oregon Dept. of Fish and Wildlife, unpublished data). If competition does exist where the habitat is suitable, removal of competing species can benefit native trout (Plick and Webster 1992, Moore et al. 1983).

If introduced fish pose a risk to bull trout recovery, alternatives to reduce the risk should be reviewed. If there is both a significant risk to bull trout and a clearly identifiable action to reduce the risk, it is important to identify whether total removal or suppression is the goal.

Total removal implies that all of the adversely interacting species will eventually be removed and that some mechanism to preclude them from reintroduction should be identified. It would be beneficial to know the historic patterns of invasions by the introduced fish (Larson and Moore 1985). If a species encroached from another site through natural means, removal without excluding the invading species will probably be unsuccessful in the long term. If the target species was introduced into the target area by man, removal alone may be successful.

Suppression implies that a reduction in numbers of adversely interacting species will allow recovery of bull trout. This could be a short term project for experimental purposes as occurred in Great Smoky Mountains National Park (Moore et al. 1983). It could

<table>
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<th>Table 1. — Checklist of questions for projects involving removal or suppression of fishes thought to adversely interact with bull trout.</th>
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<tr>
<td>The following questions should be answered before any suppression or removal program is initiated:</td>
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<tr>
<td>I. Assess the need for removal or suppression of introduced species:</td>
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<tr>
<td>A. Is there another alternative that may also protect bull trout?</td>
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<tr>
<td>II. Clarify goals and measures for success:</td>
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<tr>
<td>A. What life history form of bull trout will benefit?</td>
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<tr>
<td>B. What is the expected response of bull trout? Is the habitat available to support the expected response?</td>
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<tr>
<td>C. What is the spatial scale being considered? Is this project site-specific, or does it relate to a larger area?</td>
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<td>D. Is this a suppression or removal effort? If it is suppression, what are the long term commitments?</td>
</tr>
<tr>
<td>E. What will be the measure of success or failure?</td>
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<tr>
<td>III. Evaluate how the removal or suppression fits into the recovery program:</td>
</tr>
<tr>
<td>A. How does this project fit into the genetic plan for the drainage?</td>
</tr>
<tr>
<td>B. Is a recovery plan in place? How does this project factor into that plan?</td>
</tr>
<tr>
<td>IV. Planning the effort:</td>
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<tr>
<td>A. Have possible problems been anticipated? Have contingencies for accidents been explored?</td>
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<tr>
<td>B. Are there resources available for long term implementation and monitoring?</td>
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<tr>
<td>C. What is the potential for reinvasion or compensatory population response by the target species and how will this be addressed?</td>
</tr>
<tr>
<td>D. What non-target fauna exist and what are the expected impacts to them?</td>
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<tr>
<td>E. How will fish disposal be handled?</td>
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<tr>
<td>F. What might be the public response/support/opposition?</td>
</tr>
<tr>
<td>G. What kind of NEPA (National Environmental Protection Act) or MDEA (Montana Environmental Protection Act) document is necessary?</td>
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<tr>
<td>H. Is there potential for offsite mortality? How will it be taken care of?</td>
</tr>
<tr>
<td>I. Is the body of water a source for domestic livestock uses? Have all adjacent landowners been contacted?</td>
</tr>
<tr>
<td>J. Have all necessary permits been obtained (Water Quality, U.S. Forest Service, etc.)?</td>
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also be a long term project, but commitment of time and money for the long term is necessary. If species interactions alone are not the true cause of bull trout decline, then suppression alone will not work and the adversely interacting species will probably return to pre-suppression levels.

Direct Methods for Removal and Suppression of Introduced Species

Toxicants

Removal of undesirable fish from lakes and streams in the United States began early in the century and has accelerated in the past 40 years as toxicants and technology improved (Marking 1992). Toxicants can be very effective in capturing and removing fish (Krumholz 1948). This makes them useful in many situations but it also increases the likelihood of misapplication. Typically, in closed lakes, the toxicant is contained and can naturally dissipate, but in streams, it is necessary to use neutralization methods to prevent uncontrolled dispersion of the chemical. Even with neutralization efforts employed, the possibility of a downstream fish kill exists.

Toxicants that selectively kill a target species without harming non-target species are the most desirable. Baits impregnated with toxicant have been used to kill specific species (Rach et al. 1994). No selective toxicant is available to use against fish species that are suspected to compete with bull trout. In the West, the most commonly used toxicants for removing fish are rotenone and antimonials. Both toxicants are appropriate for lakes. Antimonials is effective in streams because fish do not detect and avoid like they do rotenone (Dan Carty, U.S. Fish and Wildlife Service, Yellowstone National Park, personal communication). Antimonials is highly effective in cold water temperatures with a neutral pH and neutralizes with agitation in stream environments. It is less toxic in alkaline waters. However, the Environmental Protection Agency certification for antimonials will expire within two years and it may not be produced after 1998. Rotenone is effective at all pHs, but is not easily neutralized, especially at temperatures less than 50°F (common in bull trout waters).

Lakes

Historically, total removal has been accomplished in many lakes (Flick and Webster 1992, Foye 1964, Ball 1945). Removal is more difficult in larger and more complex lakes with springs and inlet and outlet streams (Foye 1964). Selective poisoning of some species is sometimes possible (Breenbank 1940), and in large, complex lakes, suppression of certain species, rather than total removal is often the goal. Typically, the suppression effort must be repeated every few years because the target species returns to pre-suppression levels.

Rivers and Streams

Toxicants have been used for native trout restoration projects in small headwater streams (Rinne and Turner 1991, Gresswell 1991, Rinne et al. 1981). Usually, a barrier is identified or built, the stream above the barrier is modified and the native fish are reintroduced afterwards (Pittenger et al. 1993, Propst et al. 1992, Stefferud et al. 1992). Successful removal of introduced species to benefit native trout species in this situation has been variable. Examples of projects that were not successful at total removal of the target species are numerous (Rinne and Turner 1991). Brook trout removal from streams is likely further complicated by their affinity to groundwater upwelling that may act as a refuge from toxins. Typically, toxicants should be used two years in a row on a reach of stream to increase the likelihood of success. As the stream increases in size, both physical and social problems increase. Projects on large river systems are complex (Art Whitney and Bill Hill, Montana Department of Fish, Wildlife and Parks, personal communication, Moyle et al. 1983, Binns 1967). Many attempts at removing fish species from large rivers or lakes have been controversial (Holden 1991, Hubbs 1963). Public acceptance of fish removal or suppression projects is not likely to occur in the large rivers, streams and lakes which support considerable recreation and other uses, particularly because introduced species in these waters are typically popular sport fish.

Based on the collective experience of the Montana Bull Trout Scientific Group, a review of pertinent literature and discussions with other scientists, we expect the removal of introduced species using toxins
will be a potentially useful but limited tool in bull trout recovery. Due to the tenacious nature of introduced species in natural waters and the time consuming and costly nature of removal projects, we anticipate that chemical toxins will be a useful tool in only a few small streams and lakes.

**Trapping and Netting**

In lakes, seasonal trapping or netting may be used to remove introduced species. A commercial operation would most likely be necessary to provide the necessary amount of effort to seriously deplete a large lake trout population. The possibility of incidental catch of bull trout is a complicating factor in any large-scale trapping and netting effort, because the loss of just a few bull trout could have a serious impact on the population. The complicated interactions within a lake between many species of fish make any predictions tenuous. In very specific circumstances, when spawning of the target species is limited to one or few tributaries, trapping of spawning adults could lead to total removal.

**Angling (sport)**

It is possible that a situation exists where angling for an adversely interacting species would benefit bull trout, particularly in combination with other suppression techniques, but the use of angling to remove adversely interacting species is not expected to be a major factor in the recovery of bull trout. The loss of bull trout through incidental take poses a significant negative risk if angling were used to remove other species. The methods that capture brown trout and lake trout might also catch bull trout and some incidental mortality of bull trout would occur. Angler misidentification of fish species is also a major problem. A serious educational effort would be necessary, but is not likely to be completely effective even in the best of circumstances.

**Electrofishing**

Electrofishing is an effective technique for capturing large numbers of fish in many situations. It could be used to help suppress target species but would not be effective at total removal. Some situations may occur when removal by electrofishing could help bull trout gain a short term advantage over introduced species, but this could likely be effective only after habitat modification or some other environmental change had occurred that could conceivably provide a new ecological advantage for bull trout. While electrofishing is effective at capturing large proportions of the fish populations in many situations, it has the potential to damage individual bull trout if not properly used. Overall, electrofishing to remove target species will be too costly and time consuming to be a major factor in bull trout recovery.

**Barriers**

Throughout the western United States, native trout recovery projects have typically focused on small, headwater populations. In most cases, an upstream barrier is either naturally present or constructed and the introduced species is removed upstream of the barrier by using toxicants.

Although barrier construction presents long term problems, in some circumstances, barriers could be used to preclude the movement of an introduced species into a critical bull trout refuge. Most likely, this barrier would be designed to stop upstream movement of the introduced species (see the Swan Bull Trout Status Review). This type of structure could be a long term solution if the area upstream of the barrier contains all of the habitat components (core areas and nodal habitats) that are necessary for the long term survival of the bull trout population. A barrier would be most useful where upstream genetic interchange by bull trout did not exist or, where it could be provided with the barrier in place (e.g., by selectively passing individual fish over the barrier).

In some cases, the re-establishment of a migratory component may not be possible and the use of permanent barriers would be appropriate. In these cases, true recovery is not possible, and the effort will be to protect the remaining resident populations.

**Indirect Methods:**

**Habitat Management**

Watersheds presently supporting bull trout obviously have the ecological components that allow bull trout to successfully compete with introduced species. We do not understand exactly what environmental factors allow the persistence of bull trout in the face of potentially invading species. But in general, the protection of habitats supporting bull trout will be the most effective means of maintaining whatever advantage bull trout enjoy over introduced species. Habitat protection in core and nodal habitats, where bull trout populations are presently
strongest, should be a primary emphasis. Over the years, many habitat manipulation projects have been completed, with varying amounts of success (Reeves et al. 1991). Typically, they are aimed at increasing some perceived limiting habitat, such as pools, spawning areas, rearing areas, etc. Many projects have resulted in increases in size and number of both native and introduced species. Although we can identify some of the habitat preferences of bull trout, they are often similar or overlap the preferences of other salmonids. In a stream where bull trout are competing with introduced species, these improvements may not benefit bull trout. A review of stream improvement projects in Wyoming indicates that we do not have knowledge sufficient to favor one trout species over another through habitat modifications (Allen Binns, Wyoming Game and Fish Dept., personal communication). Maintenance of high quality habitat is the first priority in bull trout recovery. Habitat restoration on a watershed scale should help with bull trout recovery, but instream habitat manipulation on a small scale is of limited value, particularly if introduced species are present.

**Non-target Species Considerations**

When suppression or removal of introduced fish species is contemplated, the effects of the project on non-target species must be considered (Wiley and Wydoski 1993). There will commonly be a risk of loss of unknown species, particularly when toxicants are used. This should be kept in mind during planning of the project. Some considerations concerning non-target species are:

1. A list of species previously observed in the area could be obtained from the Montana Natural Heritage Program.
2. When using toxicants, assume all gill-breathing aquatic species will be eliminated from the treated reach. If a rare species is present, some means of protecting that species should be taken (e.g., removal and reintroduction after treatment).
3. Populations of native fish, amphibians, plants and other sensitive taxa should be protected.
4. Some taxa of invertebrates and other plants and animals will not be found using normal sampling procedures. Typically, invertebrate biomass recovers in a short period of time after toxicants are used. However, rare species that are present only in small numbers or cryptic taxa are difficult to account for before and after the project (Minckley and Mihalick 1981). The effect of the project on rare taxa would likely be poorly understood. Also, the effect on taxa that are poorly sampled by ordinary methods would be unknown.

5. In situations where “unusual” habitat exists that may support a species with restricted distribution, some means of protecting these species should be taken.

**RECOMMENDATIONS**

The protection of habitats supporting bull trout will be the most effective means of maintaining a competitive advantage over introduced species. Habitat protection in core areas and nodal habitats and maintaining the integrity of their watersheds should be a primary emphasis of any bull trout restoration program.

Many of the historically used methods of removal or suppression would be useful to some limited extent. A combination of these methods may be most effective. However, at the present time, although we recognize the considerable impact that introduced species are having on bull trout, removal or suppression is not feasible on a large scale. It is clear from reviewing the literature and discussing this subject with many professionals, that new, innovative means for removal or suppression are necessary if this method is to become a major factor in bull trout recovery. A recent review of fish control projects found that less than 50% of 250 projects were considered successful (Meronek et al. 1996). The criteria for success used in Meronek et al.'s study were much less stringent than would be necessary for bull trout recovery.

The use of removal or suppression in the traditional sense will only be a small part of bull trout recovery. Any projects that do proceed should be monitored closely so that more can be learned about various tools to deal with the problem of introduced species. The Scientific Group recommends a panel be established to review all removal and suppression proposals. This panel would serve as advisers to
others that are contemplating projects and would
work to ensure that effective monitoring and
evaluation are conducted.

Before removal or suppression of established
introduced fish populations is undertaken, we
recommend discontinuing the introduction of
species that may adversely affect bull trout. The
most common means of nonnative species
introduction into bull trout range are State and
Federal stocking programs, introduction through
private pond permits, and illegal fish translocations.
Each of these must be carefully controlled if we
expect long term success in removing or suppressing
introduced species within the recovery area. Any
planned introductions should be formally and
publicly scrutinized through the proper
environmental review process. If there is any reason
to suspect that the introduction could directly or
indirectly impact a bull trout population, it should
not take place.

Presently, the stocking policy of Montana Fish,
Wildlife and Parks discourages most stocking in
streams that support wild or native trout. This
reduces impact on bull trout populations. The most
common introductions today are of westslope
cutthroat trout (Oncorhynchus clarki lewisi) which
are typically introduced into mountain lakes.
However, within western Montana, some stocking
of introduced species does continue to occur. The
stocking of nonnative species, except kokanee,
rainbow trout and hatchery westslope cutthroat
tROUT, should be scrutinized through the MEPA
process at all sites, including those where a historic
and/or current record of stocking exists. Within
core areas and nodal habitats all introductions of
any species should be scrutinized through the MEPA
process.

Private pond permits are numerous and new
applications continue to increase. We recommend a
review of past permits and, if negative interactions
are likely, consider revoking or modifying the permits.
Any new permits should consider potential conflicts
with bull trout. Illegal introduction of fish by the
public is a serious and growing problem. While this
is a difficult problem to address, every possible means
should be taken to stop the illegal introduction of
fish into bull trout waters.

Priority Situations for Removal or
Suppression

Although the Scientific Group concludes that
removal and suppression of introduced species will
only play a minor role in bull trout recovery, we
have identified five situations where such
intervention should be considered. These five
situations are not listed in any particular priority.

1. Where a recent invasion has occurred or a
   localized population of introduced species exists.
   If the invader has a high potential of spreading,
   it would be a high priority. This is the type of
   situation where a total removal program is likely
to be most feasible and successful.

2. In areas where core areas and nodal habitats
   must be protected.

3. In critical, site-specific situations where a unique
   bull trout population is immediately threatened
   with extinction. It is important to determine
   whether the effort is a lost cause or has some
   possibility of success.

4. Where preservation of native species is the
   highest fisheries priority (e.g., national parks,
   tribal lands, federal lands, wilderness areas).

5. Innovative projects that attempt to identify new
techniques that give bull trout competitive
   advantage over introduced species. More
   knowledge is necessary concerning the removal
   or suppression of introduced species. Although
   removal projects are experimental in nature,
innovative experimental projects that clearly
improve understanding of how this tool might
best be used should be a high priority.

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Abstract—Brook trout *Salvelinus fontinalis* were native in southern Minnesota spring-fed tributaries of the Mississippi River drainage below St. Anthony’s Falls in Minneapolis. Development after 1850 reduced brook trout habitat quality, distribution, and abundance. Since 1880, native and non-native brook trout, and exotic brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* have been widely stocked. Native stocks of brook trout are probably extinct. In southeast Minnesota, wild brook trout have been restored to most suitable streams by stocking. To increase abundance, we recommend habitat improvement in streams where brook trout are the only salmonid, and experimental management in streams where brook trout occur with other salmonids. In the Twin Cities metropolitan area, urban watershed management should include protection and enhancement of the remaining trout streams, and restoration of former trout streams. In Pine County streams, we recommend removal of beaver dams to improve trout movement and cool water temperatures, and instream habitat improvements to increase abundance.

INTRODUCTION

Brook trout *Salvelinus fontinalis* were native to some streams in southern Minnesota, and in the Lake Superior drainage (Flick 1991). In east central and southeastern Minnesota, brook trout were native in spring-fed streams of the lower Mississippi River drainage, including the St. Croix and Minnesota rivers (Eddy and Underhill 1974). St. Anthony Falls in Minneapolis prevented upstream movement of brook trout into the upper Mississippi River drainage (Waters 1977). Brook trout were also native to the Lake Superior drainage in northern Minnesota (Eddy and Underhill 1974). A precise pre-settlement distribution of brook trout in Minnesota is unknown.

 Fisheries managers of the Minnesota Department of Natural Resources (MNDNR) recently proposed to increase brook trout management (MNDNR1996a). Therefore, we reviewed stream surveys, historical accounts, and scientific literature; determined the resource history, the status of wild brook trout, and the factors limiting brook trout distribution and abundance; and recommended management strategies. We here consider three regions in southern Minnesota (Figure 1): southeast Minnesota, the Twin Cities metropolitan area, and Pine County.

RESOURCE HISTORY

Agricultural development of Minnesota began about 1850. The abundant brook trout populations were exploited for food (Johnson et al. 1949, MNDNR file data). Logging and the conversion of riparian corridors and watersheds to agriculture soon degraded physical habitat, and water quality and quantity. Industrial and urban development replaced agriculture in some areas. By 1890, brook trout from native
and out-of-state sources (D. Bathel, MNDNR, personnel communication), and exotic brown trout *Salmo trutta* and rainbow trout *Oncorhynchus mykiss* had been stocked throughout the native range and in other areas of the state.

**Southeast Minnesota**

We assumed that all spring-fed streams in this native range (Figure 1) supported brook trout, and that shade determined the downstream distribution as well as the distribution in streams without springs. Before this productive (alkalinity 225 mg/l) forest-prairie region was developed for agriculture, brook trout were abundant (Thorn et al. in press). Exploitation, degradation of physical habitat and water quality and quantity, and stocking of exotics may have extirpated native brook trout stocks by 1900 (Thorn et al. in press). All watersheds and most streams were stocked with trout to provide fisheries from the 1880s to the 1940s (MNDNR files).

By the 1940s, wild (reproducing) brook trout were rare. Johnson (1946) and Hiner (1947) found brook trout in 4 of 25 streams, and reported reproduction in 2. Stream survey reports recommended brown trout stocking for most of those degraded streams (Johnson et al. 1949) because of better survival. Therefore, few brook trout were stocked after 1950. Also, most rainbow trout stocking stopped after 1970.

By the 1970s, soil conservation practices begun in the 1930s and 1940s had reduced flooding, erosion, and sedimentation, had increased flows, and had extended cold water downstream (Thorn et al. in press). The reintroduction of brook trout began in the 1970s after stream surveys reported wild brook trout in 2 of 75 streams (MNDNR files). Brook trout from these two streams and from hatcheries were stocked into many streams throughout the region. Stocked brook trout survived, grew, reproduced, and moved into unstocked streams. Wild brook trout are now present in 54% of the 156 streams. Allopatric and sympatric populations exist in 16 and 69 streams, respectively.

At the present time, lack of reproductive habitat prevents occurrence of brook trout in most of the 46% of trout streams without wild brook trout. In streams with wild brook trout, downstream distribution is influenced by high water temperature and competition from brown trout. In these degraded streams, adult habitat limits abundance in allopatric streams, and competition from brown trout limits abundance in sympatric streams. Anglers prefer brown trout over brook trout in streams with both species (Hirsch 1989; Thorn 1990).

Seventeen additional streams now have the potential to support brook trout (MNDNR file data). Wild brook trout from two streams are being cultured for reintroduction into these remaining streams. With these last stockings, brook trout will have been reintroduced into all spring-fed streams with suitable habitat within the suspected native range.

Allopatric brook trout populations occur in small streams that have degraded habitat, are lightly fished, and have lower biomass than brown trout streams. The mean width of these streams was significantly less than that of streams when brook trout were sympatric with brown trout (2.4 vs 4.5 m, t-test, P <0.01). The mean stream length with allopatric brook trout populations was 3.2 km. Cover was also significantly less abundant (means of 5.6 vs 7.7 on a scale of 1-15, P <0.01). Public access is limited to 17% of brook trout stream lengths, with 50% of this access being on one stream. In 1995, fishing pressure was 231 hr/km on a brook trout stream under normal regulations, and 208 hr/km on a brown trout stream under a no-kill regulation (Bushong 1996). In contrast, pressure on the larger brown trout streams can exceed 1,600 hr/km (Thorn 1990). Biomass of brook trout in allopatric streams averaged 60 kg/ha and biomass of brown trout in the larger streams can exceed 300 kg/ha (Thorn 1988). In most streams with both species, brown trout are more abundant (MNDNR files).
**Twin Cities Area**

The original distribution of brook trout in the short, spring-fed tributaries of the Mississippi, lower Minnesota, and St. Croix rivers (Figure 1) is unknown. This productive (alkalinity 200-335 mg/l), forest-brushland region was developed for agriculture, logging, industry, and urbanization. The proximity of these streams to the Twin Cities must have accelerated exploitation and degradation. The stocking history is similar to southeast Minnesota streams. We have divided these 14 streams into 2 groups: tributaries to the Mississippi and lower Minnesota rivers; and tributaries to the St. Croix River.

Watersheds of tributaries to the Minnesota and Mississippi are industrialized and urbanized. More than 75% of the land use has development. The human population density (>91/ha), housing density (7-14/ha), and minimum lot size (0.2-0.4 ha) contribute to the watersheds having 10-20% impervious surface (MNDNR 1996b). Schueler (1995) found that when impervious cover exceeded 10%, the quality of coldwater habitats declined. Therefore, each urban stream and watershed must be intensively managed just to protect the few remaining trout streams.

Two streams sustain wild brook trout, and five other trout streams do not now have suitable habitat for reintroduction. These streams are threatened from reduced water quality, increased flooding, and habitat degradation (MNDNR 1996b). Also, an unknown number of trout streams has been lost (MNDNR 1996b). Adult habitat limits abundance in the two with wild trout, and reproductive habitat limits abundance in the five streams without wild brook trout.

These urban streams have recently become more important to the local communities. In 1996, $3.0 million was spent for protection and enhancement of 3.7 km of Eagle Creek. Projects are underway to rehabilitate stream habitat and water quality and quantity in Kennally’s and Brown’s creeks. The MNDNR recently hired a metro trout stream coordinator, and a multi-agency task force is preparing management plans for Twin Cities area streams. If these efforts are successful, brook trout from the wild southeast Minnesota source will be available for reintroduction.

Habitat quality is better in seven tributary streams of the St. Croix River than in the tributaries to the lower Minnesota and Mississippi rivers because of less intensive watershed development. After logging in the late 1800s, St. Croix River watersheds were first used for agriculture. Suburban development with a population density of <1.2 people/ha, minimum lot size of 1.0 ha, and a common lot size of 2.1-4.2 ha (MNDNR 1996b) has replaced most agriculture. Therefore, habitat degradation has ceased in most streams, and six streams have wild brook trout. In these streams, adult habitat limits abundance of brook trout >age-2. Trout biomass in one stream was 360 kg/ha. Fishing pressure is light because few trout are older than age-1 and there is little public access. Research on Valley Creek has shown the stream has high productivity (Hanson and Waters 1974), that habitat degradation favors brown trout over brook trout (Waters 1983), and that sedentary rainbow trout can sustain themselves in a small, spring-fed stream (Cargill 1980).

**Pine County**

The 24 small spring-fed, soft-water (alkalinity <100 mg/l) streams of Pine County also drain into the St. Croix River. Before development, brook trout biomass probably did not exceed 50 kg/ha, and lower densities of larger trout were found downstream in larger streams with fewer springs.

Pine County watersheds were richly timbered near the St. Croix River valley (Waters 1977). In the late 1800s, logging of watersheds and riparian corridors and damming streams for log removal, reduced habitat quality and brown trout abundance. Following logging, corridors revegetated with alder *Ainsus sp.* and willow *Salix sp.* Beaver abundance increased. Beaver dams prevented trout movement between spawning, rearing, and wintering areas; increased water temperatures; and reduced brook trout habitat quality, distribution, and abundance. Some stream surveys indicated that draining wetlands and channelizing upper stream reaches for agriculture reduced stream flows and increased water temperatures.

These watersheds have not been as intensively developed as the more productive watersheds to the south, and most of the region is now forested. However, stream surveys since the 1940s have documented marginal conditions for brook trout because of beaver dams, reduced flow, reduced habitat quality, and increased water temperatures. In spite of a long history of stocking, biomass during the 1940s - 1960s was <10 kg/ha (MNDNR file data). At present, beaver dams determine brook trout distribution by influencing water temperature and trout movement, and watershed productivity and adult habitat limit abundance. Wild brook trout are found in nine streams. Biomass is <10 kg/ha (Newman et al. 1996). Brown trout and rainbow trout are stocked in one stream, and wild brown trout were recorded in one stream. Past management practices removed beaver and beaver dams, and installed some instream cover structures (MNDNR file data). Stream management plans recommend purchase of angling easements followed by intensive beaver
removal and habitat improvement. If management to restore unrestricted trout movement is unsuccessful, we recommend stocking to restore brook trout. However, because Pine County is in a different genetic Conservation Management Area (Fields et al. 1997), a local source will be needed for reintroduction into these streams.

**MANAGEMENT RECOMMENDATIONS**

For an ecosystem-based management approach to brook trout restoration, the presettlement distribution and abundance need to be determined as well as possible. We recommend the reviews of Sedell and Luchessa (1982), Zorn and Seelbach (1992), and Beechie et al. (1994) as examples for using historical data in developing salmonid restoration projects.

Native brook trout probably no longer exist in eastern Minnesota. Managers have a wild source available for future stocking in southeast Minnesota and the Twin Cities area.

Acquisition should be increased because MNDNR requires public access before undertaking any management activity (MNDNR 1994). In non-urban streams, easements have been successful for brown trout management, but in urban streams, fee title acquisition of some upstream watersheds may also be needed for adequate protection (MNDNR 1996b).

Reproductive habitat should be investigated in streams that sustained native brook trout, but no longer sustain wild trout. In most streams, better watershed management should improve reproductive habitat.

Habitat improvements for brook trout have been successful in northeastern Minnesota (Hale 1969) and in Wisconsin (Hunt 1971, 1976), and should increase abundance of allopatric wild brook trout in streams where adult habitat limits abundance.

In degraded streams supporting brown trout populations, brown trout could be experimentally removed before habitat is improved for brook trout because brown trout benefit more than brook trout from habitat improvements (Hunt 1988). However, extensive education programs will be necessary to gain angler support.

The use of regulations to increase brook trout abundance, and improve size structure should be experimental because special regulations restricting harvest usually have not been successful (Hunt 1977; Behnke 1978; Alexander and Nuhfer 1993).

Anglers need to be surveyed to determine support for increased brook trout management. Budget constraints may prohibit a brook trout management increase without a brown trout management decrease.

Restoration of urban brook trout resources will be expensive, and require participation of numerous local units of government.

Due to the lowered productivity of the Pine County streams, it may be less feasible to expend large amounts of effort and monies for habitat improvement after unrestricted trout movement is restored.

**ACKNOWLEDGEMENTS**

We thank MNDNR fisheries managers M. Heywood, D. Shodeen, T. Brastrup, R. Hugill, D. Zapetillo, T. Schlagenhoff, J. Wagner, D. Hendrickson, and J. Weiss for reviewing the report and updating data. We also thank J. Wingate and C. Anderson for editing the manuscript, and B. Dohn for word processing assistance.

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Man Made Rivers Can Work

R. J. Holloway

Abstract—After 3000 years of use and abuse by man the River Itchen in the UK is still, perhaps, the best example of a chalk, groundwater fed, river which exists anywhere in the world. It will be shown how and what actions have been taken to create and rehabilitate a river that now supports healthy stocks of wild brown trout. A history of the evolution of fly fishing is used to illustrate how, when and what major improvements have been made culminating in the present day, ongoing rehabilitation and management scenarios. Site specific examples are shown and described - e.g. channel narrowing, bank stabilization, predator control etc. The conclusion shows that the same river management principles apply when “putting the native back in wild trout” in the River Itchen in the UK as it does on any Spring Creek on the North American Continent.

IN THE BEGINNING

It was due to the melting of the great ice fields which covered most of Great Britain at the end of the last ice age, ten thousand years ago, that chiselled out the valley of the River Itchen and rounded off the surrounding chalk hill to form the topography of the Itchen catchment as we see it today.

History of River Itchen

As the ice fields retreated the hills became heavily wooded with oak, elm, yew & holly and the flood plains filled with willow, alder, reed, carr & sedge. If I can take you back to the flood plain of the Itchen, this is what we could have expected to see throughout the valley floor some four thousand years ago (Figure 1). Although Stone Age man wandered the high ground as hunter gatherers, seven thousand years ago, it was not until around three thousand years ago that Bronze Age man arrived and settled on the drier, higher ground that surrounds the Itchen valley. As they cleared the hills of woodland, firstly for firewood and to create space for their primitive forms of agriculture which included the needs of their animals, they also created tracks, from their homes on the hillside down to the wet flood plains to enable them to collect water for themselves and to water their stock. These tracks are still used today, though not for the same purposes, and at the top of each of these lanes, traces of Bronze Age and later, Iron Age settlements can still be found.

At that time, the Itchen valley floor was just oozing bog and the flood plain as we know it today was covered with dense growths of willow, alder, reed, carr & sedge etc., and with a myriad of spring fed but heavily silted streams which seeped their way slowly down towards the sea. Early man soon discovered the unique characteristics of chalk springs, thousands of which bubbled up throughout the length and breadth of the flood plain. Constant flows of quality water at a constant temperature of 10 degrees C. The inhabitants soon noticed that when winter froze and scorched off the grasslands on the hillsides, the water did not freeze in the valley bottom and the lush vegetation which grew lasted almost the year round. To make the most of this the inhabitants started to clear the valley bottom to construct the green and fertile pastures we see today for their own use and for their stock. The myriad of boggy streams were in time channelled into fewer and fewer streams until

\[1\] MIFM, River Keeper, River Itchen, Martyr Worthy, Winchester, Hampshire, U.K.
eventually one or two main channels were formed and, in places, these original channels can still be seen today. In and during the intervening centuries, valley residents have used these man-made channels for many and various purposes. History informs us that the next major influence was the arrival of the Romans in the month of August 55BC and being the clever engineers they were, used the river water for their own benefit and even today Roman culverts and channels are still in use under and around the ancient city of Venta Belgarum (Winchester). They also constructed water meadows around the City for agricultural use and, again, some of these are still in use today. Following the retreat of the Roman Empire in AD440, the Itchen Valley, like the rest of Great Britain, passed through a period we call the Dark Ages. As the influences of the well organized Roman civilization retreated civilized progress in this country almost came to a halt and it is not until the early Middle Ages that we can trace any further major changes in the valley. In the interim period, the Viking, Angles, Jutes & Saxon invasions took place and their influences tended to break up what meagre stable civilization existed and, except for some Saxon influence, it was not until the Norman Conquest in 1066 that we can see my major forms of civilization returning to the valley.

It was the spread of Christianity and the construction of the original Church in Winchester that eventually became Winchester Cathedral, more than a 1000 years ago, we can really say that civilization as we know it, returned to the Itchen valley. It was for the construction of this wonderful building which was built on a bog and, to this day, still floats on a raft of oak logs, that the then Archbishop William of Wykham decreed that as much oak as was needed to build the Cathedral should be felled from his lands on the hills of the upper River Itchen valley and be floated down the river for the use of the builders. This indicates there must have been no obstructions to impede the flows and sufficient water to float huge green oak tree trunks, several miles along the river course.

In 1348 the then Bishop of Winchester, Bishop de Lucy, directed that a dam should be built across the valley at Alresford, some eight miles from the source of the ever. It was duly built and it impounded 200 acres of water, the purpose of which was to create sufficient head of water which, when released in a controlled manner, would create such a head of water to allow large rains which were loaded with bales of wool to ride the flood all the way down the river to the town of Southampton, some thirty miles away. The wool was then ferried across the English Channel to supply the growing wool trade with Europe. This dam is still there and although the impoundment is now only about 20 acres, as the pond has silted and grown in over the centuries, and is now a nature reserve.

No accurate records of fish or fish life are known during these periods, in fact I very much doubt if there were many fish species which could survive in some parts of the main river channel, probably only in the headwater streams. This is borne out by an account in the City records of Winchester, when in 1538 Lower Brook Street, which still runs parallel and alongside the Itchen as it passes through the lower end of the City, the inhabitants of this street had to be evacuated to Middle and Upper Brook Street, higher up the City as the Stench from the river was so great that the inhabitants were unable to tolerate it and cholera was rife.

The next major influence by man on this man-made river was the construction of water mills from the late 1500’s through to the mid 1700’s. Grist mills and sawmills were built to an intensity of a mill per mile of the river. The last operative mill was closed just after the last war and those which have not been demolished have now been transformed into desirable living accommodation. It was at the height of this milling era that we see the first river keeper employed. His job then was little to do with fish but to keep the millheads clear of the prolific aquatic weed growths and to maintain the man-made river banks which created the heads of water to power the mills. This valley being the centre of the wool trade, many of these millheads were used to dip and wash sheep and also to wash & dye the shorn wool. Several mills were called Fulling Mill as “fulling” is a medieval English word for sheep dipping or wool washing. Even in these early times various crude chemicals were used to dye wool and to wash sheep to kill parasites and these would have been detrimental to the fish populations.

It was in the late 1700’s and early 1800’s that the mills began to fall out of use as the Industrial Revolution grew and the Reform Acts of 1832 took their toll and life began to change in the Itchen Valley.

Wealthy people whose riches were accrued from the Industrial Revolution began to buy up vast chunks of land that included substantial lengths of the river. It was these wealthy industrialists and bankers (or “robber herons” as they were known locally) who
had the money and the time to take their pleasures from within their estates and to partake of the harvest of fish from the river. It was, by this time, that the river had partially recovered from most of the misuses it had suffered over the centuries, just by sheer neglect and nonuse by man, the river had cleansed itself and had started to regenerate quite naturally. Though one last agricultural use persisted in places right into the 20th Century and that was the drowning system of the water meadows.

Although most of the mills had ceased operation but were still in place, the river keepers had still to be employed to control aquatic weed growths and to carry out necessary bank maintenance, mainly to protect valuable land and property in the flood plain from summer flooding. It was the evolution of dry fly fishing and the building of the split cane rods which helped to shape the management of the Itchen from this time on and has continued to do so, right through until the dawn of the 21st Century. Regular accounts of the sport of fly fishing for fish and especially brown trout can be found in the literature of England from the 11th & 12 Century onwards yet it was on the banks of the Itchen and Test that dry fly fishing evolved and in the middle to the late 1800’s it was those gentleman of substance who had the time to spare who, unwittingly, created a form of sport which really appealed and that helped to shape the management of the river that we see today. It was those who had followed the preachings of those early dry fly fishing disciples, Mottram, Sheringham, Marryat and Halford and more lately, Lord Gray, Sques, Dermot Wilson and Frank Sawyer who influenced the owners of this wonderful river. Dry fly fishing on the Itchen and Test became the way to fish and to increase this opportunity to practice the art, the landowners employed more and more river keepers to maintain, enhance or restore the rivers back to a state where they offered even more top quality dry fly fishing for wild brown trout.

Up and down the chalk streams of Hampshire, vast amounts of money was spent by these landowners on their particular beats, to such an extent that there arose great, but friendly rivalry between beats and between rivers as to who could produce the best dry fly quality fishing. In those days access to the rivers was kept strictly to the owners and the owners’ guests. It was only in the latter years that commercialism crept in and access has become more readily available but skill constrained in most cases, according to the size of your bill roll! Fishing clubs have been formed as have various fishing associations over the years and each have acquired rights and tenancies as they have become available, again to such an extent that every inch of the bank of the River Itchen is owned and fished by somebody. Immoral as it may appear to some, if it was not for these landowners who loved their rivers and their sport and paid out of their own pockets for the rivers to be protected and improved and maintained properly for their own use, we would not have such fragile gems for people to enjoy today.

In 1907 the Test & Itchen Association was formed by the landowners who aimed to establish a common and agreed management strategy for both the River Itchen and Test. This Association works closely now with all the relevant government agencies and together the overall management of our rivers is in good, capable hands. Of course, there are many problems to face each year as any river and it’s catchment has to do in the modern age, as towns and villages expand and the demands for water and space grow. I believe that each and every river must strive to have in place the main foundation stone of a fishery management philosophy.

Each river and its total catchment must be viewed in the context of one single aquatic ecosystem which is managed as a whole unit.

Proceeding onwards, as more and more people took up the art of dry fly fishing, demands for quality dry fly fishing grew, in some cases and on some beats, fishing pressure has been allowed to grow to such an extent that the self sustaining stocks of brown trout were unable to supply the demand. Fisheries became overfished and before catch and release became popular, stocking with brown trout and imported rainbows became the recognised remedy in the early days. With this heavy stocking came the commensurate decline in the quality of the fishing experience and demand began to tail off. Fortunately, some of the forward thinking owners and keepers had the foresight to establish fishery management policies that are now aimed at the protection and enhancement of the wild brown trout and it’s habitat with the aim to produce self sustaining stocks of wild brown trout. By fighting hard to protect the river flows in quantity by reducing abstraction, and quality by more stringent pollution controls, further degradation is being controlled. By planning and lobbying for the establishment of a total catchment management plan that views the whole aquatic ecosystem in the context of one unit further protection
measures come into line e.g. the control of detrimental land use practices, the encouragement of creating and enlarging buffer zones, and all the various uses of environmentally sustainable economic development principles.

**Catchment Management**

By establishing this basic catchment management philosophy, and not until, can any site specific remedies really be contemplated with confidence. So many times in the past, time consuming, labor intensive and expensive work has been undertaken attempting to remedy the symptoms of degradation in a fishery, when the causes of those symptoms are unclear or not understood or, even unknown. For example, it is of limited benefit to regularly dredge silt from a stretch of river if the root cause of the build up of silt is not identified. It will often be found that problems do not actually derive from within a river but rather beside the river or, in many cases, quite a distance from the river’s edge.

Therefore, land uses practices and their effects within a catchment have to be studied in depth.

History teaches us that some river rehabilitation and management schemes have had limited success because they have been carried out as isolated projects without regard to the whole river catchment as an ecosystem and we also find that the end result if often piecemeal rehabilitation directed at the effects of the ecosystem disorder rather than its causes, therefore, again we have to manage our aquatic ecosystems as a whole, not in parts.

Important as this fundamental concept is, it is an ideal which is not always easily attainable. It is, at the same time, important to recognize that local rehabilitation works can often produce significant local benefits, for example if excessive bankside grazing by livestock is a problem on a fishery, then treating the cause and the symptoms by fencing the river, are one and the same thing. On the other hand, it can be a waste of time constantly cleaning and restoring spawning gravels if the factor limiting survival is excessive silt laden stone water runoff.

Understanding the catchment is usually half the problem solved. Once the factors which affect the health of the aquatic ecosystem have been identified and understood then, site specific rehabilitation, restoration and conservation work can be drawn up and earned out with more confidence.

**Practical Techniques**

With the history and philosophy lesson over, I would like to take you briefly through some more of the practical techniques used on the River Itchen. Bearing in mind all I have said, and once the cause of the problem has been identified we will look at figures 2-8.

Of course, it is all a master of degree as to how any civil engineering is carried out, because the methods used on the placid, springfed rivers of the Hampshire Basin would not, for example, be man enough on the Yellowstone River here in Montana. The principles, however, are the same. Powerful spate rivers such as the Yellowstone will, and must, have their own tailor made management techniques. On the spring fed creeks of this Continent (North America) chalk stream restoration and enhancement techniques would work once a program is formulated which takes into consideration local conditions.
On the River Itchen, channel narrowing is undertaken where erosion has widened the channel to such an extent that the water is too shallow. By narrowing the channel the flows are speeded up and this keeps the silt on the move, deepens the channel and improves macrophyte growth and, therefore, enhances good wild brown trout habitat. Care has to be taken not to over narrow as this can cause excessive erosion downstream especially if the 10/50/100 year historical flood events are not taken into consideration. Being a totally man-made river, the banks of the Itchen have to be regularly repaired as the river is always trying to return itself to its original natural state.

Lack of good natural spawning conditions have been shown to be a major constraint on the maintenance of the wild trout populations of the River Itchen. To address this problem, channel narrowing helps to keep spawning gravels clean and free from silt. Owing to the high calcium content of the water, gravels become naturally compacted over time so regular raking and water jetting of these compacted substrates does open up more areas for potential spawning. At times, where gravels are not satisfactory, importation and planting of gravels of the right size is undertaken and has been proven successful. Predator control is an ongoing occupation for river keepers, mink, otters, herons, cormorants, pike and human poachers constantly have to be
addressed. Constant vigilance is the watchword. As I tell my students who aspire to become river keepers in England, to be successful in managing and keeping a wild trout fishery one has to be, firstly - fully conversant with the whole life cycle of the wild brown trout and all its needs for survival from egg through to at least 4 years old, and then to be able to pinpoint and identify all the limiting factors that control survival of the trout throughout this cycle and be capable of treating these factors. To think like a wild brown trout may be an over simplification but I find it is a good and simple maxim to follow.

Towards Good Stream Management

So let's take the theme of this meeting “putting the native back into wild trout” by highlighting the fundamental principles of good and practical river management that will lead us towards achieve that goal.

Experience has taught me, over the past 40 years of involvement with the chalk streams of England, that Nature knows best and that in no way can we change her ways, we can however help and assist her in the healing process of degraded streams. By understanding how nature works, we may be able to create or recreate the right conditions for a species of fish that may never have inhabited that stream. Not until all the detrimental land use practices and storm water runoff processes within the catchment have been identified and, where necessary, mitigation and control measures implemented, will any major stream rehabilitation be effective or carried out with any confidence. So good catchment management is a priority.

Before any rehabilitation work on a stream is even contemplated, lot alone planned, a historical assessment has to be made of the stream and its catchment to ascertain what the pristine conditions were like and how and why conditions have changed through time down to the present. This assessment may reveal that it is not feasible or desirable to return the stream back to its pristine state. On the other hand, it may reveal that all the stream needs is added protection and nature will do the restoration. This initial survey will, therefore, pinpoint and identify all the limiting factors that are controlling survival of the target species. Once this survey and assessment is completed and given water quantity, quality and that all seasonal flow fluctuations and temperatures are acceptable, we are now armed with sufficient information to plan and design the restoration works necessary to recreate or create the right conditions that allow for the establishment, restoration, or enhancement, of a self sustaining stock of wild brown trout. The end result may be, however, a stream that is quite different from its historical pristine state, yet what has been produced is now a functional stream whose stability is maintained by and is compatible with all the prevailing catchment conditions.

To help us towards achieving this goal there is a five stage process which will underpin any rehabilitation program which determines the ultimate success of this program. These stages are:

1. A historical catchment and stream assessment which includes identifying limiting factors.
2. Planning.
3. Design.
4. Construction.
5. Evaluation.

It cannot be over emphasized how essential it is that after completion of any rehabilitation program that the project has been evaluated accurately and to ensure this, evaluation must be incorporated into the scheme of things at the planning stage. Unfortunately, in my neck of the woods, evaluation to date, has ranged from a glance over a road bridge, to a tramp up the stream with a fishing rod, through to the occasional electro fishing check. I do question these types of evaluation methodology, because to be of any value the evaluation has to be performed in a repeatable and standardized form e.g. regular assessments have to be made for a period of at least two complete life cycles of the target species - i.e. wild brown trout in a chalk stream would be 8 years. Without consistent standards of evaluation how can we adjust and learn from our mistakes and plough any newfound knowledge and experience into future, projects?

Yes, I believe man can put the “native” back into wild brown trout. Man has the knowledge and expertise - all that is needed is the will and to remember that any rehabilitation projects are approached in a well ordered and standardized manner. With all the stream classifications now available and with the right data, methodologies, models and monitoring -and evaluation and case history studies, all these should be blended into a useful process whereby habitats can be assessed, improvements planned, effects and responses predicted, monitoring designed and performed, construction assessed and post project evaluation completed, all in a repeatable and standardized form. If anyone doubts that this is possible, let us just remember that man went to the moon and back safely, just because the late Jack Kennedy said that man would.
Snorkel Counts Can Differ Like—Day and Night

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Abstract—Snorkeling is frequently used to estimate summer abundance of trout in clear, moderately sized streams. But, in the North Umpqua River, OR, we found that snorkelers observed fewer trout during the daytime than by the same snorkelers at night. To test the hypothesis that daytime and night counts of trout >8 cm long were not different, we compared paired daytime and night snorkel counts of trout in 5 reaches during August 1994. Reaches contained a variety of habitat types and trout (brook, rainbow, and brown trout in various combinations), flows ranged 5 to 80 cfs and water temperatures from 8 to 18° C. Despite clear water, hot summer weather, and excellent visibility, daytime snorkeling accounted for only about 1/2 of the trout observed during night snorkeling. In the extreme case, 2 trout were counted during the day but 80 were counted at night. The count differential was related to habitat type (increasing in: cascades, riffles w/ pockets, riffles, glides, and pools) but not to water temperature. We believe that many trout were hiding among streambed cobbles during the day, but became active in the water column (and hence more easily observed) at night.

INTRODUCTION

During PacifiCorp's relicensing studies on the North Umpqua River in southern Oregon, biologists observed few trout during daytime snorkeling relative to the number seen when electrofishing or night snorkeling—even during the summer. In August 1994, we conducted a simple experiment to test the hypothesis that daytime and night snorkel counts were not significant different, and to see what factors influenced any observed differences. Two biologists systematically snorkeled each reach by working upstream in a parallel formation; daytime observations occurred between 1400 and 1800 and night observations between 2100 and 0100 hours. Counts occurred during a dark moon phase. Trout were separated into three lengths categories: <8 cm, 8 to 15 cm, and >15 cm.

A total of 109 trout were observed in the daytime and 333 at night. For trout <8 cm long, daytime and night counts (33 and 30) were not different, but for larger trout daytime and bight counts were different (P<0.06). Night counts were substantially higher than day counts for all species and temperature combinations. In two reaches, we followed snorkel counts with multiple-pass electrofishing and found that night counts were closer to the estimated population.
Overall, the difference between daytime and night counts tended to be least in cascades (where daytime counts sometimes exceeded night counts) and greatest in glides and pools. A stepwise regression model using integer codes showed that habitat type was correlated with the difference in counts (P<0.03), but accounted for only about 10 percent of the variability. We believe that many trout were hiding among the streambed cobbles during the day, but became more active in the water column (and hence more easily observed) at night. Since few trout were large enough to be piscivorous (>30 cm) and angling was non-existent in these reaches, we speculate that this behavior may help to avoid avian predators. We recommend that biologists observing trout for population estimates or behavior studies consider the potential limitations of daytime observations and possible value of night observations.

ACKNOWLEDGMENTS

The authors thank T. Hardin, D. Leonhardt, T. Olson, B. Richardson, A. Scott, and M. Ward for assistance.
Back from the Brink? The Preservation and Restoration of Coaster Brook Trout in Lake Superior¹

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Until the 1870's, a large form of brook trout, regionally called a "coaster", was abundant and widespread in the nearshore waters of Lake Superior and provided an exciting fishery. By the early 1900's, coasters were reduced to a few remnant populations in isolated areas that have persisted to the present. The primary cause of this reduction apparently was overexploitation, which may have worked in conjunction with a number of other factors. Reduction of coaster populations was so swift and thorough that little scientific information about them was ever collected. However, ongoing and recently completed studies in genetics, biology, and life history are shedding new light on these unique brook trout stocks and are revealing both some encouraging indicators for restoration and a high degree of vulnerability to overharvest. The success of restoration efforts will likely hinge on gaining broad public support, the cooperative interaction of U. S. and Canadian federal, state, tribal, and provincial agencies, and on protecting native and reintroduced stocks from overharvest.

THE LAKE SUPERIOR BROOK TROUT

Early European settlers called the large form of native brook trout (Salvelinus fontinalis) in Lake Superior a "coaster" because of its preference for shoreline habitat in the lake. We follow Becker (1983) in using the term "coaster" for any wild brook trout that spends part of its life in Lake Superior. We arbitrarily extend this definition to include Lake Nipigon (Ontario) because of the physical linkage of the two systems, and similarities in habitat and in the population attributes of brook trout. We use the term "anadromous" to describe generically any migratory brook trout population, and the term "sea-run" to describe migratory populations that reach salt water. It is not clear whether, or to what extent, migratory populations of brook trout differ genetically from non-migratory populations. The coaster has never been described as a separate subspecies of brook trout. Biologists now appreciate that the Lake Superior coaster populations, while not fully described by ongoing genetic analyses, may be unique and comprise an "evolutionarily significant unit" (Behnke 1994).

According to numerous journal accounts and newspaper clippings of the 1800's, coasters were abundant along sheltered, rocky coastline areas around the lake where they provided a valuable sport fishery. By the early 1900s coaster stocks along most areas of the Lake Superior shoreline were reduced to scattered, small remnants. Coasters apparently exhibited an anadromous life history strategy involving migration into streams for spawning during autumn, but some may have spawned in the lake as well. Many of the specific details of their life history remain unknown because most populations were greatly reduced or eliminated before they could be studied.

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Information specific to the Lake Superior coaster is being gained through ongoing studies in the Nipigon River system, Ontario and at Isle Royale, Michigan, and by gathering anecdotal historic information from newspapers, journals, and writings of early residents of the region.

**Historical Distribution**

Numerous historical accounts during the mid-1800s described the occurrence of large brook trout in shoreline and tributary areas around Lake Superior, but it is not always clear if the fish being referred to were anadromous. Brook trout and lake trout (*Salvelinus namaycush*) were the only salmonines indigenous to Lake Superior and some early writers did not differentiate between these species (Goodier 1981; Wilson 1991). From these accounts we have carefully inferred the likely historical distribution pattern of coasters in Lake Superior.

In 1860, the Canadian Government Overseer for Fisheries on Lake Superior noted that speckled trout (a commonly used name for brook trout) were present in great numbers in the creeks and rivers of Lake Superior's north shore (Goodier 1981). Waters (1983) suggested that historically, brook trout were probably present below the first impassable barrier in all streams along Lake Superior's north shore. In eastern Lake Superior, the St. Mary's Rapids was a major destination fishery. From this hub of Great Lakes travel, anglers hired boats and guides to explore the fishing opportunities offered by Lake Superior's nearshore waters and many tributaries. In 1865, R. B. Roosevelt (1885) found brook trout to be abundant in the St. Mary's Rapids and up the coast from Gros Cap, including the Chippewa, Batchewanna, Agawa, and Nipigon rivers. The south shore of Lake Superior, from Sault Ste. Marie, Michigan, west, also supported coaster populations in association with many spawning streams.

The total number of Lake Superior tributaries that once supported spawning coaster populations is thought to have exceeded 61 in Ontario, 25 in Michigan, 12 in Wisconsin, and 9 in Minnesota (Newman and DuBois 1997). Shiras (1935) stated that prior to 1890, coasters inhabited all the nearshore waters of Lake Superior for more than 1,600 km (Lake Superior has 4,385 km of shoreline including islands). Exceptions to this were areas with pure sand beaches or steep, wave-washed cliffs. Coasters preferred more sheltered waters, generally within 15 m of shore, or about islets and shoals in depths < 7 m. Streams with cool temperatures invariably supported resident brook trout and, in the autumn, spawning coasters from the lake.

**Biology and Ecology**

**General Description**

Although most salmonines are anadromous, species differ greatly in the extent to which they exhibit anadromous traits. Rounsefell (1958) used a number of behavioral criteria to rank salmonines according to their degree of anadromy. Accordingly, the genus *Salvelinus* exhibits anadromous traits least strongly among North American genera. Throughout their range, brook trout typically exhibit either exclusive freshwater residence or only weakly anadromous traits. These traits typically include: short periods of residence in the sea, remaining in coastal or estuarine areas (often close to natal streams), maturing in freshwater, often surviving to spawn more than once (iteroparous instead of semelparous), and having frequent occurrences of freshwater forms.

Coasters are difficult to study because existing remnant populations either may not be representative of most of the historic Lake Superior stocks or may be so reduced as to no longer exhibit traits typical of healthy populations. Additionally, the more robust populations persist in fairly remote areas. To understand the life history of the Lake Superior coaster, we must therefore collect and summarize as much information as possible from extant populations while cautiously reconstructing probable population characteristics from themes common to anadromous brook trout throughout their range.

**Reproduction**

Brook trout spawn in late summer or autumn in freshwater streams or shoal areas of lakes. They mature over a wide range of ages and sizes with a greater proportion of males than females maturing at small sizes. Size is a more important determinant of maturation than either age or growth rate (Naiman et al. 1987). Anadromous populations mature at a later age than resident populations, often not reaching maturity until their third summer (White 1940; Dutil and Power 1980; Castonguay et al. 1982). Maturation of the gonads, which is dictated by photoperiod, occurs throughout the summer. Timing of maturation varies regionally, with some populations spawning as late as

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1Despite differences in salinity and other aspects, we consider oceans and large lakes to be functionally equivalent habitats for anadromous salmonines.
December. Anadromous brook trout usually undergo final gonad development upon their return to natal streams (Power 1980).

Anadromous brook trout are flexible in choosing spawning sites with lower river and river mouth areas (White 1940; Vladykov 1942), and near-shore lacustrine and estuarine settings (Scott and Crossman 1973; Weed 1934), often used where suitable conditions exist. Specific conditions required for redds include loose, silt-free gravel or coarse sand over strong groundwater seepage. Thermal stability is a key factor in the use of spring seeps as redd sites. Declines in water temperature from the 40's to the 30's (degrees Fahrenheit) typically trigger spawning activity. Anadromous brook trout usually spawn each year once mature is reached (Naiman et al. 1987).

Fecundity of anadromous females is size-dependent and varies only slightly among stocks. However, fecundity of anadromous stocks is greater than that of resident stocks to an extent beyond that predicted from simple increases in body size (Naiman et al. 1987). Egg counts ranged from 444 to 1,857 per female for stocks from the Ungava region of Quebec (Power 1966) and 138 to 2,305 per female from Riviere a la Truite, Quebec (Montgomery et al. 1990). Nipigon strain brook trout broodstock at the Dorion, Ontario hatchery produce about 1,500 eggs per kg of female body weight (P. Richard, Dorion Hatchery manager, Ontario, pers. commun.).

Hatching time is temperature and oxygen dependent, and ranges from 100 days at 5° C to about 50 days at 10° C (Scott and Crossman 1973). Upon hatching, alevins remain in the redd until the yolk sac is nearly fully absorbed. Emergence usually occurs in March, but may be earlier or later depending on latitude. Despite extensive observations, Naiman et al. (1987) were not able to detect any significant differences in choice of spawning sites, reproductive behavior, fertility, early ontogeny, or early life history between anadromous and resident stocks.

Feeding

Brook trout feed opportunistically on a wide variety of organisms depending on their size and the availability of prey. Feeding behaviors of anadromous brook trout vary from young to mature fish and riverine to sea environments. In rivers, the newly emerged young feed on Copepoda and Cladocera and soon add Diptera (mainly chironomids and simuliiids), terrestrial insects, and the larvae of Trichoptera, Ephemeroptera, and Plecoptera to the diet during their first summer of life (White 1940; Bridges 1958; Miller 1974; Williams 1981). As they grow, aquatic insect larvae and terrestrial insects continue to form the dominant foods, but small fish become increasingly important in the diet as brook trout reach 200 to 300 mm in total length (TL) - Bridges 1958; Verreault and Courtois 1989; Montgomery et al. 1990).

The diet of coasters in Lake Superior has not been described. Miller (1968) examined the stomachs of a small sample of hatchery brook trout that had been planted in Keweenaw Bay, Michigan. He found that isopods, amphipods, gastropods, a variety of aquatic insects (mostly Diptera), and fish (primarily sticklebacks [Gasterosteidae] and sculpins [Cottus]) were the dominant food items. Coasters likely fed on whatever small fish species and arthropods were available in nearshore areas.

Movements

The movement pattern characteristic of anadromous salmonines includes the following phases: hatching and rearing of young in natal streams, migration from these streams down to the sea as smolts at ages that vary among species, movements in the sea that are poorly described for most species, and return to the natal streams for spawning by mature adults. Little is known about the movement patterns of coasters in Lake Superior beyond the assumption that they generally fit into the above model, while displaying weakly anadromous traits.

Downstream migrations of sea-run populations of brook trout were usually characterized by the sudden movement, usually during spring, of primarily 2 to 4-year-old smolts (we follow Randall et al. [1987] in using the term "smolt" for emigrating juvenile brook trout although we recognize that because of life history differences between the corks and the more strongly anadromous salmonines, the proper terminology to use is questionable [Johnson 1980]). These fish then maintained a coastal sea residence for just 1-5 months before returning to the natal stream (White 1940; Wilder 1952; Dutil and Power 1980; Castonguay et al. 1982; Montgomery et al. 1990). A variety of cues for movement have been suggested including temperature, spring flooding, lunar cycles, tides, and migrations by other species (Naiman et al 1987; Montgomery et al. 1983), but rises in river discharge appear to trigger most movements (White 1940; Montgomery et al. 1990). Anadromous populations of brook trout often live sympatrically with resident forms (Randall et al. 1987). It is not clear to what extent these life history differences between forms are influenced by genetics and the environment.
Sea-run brook trout usually make relatively short upriver migrations during late summer or autumn. Maximum distances traveled to spawning areas were between 30 and 50 km in the Moisie and St. Jean rivers (MacGregor 1973; Castonguay et al. 1982).

Movements within the ocean were quite limited for sea-run stocks; fish either remained in estuaries or traversed nearshore areas within about 16 km of their natal rivers (White 1942; Smith and Saunders 1958; Dutil and Power 1980; Naiman et al. 1987). Straying to non-natal streams for short periods of time occasionally occurred (White 1942; Castonguay et al. 1982), but extensive straying was unusual (Gibson and Whoriskey 1980; Whoriskey et al. 1981; Naiman et al. 1987).

**Age and Growth**

Limited age and growth information for several coaster stocks in Lake Superior shows growth rates to be rapid. Age and growth of a small sample of native coasters from Isle Royale were determined by scale reading and backcalculation of length-at-age (unpubl. data collected by the Michigan Department of Natural Resources [MiDNR] and the U.S. Fish and Wildlife Service [USFWS]). Mean TL at each annulus were 112-113 mm at age one, 213-215 mm at age two, and 336-366 mm at age three.

At Grand Portage, Minnesota, backcalculation of scale samples from two consecutive year classes of returning adults indicated growth rates of about 127 mm (5 inches) per year for ages one through three (LEN unpubl. data). Nipigon River coasters commonly reach sexual maturity at age three, when first-time spawning males average 401 mm TL and females average 457 mm TL. Most spawners range from 1 to 2 kg in weight, with the largest fish weighing up to about 4.5 kg (RJS unpubl. data). Samples of spawning populations at Isle Royale and Grand Portage confirm this pattern of maturation. With the exception of a low number of precocious age 1+ or age 2+ individuals (<10%), sexual maturation occurred at age 3+, and at lengths greater than 363 mm.

Coasters of the Nipigon River have an unusually long life span with spawners commonly reaching three to five years, and occasional large individuals reaching eight years (RJS unpubl. data). By contrast, Becker (1983) described female brook trout in inland populations in Wisconsin as usually maturing as yearlings, at a minimum TL of about 127 mm. He described their life expectancy as rarely more than three years. Successful preservation and restoration of coaster populations will include management strategies that recognize the substantial differences in growth rates and sizes at sexual maturity between coasters and inland populations.

**Size Structure**

Coasters along the north shore of Lake Superior were apparently larger than those along the south shore of the lake during the mid and late 1800's. Roosevelt (1985) stated that Lake Superior coasters averaged more than two pounds in weight, but that those on the south shore averaged a pound while those along the north (Canadian) shore averaged fully two pounds. These size differences could have been due to population density differences, unique growth characteristics of genetically separate strains, or to differences in forage characteristics between the two areas. Maximum sizes may have also varied over time. According to Shiras (1935), "the largest speckled trout taken on the south shore of Lake Superior prior to 1890 weighed 5.25 pounds; a much larger number varied from four to five pounds; and the minimum weight was about a pound." He added that since 1900, speckled trout weighing more than 6.5 pounds have been taken along the south shore of the lake. Shiras attributed this increase in maximum weight over time to a decreased number of trout in relation to the food supply. More recently, large coasters from Lake Nipigon and the Nipigon River have dominated fishing contests from 1946 through 1989. The Molson Big Fish Contest (Wilson 1991) lists several fish each year that range in weight from 2 kg (4.25 lb.) to 4.6 kg (10.2 lb.).

Shiras (1935) stated that the immature trout did not enter the lake from the breeding streams (as smolts) until they weighed about a pound. This statement is at odds with all other available information on anadromous brook trout. Brook trout smolts have usually outmigrated at an average size less than 200 mm TL (less than one half pound), which is consistent as well with smolt sizes of many other anadromous salmonines (Wilder 1952; Dutil and Power 1980; Castonguay et al. 1982; Montgomery et al. 1990).

**FACTORS THAT LIMITED ABUNDANCE**

Coasters have been eliminated from many areas of Lake Superior, particularly along the south shore, and are substantially reduced in abundance lake-wide relative to their probable historical condition. The composite picture of coaster losses from south shore areas depicted by most accounts is of an abrupt decline from the 1860's through the 1880's, with a continual further decline thereafter. While migratory brook trout have suffered the most
conspicuous losses, stream resident populations also appear to be substantially reduced in the Lake Superior basin (D. Pratt, WDNR, Superior, pers. commun.).

The opening of the Lake Superior watershed by road, rail, and water removed protection of coasters by isolation. Many factors have been implicated in their reduction including overexploitation by sport and commercial fishers, logging effects, other habitat losses including loss of spawning areas, pollution, loss of genetic diversity and/or altered genetic profiles, man-made barriers to migration including hydroelectric dams, and competition with exotic salmonines. Possibly several or all of these factors worked in concert to reduce coasters, and some factors may have been more important in some areas of the lake than in others. Although the exact role these factors played in the decline of coasters is uncertain, it is important to examine their potential effects carefully, because the forces that contributed to the decline may also function to impede restoration.

**Overfishing**

Overfishing has frequently been implicated as one of the primary factors in the reduction of coasters. As access to the Lake Superior watershed improved in the late 1800's, areas with good brook trout fishing were widely promoted for tourism. Commercial fisheries that targeted coasters were active around Isle Royale (S. Sivertson, Duluth, MN, pers. commun.), in Wisconsin's Bois Brule River (O'Donnell 1944), and in the Nipigon River (Wilson 1991). Accounts by Roosevelt (1985) and Wilson (1991) stated that many hundreds of barrels of coasters were sent to commercial markets. These early fisheries were concentrated on stocks that were vulnerable because they occupied a narrow band of Lake Superior shoreline habitat and specific, small spawning habitats in streams.

A number of specific lines of evidence support the contention that overfishing was the main factor that reduced coaster populations. First, brook trout are known to be highly vulnerable to angling and their populations can be greatly reduced in localized areas with only modest angling effort (MacPhee 1966; Power 1966; Havey and Locke 1980). Anadromous brook trout, throughout their range, appear to be especially vulnerable to angling because of their close association with nearshore areas in the sea and habitat of congregating in streams at certain times of the year for feeding and spawning (Power 1966).

Second, the limited historical record clearly implicates overfishing, especially in the spawning streams, in the decline of coasters (Winchell 1880, cited in Smith and Moyle 1944; Shiras 1935). Shiras (1935) reported that coasters were taken by anglers in great numbers as they gathered at the mouths of streams or lay in pools in the lower reaches prior to spawning. He suggested that this practice, and the setting of gillnets along the shoreline, eventually extirpated coasters from U. S. waters.

Third, the present distribution of coasters in Lake Superior is consistent with the overfishing hypothesis. They have been virtually eliminated from areas easily accessible to large numbers of people and exist only in more remote areas, such as some rivers along the north shore, at Isle Royale, and in the privately controlled Salmon Trout River in Michigan where they are largely protected from angler harvest.

Fourth, there is growing evidence to support the theory that smolting and maturity (and hence growth) are physiologically opposed processes in anadromous salmonines (arguments summarized by Thorpe 1987). Salmonines appear to make a physiological "decision" early in life either to mature at an early age or to delay maturation and smolt. Growth rate seems to play a major role in this decision, with faster growing juveniles being more likely to opt for early maturation. Heavy exploitation selectivity favors early maturation of brook trout because larger, later-maturing fish have a higher risk of being harvested before they spawn than do early-maturing fish. A trend toward early maturation could therefore reduce the tendency of a population to smolt because of the opposed nature of smolting versus maturation.

Additionally, if overexploitation led to reduced densities in juvenile rearing areas (through reduced egg deposition), it would favor increased juvenile growth rates which could again reduce the tendency to smolt. Supporting evidence for these ideas is starting to accumulate in salmonines. For example, Zalewski et al. (1985), using a resident, nonmigratory population of brown trout (Salmo trutta) for experimental stocking, found that fish planted in the least productive of a range of habitats, where growth rates were lowest, did not mature there but smolted. Caswell et al. (1984) suggested that increased fishing pressure at sea caused an increase from 31% to 75% in male parr maturation in the Atlantic salmon (Salmo salar) of the Matamek River, Quebec. Thus, for brook trout, which lack a strong tendency for anadromy, there is a sound theoretical basis, and some emerging evidence, for the theory that heavy exploitation could favor a shift toward exclusive freshwater residence. The evidence in aggregate therefore supports the conclusion that overfishing was the main factor in the decline of coasters.
Widespread Stocking of Domestic Strains

The genetic profiles of native brook trout populations throughout accessible parts of the Lake Superior basin have likely been altered through breeding with domestic stocks which have been widely planted for many years. Domestic stocks have been strongly selected to favor fast growth and early maturation, which appear to be directly opposed to smolting (e.g. Thorpe 1987). Thorpe et al. (1983) showed experimentally that the incidence of male Atlantic salmon that matured before smolting increased from 7% to 30% in three generations when rapidly developing fish were selected as brood stock. Thus the genetic contribution of domestic stocks may serve to reduce the tendency of an anadromous salmonine population to smolt. However, even if genetic contributions from domestic brook trout stocks negatively affected coaster populations, such an affect would have come too late to have been the primary force in their decline. It is possible that genetic influences of stocked strains may have functioned to inhibit the resurgence of the migratory trait in brook trout, at least in heavily stocked areas, and may continue to do so.

Losses of Critical Habitat

Several types of habitat losses, mostly resulting from early logging operations, have been implicated in the decline of coasters. When forested watersheds in the Lake Superior basin were largely clear-cut near the turn of the century, the loss of forest cover in riparian areas must have caused widespread erosion and sedimentation of streams. Loss of canopy shading resulted in some warming of coldwater streams. Clear-cutting and ensuing wildfires altered water storage and retention capacities in watersheds. Groundwater flows critical to brook trout survival and reproduction may have been reduced. Heding and Hacker (1960) reviewed the role of springs in brook trout reproduction and abundance, and observed that "Springs are the 'life blood' of our trout streams. Destroy that 'life' in a trout stream and it's gone-forever."

During the early logging many streams in the Lake Superior basin were used to transport logs downstream (Harmon et al. 1986, Dubois and Pratt 1994). This was done by building logging dams (also known as splash dams) at strategic areas. After the resulting impoundments were filled with logs, the dams were breached sending a massive flow of logs and water downstream. This surge of material undoubtedly damaged stream banks and other existing habitat. Logging dams, although short-term, could have reduced the migratory component of brook trout in some streams by blocking runs at critical times. Furthermore, the practice of snagging (removal of large logs and rootwads from stream channels) was in common use to create unobstructed channels for the quick transport of logs. Large woody debris is now known to perform a crucial function in the creation of habitat for fish (Harmon et al. 1986). The extent of loss to brook trout populations from habitat damage from forest clearing (warming of water, damaged stream banks, sedimentation, loss of instream woody cover, possible reduction of critical ground water flows, blocking of spawning runs) must have been substantial, but is not quantifiable. Some losses of spawning areas probably also occurred.

The timing of habitat losses is most consistent with the latter stages of coaster reduction. Therefore, most forms of habitat loss were probably not major factors in the initial decline of coasters, but likely contributed to the latter stages and may have worked to suppress the resurgence of coasters to the present.

Beaver (Castor canadensis) activity may have also played a significant role in the historical abundance of coasters along some south shore areas of the lake. During periods of high beaver density, excessive damming of tributaries could have reduced access of coasters to spawning areas and inhibited recruitment. Conversely, when beaver numbers were low, as they were in northern Wisconsin during the mid and late 1800's because of high trapping intensity, then access of coasters to spawning areas may have been less restricted than the historical average leading to high recruitment. This could have led to above average densities of coasters along the south shore of the lake during the time period most often used as a rough benchmark of historical coaster abundance (D. Pratt, WDNR, Superior, pers. commun.).

Competitive Interactions

Fisheries managers are often concerned that competition with thriving populations of naturalized salmonines may have reduced, and may be continuing to suppress, coaster populations in Lake Superior. Unfortunately, there is little direct evidence about interspecific competition involving anadromous brook trout from which to draw inferences.

There is direct evidence from several areas of Lake Superior that coasters can coexist with exotic salmonines. In the Nipigon River, coasters coexist with pink salmon (Oncorhynchus gorbuscha), chinook salmon (O. tshawytscha), rainbow trout (O. mykiss), and brown trout, as well as with their native congener the lake trout. Smaller
streams in Ontario such as the Cypress, Big Gravel, and Little Gravel rivers also have a suite of naturalized salmonines, including coho salmon (Oncorhynchus kisutch), coexisting with coasters. Unfortunately, there is no way to determine what the densities of coasters in these streams were prior to the establishment of exotic salmonines. Shiras (1935) suggested that the introduction of rainbow trout may have influenced the survival of brook trout in Lake Superior.

Evidence pertaining to stream-resident brook trout in the Lake Superior basin suggests that negative effects on coasters from competition with exotic salmonines are possible during their riverine life history stage. Rose (1986) documented a growth reduction of subyearling brook trout in a Lake Superior tributary following emergence of rainbow trout in June. He suggested that such growth reductions could result from interspecific competition for food and space, and that they may represent a mechanism by which brook trout could be excluded from some areas by rainbow trout.

Juvenile coho salmon may be the most serious competitive threat to brook trout in Lake Superior tributaries because of similar habitat preferences of the two species and the earlier emergence (2 - 3 weeks) and larger size at emergence of coho salmon (Fausch and White 1986). Moreover, in a laboratory study, Fausch and White (1986) found that coho salmon dominated brook trout of equal size and noted that coho salmon should have an advantage over brook trout in Great Lakes tributaries when resources become limiting. Two decades of unpublished population data from Wisconsin tributaries to Lake Superior suggests that the establishment in the early 1970's of coho salmon has not measurably affected existing stream-resident brook trout populations in those streams (B. Swanson, WDNR, Bayfield, pers. commun.). However, population data from three streams in the Upper Peninsula of Michigan tentatively suggest a depressant effect by coho salmon on brook trout (Stauffer 1977). More testing is needed to establish the competitive effects of coho salmon on brook trout.

Studies from outside the Lake Superior basin have also shown that competition with rainbow trout and brown trout could negatively affect brook trout (Fausch and White 1981; Cunjak and Green 1983; Waters 1983; Larson and Moore 1985). However, habitat-related factors were also clearly involved in some of these reductions of brook trout and encroachments of non-native salmonines.

The potential for competitive interactions between coasters and naturalized salmonines while in Lake Superior is speculative. Significant qualitative and quantitative changes in the forage base of nearshore waters have occurred since the late 1800's (MacCallum and Selgeby 1987), when coasters were last abundant in Lake Superior. Now there is a much more diverse predator complex exerting pressure on available forage. However, these predators may be less strongly tied to extreme nearshore areas than coasters, so the severity of direct competition in the lake may be minimized.

Thus, the existing data pertinent to the competitive relationships between coaster brook trout and exotic salmonines are limited, often indirect, and of doubtful overall applicability. The extent or severity of direct competition between coasters and any one, or any combination of salmonines in a given habitat is unknown. The composite picture of the evidence reviewed suggests that while coexistence is obviously possible, the potential for competitive interactions between coasters and several naturalized salmonine species warrants some concern. However, the reduction of coasters was well under way decades before competition with exotic salmonines might have come into play during the 1920's and 1930's. It therefore appears doubtful that competition played a large role in reducing coasters, although it is possible that it may have acted to suppress their resurgence.

**CURRENT STATUS OF COASTER STOCKS**

In Ontario, the status of coasters is unclear in most waters because of inadequate sampling. They are thought to be absent or exist at low population levels in most of their historic habitats. Adults infrequently appear in catch reports from many areas of Lake Superior and tributaries (S. Greenwood, OMNR, Sault Ste. Marie, pers. commun.). Only a few rivers including the Nipigon, Cypress, Gravel, and Little Gravel are known to have consistent runs that support active fisheries. Population densities per stream are unknown, but the Nipigon River is thought to have the largest population. A viable population of lake spawning coasters also exists in Lake Nipigon. Recent surveys and a voluntary angler diary system show that densities of juveniles and adults in the Nipigon system are increasing (RJS unpubl. data).

In Michigan, the privately controlled Salmon Trout River is the last river in the United States thought to have a spawning run of coasters, but the status of that population is in doubt (Bullen 1988). Detailed harvest records maintained by the Huron Mountain Club show that fishing in the Salmon Trout declined dramatically after about 1950. Electrofishing surveys in 1974 produced only
14 fish, most of which were under 31 cm total length (B. Miller, MiDNR, Baraga, pers. commun.). In October 1996, six adult coasters estimated to range from 40 to 46 cm in length were observed spawning in the lower Salmon Trout River suggesting that a viable population may still exist (J. Farwell, Huron Mountain Club, Big Bay, pers. commun.). Coasters are infrequently reported from a number of other locations along the Michigan shoreline, but the MiDNR considers coaster abundance to be very low in its waters (B. Miller, MiDNR, Baraga, pers. commun.).

Michigan's Isle Royale maintains at least one remnant coaster population that supports a fishery of unknown size. Washington and Grace creeks on Isle Royale are reported to have spawning runs and an active fishery exists in the Tobin Harbor area. Results from an ongoing radio telemetry study suggest that coasters spawn along the shoreline of Tobin Harbor or in nearby stream estuaries, but have not shown evidence of spawning in streams (LEN, unpubl. data).

In Minnesota, a few adult upstream-migrating brook trout have been observed in the Little Marais River in recent years (B. Borkholder, Fond du Lac, pers. commun.), but no viable populations have been confirmed. A cooperative experimental introduction of Nipigon strain coasters by the Grand Portage Band and the USFWS has resulted in gravid adults returning to two streams on the Grand Portage Indian Reservation and a modest amount of recruitment in one stream (R. Novitsky, Grand Portage Band and LEN unpubl. data). Radio tracking of these fish has contributed knowledge about movement patterns and habitat use in the lake.

In Wisconsin, no viable coaster populations are known. The last report of apparently native coasters involved a few large fish from the Bois Brule River in the 1940's (O'Donnell 1944). Several streams had runs of brook trout during the late 1960's and early 1970's, but like occasional fish caught in Wisconsin waters of Lake Superior in recent years, they were thought to result from stockings (B. Swanson, WDNR, Bayfield, pers. commun.).

MANAGEMENT AND RESEARCH ACTIVITIES

Prior to 1992, management strategies in the U.S. were generally limited to stockings of a variety of brook trout strains (including the Lake Nipigon strain), preservation of inland stocks, and protection of stream habitats. Until recently, these efforts tended to lack integration among agencies. In Ontario, efforts to manage coasters began in 1989 with the formation of a brook trout strategy report, creation of spawning sanctuaries, construction of spawning habitats, implementation of minimum water flow agreements, and the establishment of more restrictive harvest limits on the Nipigon River in 1990-92.

Since 1992, all of the fishery management agencies on Lake Superior have initiated or expanded brook trout management or research. Most agencies are now involved in a variety of activities such as establishing lower bag and size limits to reduce harvest, creating spawning refuges for native stocks, implementing river flow management programs to protect critical life stages, restoring degraded spawning habitats, and evaluating existing lake and stream habitats. In addition, tribal agencies are focusing on implementing experimental reintroductions and developing appropriate brood stocks. The USFWS is providing technical and funding assistance to Lake Superior management agencies, developing partnerships among tribal, state, provincial and private agencies to fund research and management projects, and providing public information and educational materials about coasters.

COORDINATING RESTORATION EFFORTS FOR ALL OF LAKE SUPERIOR

Fisheries management authority and research capabilities for Lake Superior are divided among many agencies including the Departments of Natural Resources of Michigan, Wisconsin, and Minnesota, the Ontario Ministry of Natural Resources, the Lake Superior Chippewa Tribal governments of Grand Portage, Red Cliff, Bad River, Keweenaw Bay and Bay Mills Reservations, the Chippewa Ottawa Fishery Management Authority, the Great Lakes Indian Fish and Wildlife Commission and the USFWS, National Park Service, U. S. Geological Service and the U.S. Forest Service. Coordination of management efforts for Lake Superior is the responsibility of the Lake Superior Committee (LSC), and it's Lake Superior Technical Committee (LSTC) provides technical data and management recommendations. All agencies with management authority on the lake are represented on the LSC.

In 1992, initial efforts began that brought the many agencies involved with fisheries management on Lake Superior into a cooperative management approach for coaster brook trout. Responding to concerns expressed by field personnel, the USFWS organized a workshop on coasters which was attended by biologists from most of the agencies that have fisheries management authority on Lake Superior. Those attending were in consensus that coaster
stocks were severely depleted in Lake Superior, that existing remnant stocks needed protection, and that extirpated stocks should be re-established where feasible. The views of the workshop were brought to the attention of the LSTC, which responded by creating an ad hoc subcommittee on brook trout in Lake Superior (BTSC) with members representing each of the agencies. The BTSC was charged with a number of responsibilities including:

- Collecting and exchanging among member agencies all available data on coaster stocks in Lake Superior.
- Producing a status report on Lake Superior coasters.
- Crafting an objective statement for coaster restoration.
- Developing a restoration plan for coasters.

The subcommittee has completed all of its charges except the production of the restoration plan, which is still in progress. The resource managers represented on the subcommittee have widely divergent resources and approaches to managing coaster stocks, but are in general concurrence as to the major issues and challenges that should be addressed in the restoration plan. Paramount among those issues are:

- Obtaining a better understanding of the basic biology and ecology of coaster stocks despite the many obstacles facing such research. This information is needed to guide conservation of existing stocks and restore extirpated stocks.
- Understanding the genetic relationships of coasters and other regional non-migratory brook trout. Clarifying these relationships will be essential for protection of existing native populations and for proper selection of sources of wild strains to establish brood stocks for future reintroductions.
- Understanding the habitat use patterns of coaster populations. Contemporary populations occupy only small segments of their former shoreline habitat and ascend only a handful of streams to spawn. Habitat requirements and use patterns are virtually unknown for both historic and contemporary populations.
- Evaluations of ongoing experimental reintroductions are needed. Inadequate resources have hampered agencies from completing evaluations in the past.
- Preventing overharvest of coaster stocks which are highly vulnerable to exploitation by angling and netting.
- Determining the competitive relationship of coasters with introduced salmonines. Managers will need to know whether and under what conditions coasters can coexist with naturalized coho, chinook, and pink salmon and with anadromous rainbow trout and brown trout in spawning streams and in Lake Superior.

Progress toward achieving a coordinated restoration effort for coasters among the many and diverse management agencies and private interest groups is clearly indicated by the proliferation of multi-partner cooperative projects now being implemented. Prior to 1992, few cooperative projects were done, now each of the agencies is involved in a number of projects with several cooperators. Further, most of these projects have received vital funding and enthusiastic assistance from private foundations such as Trout Unlimited, Wildlife Forever, and a host of local angler and sports clubs. Ongoing projects include:

- Genetic research (by mitochondrial DNA and microsatellite analysis) to characterize regional brook trout stocks and to aid in identifying best potential sources of coasters to establish new brood stocks for reintroduction.
- Collection and rearing of the Isle Royale (Tobin Harbor and the Siskiwit Bay) brood stocks of native coasters.
- Research to locate existing remnant stocks of coasters in Lake Superior, and to estimate population sizes (Isle Royale).
- Support for proposed watershed research to evaluate potential reintroduction sites for coasters and to quantify relationships between reach-scale physical habitat attributes and coaster populations, and to identify linkages between landscape attributes and physical habitat in streams. To construct a predictive model for quantifying the presence and extent of suitable coaster habitat in streams of the Lake Superior basin.

CONCLUSION

The restoration of coaster brook trout populations to native habitats throughout the Lake Superior basin presents unique challenges and obstacles to fishery managers. Among these obstacles is the continuing need for more information about the biology and ecology of these unique salmonines. A successful restoration could restore a spectacular native strain to parts of its historic habitat that once encompassed more than 100 spawning streams and a substantial portion of the Lake Superior’s 4,385 km shoreline. It would provide a tightly regulated nearshore
fishery for trophy brook trout that would have considerable appeal to anglers and could also benefit regional economies.

Recognizing the value and benefits to be gained by protecting and restoring native species (see Wiltshire, this issue), all agencies with management responsibility for Lake Superior have agreed to a coaster restoration effort. The potential scope of such an effort presents a management challenge on a grand scale. The necessity for coordinated and cooperative efforts between management agencies is clear and evident as will be the involvement and support of diverse interest groups. Also imperative is the need to preserve existing brook trout strains and habitats. Coaster restoration is not an all or nothing proposition and the extent to which it can succeed will ultimately depend on the strength of public support.

ACKNOWLEDGMENTS

We acknowledge the major contributions of the members of the BTSC who provided information for this report.

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