WILD TROUT III

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U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

WILD TROUT III

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WILD TROUT III

Proceedings of the Symposium

Yellowstone National Park

September 24-25, 1984

Frank Richardson and R.H. Hamre
Technical Editors

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Fish and Wildlife Service, U.S. Department of the Interior
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YELLOWSTONE NATIONAL PARK

Mammoth Hot Springs, Wyoming

September 24, 1984

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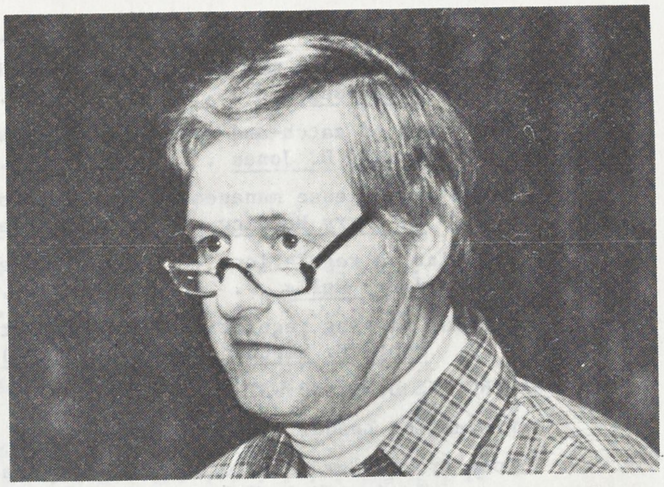
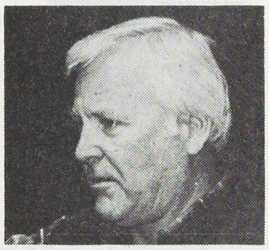


Wild Trout III: An Introduction[1]



Frank Richardson[2]

The Wild Trout Symposia, now heading into its second decade, was spawned at a luncheon meeting in Denver in 1973. At that luncheon, Pete Van Gyteenbeek, then Executive Director of Trout Unlimited; John Peters, then Chief Environmental Officer of the U.S. Bureau of Reclamation; and Frank Richardson, then Associate Regional Director of the U.S. Fish and Wildlife Service for the Rocky Mountain Region--all active in Trout Unlimited--outlined the plan for the first Symposium. Nathaniel Reed, then Assistant Secretary of the Interior for Fish, Wildlife and Parks, gave his personal endorsement and directed Interior to become a cosponsor with Trout Unlimited. In September of 1974, the first Symposium convened at Yellowstone National Park, and at 5-year intervals has returned to the mother park to again take stock of the trout and salmon resource.

The Symposium format has remained the same. New players--The Federation of Fly Fishers and the U.S. Department of Agriculture--have shared sponsorship with Trout Unlimited and the Department of the Interior. This year, the mantle of leadership fell on Roger Barnhart, Mike Owen, Gardner Grant, and Frank Richardson, ably assisted by Charlie Loveless, Pete Van Gytenbeek, John Peters, Bob Hamre, Marty Seldon, Ron Jones, Bob Barbee, and others.

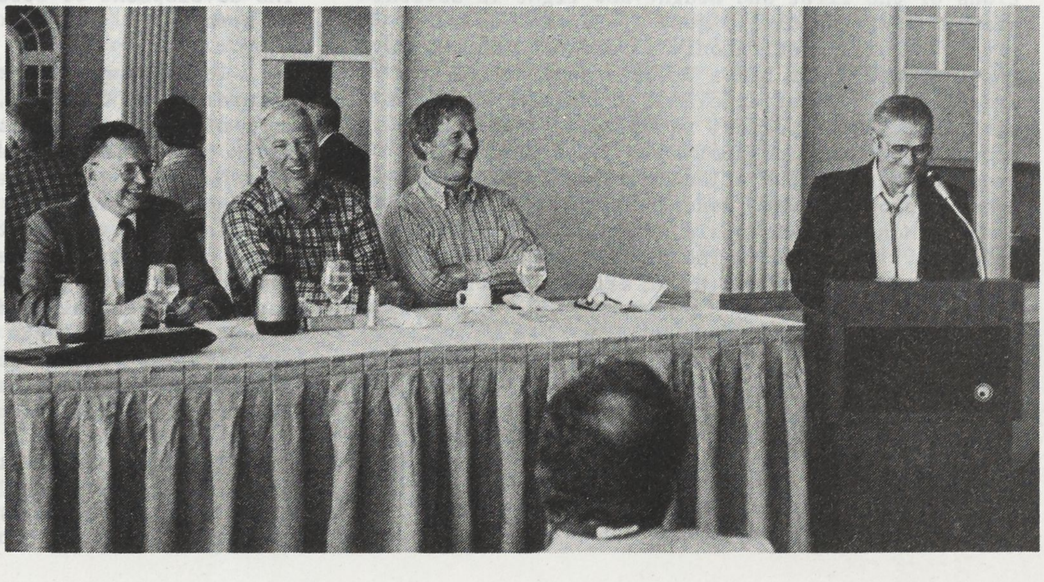
Wild Trout III will be remembered for the early snowfall; the words and wisdom of Keynote Speaker Ben Dysart; and the gentle, thought-provoking advice provided by Dan Abrams, the closing banquet speaker; but it will be remembered best for the quality of the scholarship, research, and hard work which went into the papers presented there and published here.

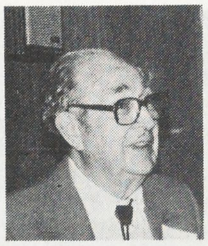
We deeply appreciate the roles played by the Assistant Secretaries, Ray Arnett and John Crowell. Without their support and encouragement, the Symposium could not have convened. Their remarks reminded us of the stark reality of this troubled resource, the limited funding, the competition among users, and the difficult and demanding effort that we all must dedicate to the stewardship of our trout and salmon.

As these words are written, plans are being formed for Wild Trout IV. In all likelihood, we will return to the grandeur of Yellowstone in the fall of 1989. There will be new faces and old and there will be memories of those like A. Starker Leopold, who were so important to the success of Wild Trout I and II. In 1989, biologists, students, anglers, administrators and conservationists will meet to share their views, renew old acquaintances, recharge their enthusiasm, and then return to their own trout and salmon waters with new knowledge and renewed dedication.

[1] Introductory remarks by the Symposium Moderator at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24, 1984.

[2] Frank Richardson, Symposium Moderator and Program Chairman, is Assistant Regional Director of Fisheries, U.S. Fish and Wildlife Service, Atlanta, GA. He also is a National Director of both the Federation of Fly Fishers and Trout Unlimited.





Wild Trout III: A Summary[1]

Willis King[2]

We are among those who share a common philosophy which proposes that wild trout, in their natural environment, represent an element that gives one hope, courage, and true recreation. Such people have come together at three symposia, held at 5-year intervals, 1974, 1979, and 1984, in Yellowstone National Park, a most suitable place. The first sponsors were the U.S. Department of the Interior and Trout Unlimited. The Federation of Fly Fishers joined the sponsors in 1979, and in 1984 the U.S. Forest Service also helped sponsor the event.

In offering this summary, I shall not attempt to mention each paper, or even each panel that was included in the three programs. All are printed in the symposia proceedings, including their summaries. I will review briefly the earlier symposia, then give deeper coverage to Wild Trout III, and give some of my reactions to the past and suggestions for the future.

The first Symposium, called "Wild Trout Management," set forth definitions and broad parameters for consideration. We seemed to reach agreement that "Wild Trout" are members of a naturally produced and maintained population in a natural setting. We did not reach agreement on what constitutes "quality fishing," and left it to the individual angler to decide for himself. We did agree on some of the elements, that it is not primarily the size of the creel or the time required to catch a trout that count. We appreciated the encouragement given all of us by Nat Reed, then Assistant Secretary for Fish, Wildlife, and Parks.

The second Symposium carried out the traditions of the first and sought new light in several areas. Some especially good presentations were given. I will mention only a few. Joe Kutkuhn's paper on the Great Lakes Trout stands out as exceptional. Other excellent presentations dealt with individual species, including the Wisconsin brown trout, Oregon steelhead, the Appalachian brook trout, and the Atlantic salmon. Broad management programs were described for Colorado, Alaska, Montana, Wisconsin, Michigan and British Columbia. Bill Platts led us through the maze of logging and grazing and their effects on the resource and its management. We first heard about acid rain in Symposium II, the good and not-so-good results of stream improvement structures, the problems underlying Indian fishing, and trout in the tailwaters below dams.

In a special session we heard the optimistic philosophy of Lee Wulff, Henry Regier's proposal for a "charr watch," and a resume of the Yellowstone trout fishery. Starker Leopold broadened our parameters and sharpened our thinking in taking us from the fish to the stream and then to the watershed. His admonitions will stay with us through many symposia and his presence will be missed.

Wild Trout III was perhaps more sophisticated in its organization and the nature of the presentations than its predecessors. It recounted progress and gave us several examples of management that are reassuring and promise to lead us forward in our determination to assure the survival of wild trout. Ben Dysart, listed as the keynoter, actually gave his presentation at the first luncheon. He accomplished the objectives of the summarizer in a very eloquent and forceful manner. His talk was a highlight of the program and should be read again. He paid tribute to Starker Leopold and emphasized the importance of skilled leadership to set the goals, and the necessity for an interdisciplinary approach to the many and complicated problems facing the wild trout manager.

In the first panel we were reminded that streams, like mountains and man himself, have undergone a long evolutionary history. Interactions of geologic processes have brought changing adjustments and new states of equilibrium. The development of forests had a stabilizing effect on streams.

In his eagerness to harness and control the natural flow of waters, man has made radical changes, many of them irreversible. We learned that dams block 50% of the access to steelhead habitat, and that hundreds of proposals for small hydro plants threaten more and more habitat for steelhead and likewise for many trout streams. The high importance of intermittent streams was pointed out as providing spawning and rearing habitat for steelhead and other salmonids in California, a concept often overlooked. The importance of habitat preservation was further emphasized in the face of greater urbanization, adverse land uses, water diversion and pollution, and the advent of acid rain.

The accounts of steelhead and salmon management in Alaska, Idaho, California, and Iceland were enlightening and well presented. The job is getting tougher and new goals must be set, utilizing new

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[1] Summarizer's address presented at Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 25, 1984.

[2] Dr. Willis King, retired Associate Director, U.S. Fish and Wildlife Service, and member of Trout Unlimited, Hendersonville, NC.

knowledge and techniques when these are available. We were interested in the system followed on the Grimsa River in Iceland, where the landowner, through an association, protects and manages fishing on his property. The Atlantic salmon is a highly regarded economic and food resource in Iceland.

Comprehensive reports were given on State programs in Missouri, Pennsylvania, California, and Washington, emphasizing the expanding role of wild trout in recreational fishing. Since natural conditions vary, regulations also vary, and the use made of stocking must be carefully evaluated. Programs are becoming more complex and must be geared to changing requirements and public concern.

The status of hatchery vs. wild fish is still not fully understood and seems to depend on the region, the species, numbers, size and method of stocking. Discussion on this subject held the audience for over an hour, and brought out the hazards of generalities.

The growing acceptance of the catch and release concept was attested by allotting an entire evening session to this subject, including six papers. Success of catch and release depends on a variety of factors and conditions. Acceptance of the premise that trout fishing is for fun--not food--requires good public information services, supportive law enforcement, and special regulations that can be changed when necessary. Catch and release must be regarded as an alternative method of cold water fish management, not always acceptable or suitable, but offering many favorable possibilities, and to the skilled angler is "the wave of the future." Although slower to initiate catch and release programs, the Southern Appalachian States are "catching on" and adopting the system, particularly in national parks, special management areas and Indian reservations. Information gathering is just as essential, with special attention to threatened species and fragile environments. An increase in average length frequently occurs following a catch and release program.

Emphasis on saving and/or restoring favorable habitats for trout was brought forth in the panel "Saving the Dirt and Water." Experiences related to minimum and critical flows were described for Montana, Wyoming, and South Dakota. Many of these efforts require highly skilled professionals in related fields: soil specialists, agronomists, chemists, hydrologists. The person trained only in fisheries soon finds himself beyond his depth. The team approach is the effective answer.

The presentations by Drs. Walton Watt of Nova Scotia and Terry Haines of Maine pertaining to acid rain were especially pertinent and professional. Tolerance levels and effects of this growing form of pollution were explained and added to our store of knowledge. Below a pH of 5.5, Dr. Watt found a significant downward trend in aquatic populations; below 4.7, numbers of living things declined to zero. While there is hope for relief, further research on sources, physiological effects on aquatic life, including tolerances to trace metals and other pollutants, and the effects on the balanced ecosystem are extremely important to our understanding of the acid rain phenomenon. Loss of genetic stocks is a most serious end result.

The fifth and final technical session combined papers related to people, money, and politics. Management of wild trout populations is no exception to the array of problems involving the above three elements. The management area broadened greatly to include the Colorado River Compact, the Great Lakes with special reference to lake trout, and salmon of the Pacific Coast. The problems are basically similar--preservation of habitat; a balance between sport, commercial, and Indian fishing; the relation between hatchery produced fish and the wild spawning populations. The bottom dollar is what it all costs, can we afford it, and what happens if we can't. The support of sportsmen's organizations such as Trout Unlimited, the Federation of Fly Fishers, the National Wildlife Federation, on national and local basis alike, is essential for ultimate success and the maintenance of wild trout populations at a level enabling some recreational use.

Wild Trout III continued the traditions of Wild Trout I and II and gave us solid examples of technical knowledge and skills which not only aid or help restore the trout species, but enhance public acceptance and support of the wild trout philosophy. The politics of fishery management were explained in the talks by Ray Arnett, Assistant Secretary of the Interior, and by John Crowell, Assistant Secretary for Natural Resources and Environment, Department of Agriculture. Trout Unlimited's support of field projects was described and examples of interstate cooperation were cited for the Great Lakes, the Colorado Basin, and the Pacific Coast.

In conclusion, I would like to pass on a few concepts and suggestions that have come to me after attending all three symposia, and reading the papers presented. Fishery management, including that aimed toward wild trout populations, has become a multidisciplinary undertaking. The biologist, no matter how skilled, cannot go it alone. At the same time, there is no escape from the need to protect spawning and living habitat conducive to natural survival. Likewise, few programs will reach their objective without the understanding and support of enforcement personnel, administrators, and information specialists. We must seek new approaches, develop new skills, but not forget the experiences of the past.

Perhaps we can make wider distribution of our Symposia reports, utilizing local chapters of TU and FFF. I think we would benefit from more illustrations in our published papers. We have made creditable progress in the past 10 years. We still have a long way to go, if wild trout are not to become just a memory from the past. A strong sentiment was expressed that the series on wild trout should be continued. I think we can safely look ahead to 1989.

Table 1.--Papers presented at Wild Trout I, II, and III grouped by subject. The listing includes all papers given or published in the Symposia record and represents the Summarizers' analyses.

Subject	I-1974	II-1979	III-1984	Total
Research	3	8	7	18
Management	10	12	10	32
Angler/Conservationist	3	3	8	14
General	4	6	5	15
Special Presentations [1]	4	3	4	11
Grand Total	24	32	34	90

[1] Special Presentations: Keynoters, Dinner Speakers, and Summarizers.

The Aldo Starker Leopold Award

Nathaniel Reed, Hobe Sound, Florida

In preparation of the presentation of the A. Starker Leopold Medal (Award), let me take a few minutes to read from a tribute prepared by his friends and associates at the University of California, Berkeley.

Aldo Starker Leopold, outstanding naturalist, superb teacher, gifted author, and beloved companion to those who shared his campfires, died at his home in Berkeley on August 23, 1983.

Leopold was born in Burlington, Iowa, the eldest son of Aldo and Estella Bergere Leopold. Boyhood exposure to his father's attainments led Starker, first to follow the elder Aldo's footsteps, and then to blaze his own trails, to become one of the world's most influential and honored authorities on wildlife ecology and management.

He was educated at the University of Wisconsin, the Yale Forestry School, and the Department of Zoology at Berkeley, where he received the Ph.D. degree in 1944. After working in Mexico for the Conservation Section of the Pan-American Union, Leopold returned to Berkeley in 1946 as Assistant Professor of Zoology and Conservation in the Museum of Vertebrate Zoology. He became professor in 1957. In 1967, he became Professor of Zoology and Forestry and moved his headquarters to the latter Department where he remained until he retired in 1978.

Starker Leopold's gifts as a teacher are widely acknowledged. Students responded to his infectious enthusiasm for his field and knew him as an exacting taskmaster who expected their best. He had an unusual capacity to simplify the complex. For those aspects of wildlife ecology that might seem overwhelmingly difficult to young students, he provided easily understood models. Leopold had a rare ability to combine scientific theory and facts with keen personal observations throughout the world's most important wildlife habitats. His courses attracted many non-major students, many of whom described them (and the professor) as "among the best in the University."

He displayed deep personal interest in his students' welfare. Whatever activity he might be engaged in when a student came to see him, he put it aside to give his visitor individual attention. For many of them, initial contacts at Berkeley became lifelong professional and personal friendships.

Many in the wildlife field relied on Leopold for help with their more difficult problems. As a result, he was heavily involved in public policy matters at the highest level. In 1968, the Special Advisory Board on Wildlife Management of the Department of the Interior, which he chaired, produced reports which led directly to significant new policies for the National Parks and National Wildlife Refuges. Similarly, through membership on a subsequent Advisory Committee on Predator Control, his views were remarkably effective in changing Federal policy toward predator animals in 1972. Earlier he did highly influential consulting on aspects of wildlife conservation policy with the National Parks in Tanzania, with the Missouri Conservation Department, and the Mexican Game Department. His effectiveness in the public policy arena was a demonstration of his ability to teach at all levels, from undergraduate students to those with the largest governmental and business responsibilities.

His influence on this broader scene is reflected in his service as a Director and for two terms as President of the California Academy of Sciences, and as a Director and Vice President of the Sierra Club. He was vigorously engaged in such public service activities almost to the day of his death.

Starker had a capacity for bridging gaps, between preservationists and managers, liberals and conservatives, hunters and anti-hunters--a talent which served the academic community well in resolving basic issues of educational policy. He kept his eyes on his main goal, a world suited to wildlife and therefore fit for people. Despite the eminence of his academic and scientific achievements, Starker will no doubt be remembered longest by students, colleagues, and friends for his personal qualities. Love of the outdoors; great personal warmth; sensitivity to others; profound appreciation and respect for the intricate beauty of nature; these were characteristics which knit Starker's life to those of his legions of friends in intimately personal ways. A superb raconteur, he always had a positive outlook and an inexhaustible zest for life, which he lived completely. Anyone who camped with Starker appreciated his skills in making camp life comfortable. His artistry with a dutch oven, his insistence on maintaining such amenities as the bath and the sundowner in the face of obstacles, and his complete awareness and understanding of the natural world around him, gave new meaning and enjoyment to outdoor life for all who shared it with him.

On fall outings, the nightly appearance of the Pleiades was Starker's signal it was time for sleep. Last August 23rd, the Pleiades rose for him for the last time. Requiescat in pace.

I deeply regret not being able to be with you for Wild Trout III. I am confident that Starker would be overjoyed by the number of participants and the range of papers that will be (have been) delivered.

Starker was so proud of the innovative and courageous papers that the young biologists presented at Wild Trout I and II which have led to such outstanding progress in establishing high quality fisheries--especially in the States of Idaho and Montana.

On a personal note; I miss him. I miss him as a counselor, as a wildlife expert, and as a fine companion in the field and on the stream.

I hope that when I cross that last river that there will be a spring creek, with a good hatch, with trout sipping quietly and beside the green sand will be my friend - Starker Leopold.

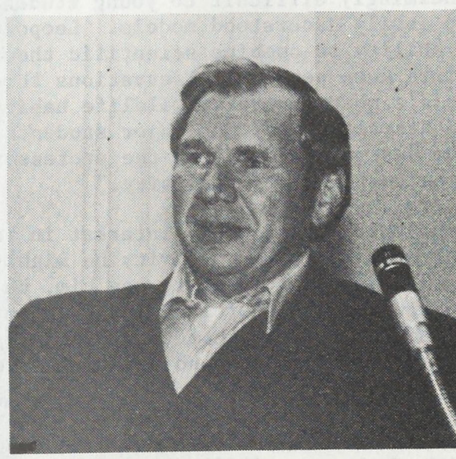
ALDO STARKER LEOPOLD

1913 - 1983

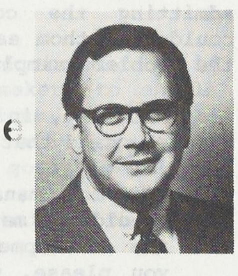
Photo from
Wild Trout II 1979

AWARD RECIPIENTS

Marty Seldon



Bob Behnke



Watersheds, Water, and Trout: A More Appropriate System for Today's Agenda[1]

Benjamin C. Dysart III[2]

Abstract.--To effectively meet the challenge for providing quality wild trout, quality habitat, and quality angling, the system dealt with must be expanded beyond fish and fish water, and adequate attention afforded the watershed and land use. The circle must also be expanded from principally biological scientists to include more managers and professionals from critical disciplines like engineering, since these individuals tend to make the land use decisions.

INTRODUCTION

It's a pleasure, in fact it's a great honor for me and National Wildlife Federation, to be a part of this Wild Trout III Symposium.

While I'm an engineer, and I presume most of you are biologists or direct the work of biological scientists, I think we share some important values and experiences.

For example, I've had the privilege to pursue trout in some right good waters--like floating the Big Hole over in Montana with Tony Schoonen, fishing for cut-throat in the upper Snake here in Wyoming with Paul Bruun, for rainbow in several rivers flowing into Lake Iliamna, tributaries of Penn's Creek, spring-fed lakes in central Montana and Prince Edward Island with the likes of Frank Martin and Lorne Keizer, respectively, and various streams and lakes--some named but mostly unnamed--with Dennis Pattinson in the bush of northern Saskatchewan.

At home in South Carolina, I pursue the little wild rainbows in the Whitewater River, where I always wonder why it's so hard to keep tight loop, but so very easy to hang flies on a rhododendron limb 10 feet up--lots of them.

I know the exhilaration that comes from a good rod-bending wild rainbow, that can strip off about all my fly line six times and get up on top of the water five times, as well as the satisfaction of releasing it to be caught again another day.

And, while I'm an engineer and most of you are biologists, I'm greatly indebted to many people who've helped open my eyes, made me see more than I was taught to see as an engineer, even get me to where I start to understand some of the simpler complex realities of resource systems as viewed by non-engineers. A majority of these individuals I'm indebted to are or were good biologists--researchers and academic colleagues, as well as first-rate field biologists out in the real world.

I've learned a lot from such professionals, like sharing the fellowship of a day astream with rabid--and some less rabid--fly fishermen, drinking coffee around a camp-fire, botanizing in the mountains, learning that all critters under cobbles aren't stone flies, and eating sardines and crackers on gravel bars. And I expect to learn more from you here at this meeting.

From time to time, for some reason, people will ask me what my favorite dry fly is. I used to tell them it was anything that's big and yellow, so I can see it since I passed 40. Fred Johnson of the Pennsylvania Fish Commission, and an expert fly fisherman, told me privately that it'd sound a lot better if I'd simply respond "number 10 yellow sulfur flies"!

LOOKING BACK BRIEFLY

At the first Wild Trout Symposium in 1974, the participants believed they were grappling with the big issues and setting major goals; and they were. But in hindsight--and in our rapidly increasing recognition of the complex interplay between watersheds, watershed management, and fisheries production--the goals might seem a bit modest.

In the wild-trout business, as in all other spheres including my own environmental and water resources engineering area, things have gotten tougher, a lot more complex in recent years. Part of it has to be just recognizing or

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[1] Keynote address presented at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, Wyo., 24 September 1984.

[2] Benjamin C. Dysart III is President and Chairman of the Board, National Wildlife Federation, and a professor of environmental and water resources engineering at Clemson University, Clemson, S.C.

admitting the complexity that we didn't or couldn't fathom earlier. But part of it is that the problems simply are tougher and more complex.

Nat Reed, in his concluding remarks at Wild Trout I, said that:

> You managers of wild trout fisheries shoulder a major responsibility to accelerate the development of an ethic which zones, if you please, wild trout waters from stocked waters. An ethic which incurs restrictions of tackle and kill which are the very tools of development of that elusive term, "quality sports."

One of Reed's goals, as then Assistant Secretary of the Interior for Fish and Wildlife and Parks, was for the Fish and Wildlife Service to take a leadership role in developing strains of fish that would survive after stocking to be strong and healthy and to provide what he termed "a sporting quarry in a real world of angling."

To the early Symposium goers, a consummate concern seemed to be the type of trout in streams and the way in which those trout were to be pursued by anglers. Professionals were challenged to champion these concerns; and indeed the maintenance of the genetic integrity of wild trout is a worthwile goal from biological, economic, and recreational standpoints.

I wonder: have we allowed the immensity of our problems to divert our focus from the big conservation picture, from the maintenance of the integrity of our watersheds? Aldo Leopold said it long ago: "In our attempt to make conservation easy we have made it trivial." That's always a danger.

The most frightening assault on our fishery comes not from slob fishermen--I certainly won't call them anglers, not from plants of self-destructing hatchery fish, and not even from overfishing. The assault on our fishery rains down from the heavens in the form of acid rain, is belched in from industrial effluents and municipal sewers, is in the form of soil eroded off farm and rangelands along with a wide variety of other habitat-destroying nonpoint source pollutants. And of course there's more: dams, channelization, wetlands destruction, logging, and on, and on, and on.

WONDERING

I've wondered a few times just why Frank Richardson called me back in early March to keynote this Symposium. I suppose he had a lot of good reasons.

But I'm neither a high government official in the natural resources area, nor a famous life-long trout fisherman like Nat Reed. In fact, I'm an amateur who got back into fly fishing just a few years ago because my wife insisted that I enjoy a little of the world that I was trying to save, working as a professional and as a citizen. Now that's the kind of advice we can all use more of!

Nor, obviously, am I an eminent wildlife biologist like the late Starker Leopold. In fact, I'm a civil engineer by training, though I work in the environmental and water resources area.

Though I'm now a fellow Carolinian, Willis King would doubtless be the first to insist that his background and career and mine are quite different.

So why break with tradition, and go off in another direction in picking your keynoter this year? Although there are obviously many prominent biological and fishery scholars, administrators, researchers, and sportsmen to have chosen from, I think Frank made a great choice.

You'll have to be the judge on the wisdom of the individual he selected, but I don't think there can be much question about the appropriateness of the message that I'll be bringing to you--from outside your usual circle--this morning.

MANDATE OF PREVIOUS SYMPOSIA

I think Frank listened hard to what was said at Wild Trouts I and II--especially II--and the same things came into focus for him as have come into focus for me in my teaching, research, consulting, and volunteer conservation leadership efforts over the years. And I think I saw the same things as I read the proceedings of the 1974 and '79 Symposia.

In 1974 at Wild Trout I, I think Frank heard Willis King, in his keynote and summary remarks, talk about wild-trout habitat, habitat deterioration, the well-being of ecosystems, and what determined that well-being. He heard Warren McNall refer to the need to protect watersheds along with improving stream habitat, and Ray White talk about the linkage between in-stream management and land use.

And he heard Starker Leopold speak to stream degradation and watersheds, particularly western ones, which were subject to what he called "multiple exploitation" and our need to "fully understand the impact of multiple use" if we were to be in a "position to make appropriate management decisions."

And at the 1974 Symposium, both Nat Reed and Willis King spoke of the diversity of those distinguished trout experts assembled: researchers, managers, field biologists, administrators, and even students and anglers.

NEED TO CONSIDER WATERSHEDS

In 1979 at Wild Trout II, Starker Leopold, in his symposium summary, bored in tight on the watershed topic. He pointed out that, of the 24 outstanding papers presented by distinguished individuals, only three were primarily concerned with watershed problems.

He went on to say, and I quote:

> This breakdown is in no way surprising. Most of us are in positions that call for managing or studying fish, or the water in which they live. We are not responsible for managing the whole landscape. Someone else decides how many cows to run in a given watershed, where and how many trees to cut, what sort of road system should be built, where towns and subdivisions should be situated, and what to do with sewage effluent or mine tailings or the drainage from dairy barns. Yet these decisions are crucial in the maintenance of productive trout streams. The management of the trout resource cannot be dissociated from management of the watershed resource, and this truism was recognized repeatedly during the conference. Hopefully, relevant research will follow.

A little later, Leopold got back on this theme, hammering away, and I quote:

> Now let me come back to my favorite theme, namely, that our major problems in perpetuating trout concern treatments of the watershed, not treatments of the trout. At the risk of sounding like a broken record, I feel obliged to repeat the admonition I delivered to this symposium five years ago. Our research is still lopsided in favor of fish, fishing, and fish water. I did note in the papers, and particularly in discussion, repeated reference to the fundamental relationship between trout fisheries and watershed management. The problem is recognized, but much more relevant research is needed. If we had at our disposal accurate, quantitative data on how grazing, logging, etc., affect trout, we could more effectively influence land-use decisions made by others.

He brought his argument to a head, in my opinion, by stating, and I quote:

> As I think Bob Behnke remarked yesterday, we are not talking about a fisheries problem, we are dealing with problems of land management. How are we to cope with issues that appear to be beyond our responsibility? We as biologists have only one option here, and that is to <u>gather</u> and <u>analyze</u> data on the actual relationships between land use activities in riparian zones and stream productivity. In my judgment we are not yet pursuing the studies needed to prepare our legal briefs in the argument. (Emphasis in the original.)

Leopold went on to point out the sort of research that could produce causal relationships between land-disturbing activities in the watershed and wild trout and their aquatic habitat.

WHAT IT MEANS

What Leopold listed was the sort of solid information needed by decision makers to enable them to properly understand options and to make better informed, cost-effective, and responsible decisions--in other words, to be good stewards of the resources, public and private, renewable and non-renewable, which are entrusted to them for wise management.

It's important that we remind ourselves that decision makers are generally not biologists, or certainly don't function as such specialists by the time they reach the policy level in either the public or private sector. Of course I could say the same thing with respect to engineers.

I think all of us here, certainly you trout experts, realize that a trout stream doesn't produce trout because we manage trout in the stream. And we don't have trout to catch because we regulate our take of those trout.

We can't focus our attention on trout alone and expect our fisheries to survive. For fisheries to survive--much less flourish--we need to protect or preserve rivers, streams, watersheds, and whole ecosystems. We must preserve our trout fisheries in total, not in part.

Trout fisheries exist because of the high quality of waters, the coolness made possible by stream-side trees and shrubs, the abundance of flow, decent clean gravel substrate for spawning, good clean pools and boulders and the like for cover--in general, the basic integrity of the waters, the whole system properly defined.

And fish survival also hinges on the integrity of the lands that surround, and determine the character and quality of, the waters and the substrate. It's those lands that surround our waters--and what we allow to go on upon those lands and how activities are conducted--that's the key to producing trout and, ultimately, catching trout. Certainly this is the case if we're talking about "quality wild trout," a "quality setting," and a "quality angling experience," however you choose to define these terms.

The lands can be pristine like a lot of those all around us today, so striking covered in snow by this early-season storm and so spectacular, spectacular for their beauty but also for their protective shielding of the waters that arise all about us on the land as hot springs, cold springs, seeps, and trickles from snow, or rain falling high on mountain tops. The protection of the land allows the trickles to come together to form trout streams and support a variety of aquatic life and other wildlife.

But land doesn't have to be unused to nurture clean waters, quality fisheries, and abundant wildlife. Agriculture and rangeland can be properly managed to protect streams and off-site values in general. In urban areas, productive fisheries--even trout fisheries--can and do coexist with man, for example the Chattahoochee River above Atlanta.

Mountains and valleys can be logged in responsible ways that preserve stream resources, just as they can be arrogantly and irresponsibly roaded and logged to degrade or destroy such resources. And such tragedies are even worse when the degradation or destruction is for deficit timber sales out in this part of the country.

The fisheries biologist generally doesn't have a lot to do with determining what areas are logged, roaded, built on, developed, or whatnot.

RESPONSIBLE STEWARDSHIP

The key to man's coexistence with nature on this earth is man's willingness to to be a responsible steward of the earth's natural resources. Our resources--whether precious soils, forests, energy and other mineral resources, vistas, wild flowers, or fish--are all interrelated in the watersheds from which all flowing waters arise.

Do we assembled here in this refuge of pristine beauty, as advocates of the wild-trout resources, have the will to work to ensure the integrity of our watersheds and the renewable natural resources contained therein? I hope so, and I think so.

DEVELOPMENT OF PROBLEMS

About two centuries ago, we started losing our Atlantic salmon because the fish were taken in large numbers, the rivers were dammed, and the water was polluted.

Did we learn to control our wastes, control over-fishing, and control our lust to barricade streams? I don't think so, certainly not to the extent necessary to wisely manage and protect the long-term productivity and integrity of the resource and the ecosystem.

Nearly a century after the demise of the Atlantic salmon, the West Coast began its campaign of polluting, over-fishing, and damming. Again, did we learn? Yes, and no. Yes, we learned that siltation, dams, pollution, channelization, flow regulation, water diversion, and over-fishing can destroy fisheries.

When Atlantic salmon were being destroyed, we were largely ignorant about the effects of habitat destruction. That's all changed. We're no longer so naive, but we still haven't stopped habitat and watershed destruction.

Sure we've made a some substantial inroads. For example, raw sewage is rarely released in large quantities into our streams now. But by and large, the insults of past centuries continue.

The pace has slowed, but sadly habitat degradation hasn't stopped. Each acre of quality habitat that's degraded or destroyed increases the value and the importance of the remainder. The acres--the tens, hundreds, thousands, and tens of thousands of acres--add up.

They add up to massive cumulative piece-meal destruction of quality habitat, just like has happened with the gouging and gutting of the hardwood bottom land overflow ecosystems in the lower Mississippi Valley.

I believe it was when Nat Reed was Assistant Secretary at Interior, and I was science advisor to Vic Veysey, then the Assistant Secretary of the Army for Civil Works, that Ray Arnett and I worked together to help make the case for the Corps's doing right by the wetland habitat of the Atchafalaya down in Louisiana.

It looks like the effort over many years of a lot of people--in and out of government--has produced some good results down there; but, at lots of locations around the country, we're losing prime wetlands like crazy.

OLD IDEAS

We, as resource managers and conservationists, did react to loss of a lot of our fisheries along the Atlantic and West Coasts through the developing science of fishery management; and we continue "managing" for better fisheries to this day.

How did we deal with dwindling East Coast and West Coast salmon? Just over a century ago, as the art of fish culture emerged, the answer seemed crystal clear: stock fish. Just like we used to stock quail, on the farm in middle Tennessee, back during the '40s.

The rationale was simple. According to J.P. Brown in his treatise on the history of fish culture, fish managers in the 1870s believed: "It was in the best interest of the country to stock any promising species of fish in any accessible body of water." He stated further that: "They gave no consideration to the advisability of stocking or to the suitability of the fish to the waters."

The results of this rationale were related by J.L. McHugh in stating that, after about 1870, our Nation "embarked on a vigorous and apparently completely futile program of fish culture that persisted for more than 60 years." McHugh recognized that at least 73 species of fish were reared in hatcheries, including at least 47 freshwater, 13 anadroumous, and 12 marine species.

In the 1930s and '40s, we began to realize that the expense and biological value of massive stocking programs were questionable. Instead of simply making more fish available, fishery managers began placing greater emphasis on altering the ways we were allowed to catch fish.

We entered an era of size limits, rough-fish controls, creel limits, and emphasis on the balance between predator and prey. Slowly, too, we began to emphasize improvement of in-stream habitat, access to spawning grounds, and pollution control.

A lot of things were tried over the years; and some worked--usually with side effects and with less success than hoped for; and a lot of approaches failed or were discredited. In the early 1970s, fishery managers began to realize that an understanding of the dynamics and biology of fish and other aquatic life alone was insufficient to truly manage a fishery.

We began to explore the science of fisheries in a multi-disciplinary way; and chemists, economists, geologists, computer specialists, land-use planners, and lawyers all became part of the science of fisheries. But I would ask: how about the foresters and, probably a lot more critical, the engineers? I think we have yet to integrate fully this broader perspective of fishery management into our everyday business, or even into our advocacy for the wild trout resource.

New voices are calling, telling us to look at the big picture; but are we listening? On the West Coast, for example, extensive salmon and steelhead enhancement programs are expanding to this day.

Peter Larkin, in a 1974 essay on salmon enhancement entitled "Play it again, Sam," noted that, for over 100 years, there had been extensive hatchery efforts to increase the abundance of salmon on the West Coast, but that the success of those ventures is largely a matter of conjecture. He continued, stating that, from a social point of view, salmon enhancement is highly desirable and biologically feasible, but that establishment of massive stocking programs could pose threats to natural stocks.

And he emphasized that the kinds of fishery enhancement activity that would most likely provide the greatest return were those that interfere least with natural life histories. Examples he cited were removal of stream obstructions, maintenance of flow, construction of artificial spawning beds, and maintenance of water quality.

What I think I hear Larkin saying to us--all of us--is that the closer we approximate natural conditions or maintain our natural God-given stream conditions, the more successful our fisheries will be. What I'm saying is that the better we protect, restore, and enhance our watersheds, the more successful all our fish and wildlife resources will be.

DIVIDING THE PIE

Typically today, fishery management is a mix of harvest regulations and hatchery stocking. But primarily it remains an art of allocating available fish among users, especially in the complex marine and anadromous fisheries.

I like to picture harvest management as something akin to splitting up a pie at a family get together. Sometimes the clan is large, and the pie a bit on the small side. I'll say now that the pie had better be a big one at lunch today, if Ray Arnett and I both get pieces big enough to take care of us!

Everyone's happy if you start out with a large enough pie, and if everyone gets a big piece. But that's not a realistic expectation, here in the cold hard real world where most of us function, coping with an abundance of cold reality and many hard trade-offs.

The obvious solution would seem to lie not in cutting up that pie in various ways, until everyone is equally dissatisfied, but in starting out with a bigger pie.

The professional fishery manager faces the same problem that we've been talking about, except that it's probably worse--a lot worse! The manager has established a long tradition of cutting the "fishery pie" so that all users are equally provided for, according to some measure of satisfaction or dissatisfaction.

When fisheries decline or users increase, the fishery manager is under pressure to "refine" the way in which the pie is cut. Your efforts are turned to managing the fish and the fishermen. A more enlightened solution of course, it seems to me, is to get a bigger pie, through habitat improvement and--probably a lot more important--watershed protection.

Better harvest regulation and fish stocking help alleviate pressure, mostly pressure on the fishery manager I suspect; but fish stocking is just a band-aid, and better allocation is just a people-pleasing placebo. I contend that we've been too good at pleasing people, and too poor at making our pies bigger and better. Because we've been able to please most people, we've focused the public's attention on the division of the fishery pie.

NEW FOCUS

Instead, we need to focus the public's attention on managing the ecosystems, for the benefit of the fisheries and other wildlife resources and a host of other public values. In other words, we need to focus on the critical forces external to the fishery.

We establish control over watersheds by proving, beyond any doubt, that management practices on upstream land have a direct and profound effect on the productivity of our living and productive resources downstream. We should be able to support such claims in behalf of the broad public interest through strong economic and scientific arguments.

We--collectively speaking--don't lack the technology as such nor, I pray, the resolve to formulate and then effectively promote such arguments.

Your constituency and my constituency, the conservationists and anglers, including a lot of National Wildlife Federation's four-million-plus members, are waiting--waiting for scientists, prominent anglers, and ardent supporters of the fishery like yourselves to shift, to broaden, the focus toward watershed activities.

And there are probably even quite a few enlightened engineers, like myself, who can and want to be participants and partners in the work. They must be involved if there's to be any real chance of substantial progress.

LEOPOLD'S QUESTION

I think Starker Leopold's question is as pertinent this beautiful hoary hibernal day in 1984 as it was five years ago. I'm referring to the concern about who's sitting at the table making the critical calls or contributing the information that's actually used by the players holding the cards, owning the chips, determining the stakes, and calling the game.

The rest of the question which I think he implied is even more important: Who's not at the table or not adequately represented, and why aren't they? Is it because they just aren't playing? Or is it because, instead of your nickel-dime-quarter three-bump game, there are some pot-limit check-and-raise-as-many-times-as-you-feel-like-it games they're in, and you're not.

If you're concerned about who's not at the table, or guessing who didn't come to dinner, it's oftentimes the people who could make--or in fact do make--the biggest changes in the watersheds, for the good or for the bad.

Good fisheries biology and biologists are necessary ingredients, but absolutely not sufficient. If, however, you don't have the engineers engineers, the land managers, the resource developers, and top corporate or agency management at the table, you don't have a really meaningful game.

It's sort of like a two-legged milking stool. And, for any of you who haven't spent any time on a dairy farm, I'll simply say that wouldn't be very desirable.

Sometimes--maybe most of the time--it's tough to get some of them to sit at the table with us; and that's when you need grass-roots support and solid-as-a-rock arguments, and find out how much real political clout, influence, or credibility with top management you have.

Just about everything engineers and resource developers do is up-slope or upstream--literally and figuratively--from you, your fish, their habitat, their water, gravel, and everything else. Anything the engineers, developers and bottom-liners may do wrong or don't understand or place too low a priority on, comes right to you because gravity works cheap and never takes the day off.

Remember that good water quality and trophy trout never flow up-slope; it's the mud and other pollution that moves, and it always comes your way. Perhaps that's a variation on the Fourth Law of Thermodynamics--or something.

DEFINITION OF SYSTEM

You can just figure the watershed activities are providing exogenous or uncontrollable inputs to your system; orr you can insist on a change in the system boundary--a broadening, an improvement, I'd contend. Much of the frustration and problems of the past has stemmed from too small, too limited a definition of the system you're researching or managing.

The stream and aquatic ecosystem--including the water, fish, gravel and other substrate, and shading vegetation--is just a fairly small subset of the watershed. And it includes not only man, but also the various beneficial uses and abuses man brings.

APPROPRIATE CONTROL SYSTEMS

It's my contention that engineered control systems are able to intervene between desirable--and sometimes simply necessary--economic development, public or private, and off-site values and uses, public or private. Appropriate engineered systems can be designed, put into place, and properly operated and maintained to produce any degree of off-site impact that's desired, allowable, or tolerable.

I must say, however, that a lot of the so-called "control systems" aren't appropriate or effective--technically or from a cost-effectiveness viewpoint. That's right unfortunate and shouldn't be tolerated because everybody loses, including whoever is paying the tab and the fish and their habitat.

Knowledge of pathways, fate and effects, control costs, reliability, probability, risk, and the like can enable decision makers to better weigh the many pros and the cons, to have difficult resource policy decisions better illuminated, and to make more informed--and hopefully more responsible--trade-offs involving our resources. Trade-offs are a fact of life.

If we have the benefit of good, meaningful causal relationships, linking land-disturbing activities to wild trout habitat quality, you can have a lot better shot at making the solid case Starker Leopold said you needed to make.

I--and my colleagues and students--have been working trying to help do just that in our contract research, supported by federal and private-sector dollars, to develop and improve the transport, control, and economic models that tie the on-site land use and erosion and the off-site aquatic ecosystem effects together for well over a decade now. And much of this work deals with cold-water trout streams with reproducing wild trout, in the mountains not too many miles from the U.S. Forest Service's Coweeta Hydrologic Laboratory, where a lot of first-rate watershed studies have been going on for decades.

I believe there are other engineers who should be sitting at the table with you--with us--who can help make more whole, more rational, more compelling your tough deliberations on wild trout habitat management.

CLOSURE

I think the conservation community has come of age; certainly that's the situation in the mainstream I'm a part of, and where most of the people are. We affect decisions at local, state, and federal levels. We not only can make but are making a difference, and it's a substantial difference, and for the good.

The American people have demonstrated repeatedly that they want clean water, clean air, and healthy fish and wildlife.

At Wild Trout II, Fred Eiserman stated that trout habitat management is wild-trout management, and I agree. But I want to take you one step further: watershed management is trout habitat management.

But watershed management is more, much more. Through managing our watershed, we manage our wild and natural resources wherever they occur, here in the pristine mountains and valleys of Yellowstone, over in the Big Hole, on the Great Plains, in Ralph Abele's streams in Pennsylvania, or in the urban areas that dot our national countryside. With watershed management--good multi-disciplinary watershed management--we catch all our fish, figuratively and literally, with one cast.

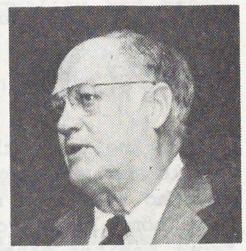
A while back, someone saw my well-worn paperback copy of Aldo Leopold's "Sand County Almanac" in my office. I was asked if I read it to learn more about being a good conservationist. To which I replied in the negative, that I read--that I studied--Leopold to learn how to be a good and responsible engineer, that I read Peter Drucker's books to be more effective as a leader of my--and NWF's--part of the conservation community.

In closing, I agree with Nat Reed, who said right here in 1974: "The blue ribbon trout waters of America need to be loved and revered. That is a goal worth working for." I want to do my part.

Thank you for asking me to be a part of Wild Trout III; and I wish you--and all of us--all the success in the world in meeting the many challenges associated with wild trout, people, watersheds, and sustained and improving high-quality angling for those who pursue it, and deserve it, and do their parts to make it happen and assure that it's passed on.

You have a fine program laid out, and I hope more of the speakers will deal with the watershed in 1984 than they did at Wild Trout II--because that's the critical game. And if you do, then I think Starker Leopold would be very pleased.

Don't Shoot the Messenger — The View from the Potomac[1]



G. Ray Arnett[2]

You know, a funny thing happened on my way here to Yellowstone -- I wound up with two speech topics! The first one had a pretty ominous title -- "Don't Shoot the Messenger." The later topic sounded most statesmanlike and elevated -- "The View from the Potomac."

I know it's impossible to be all things to all people, but I really couldn't decide how to resolve this situation.

On the other hand, I knew there would be at least a few folks her anxious to see me squirm just a bit with the first topic ... and yet I knew that the conference sponsors, in their wisdom, probably wanted my insider views on how Washington works.

I resolved this by offering a two-for-one speech special: you'll get to see me dodge critical remarks and accusations that may come whizzing by my ears; and then you'll get to hear how we've improved things for the lot of sport fishermen.

First of all: "Don't Shoot the Messenger"

When I saw the title of the paper the program committee gave me, I thought to myself: Okay, I'll take that one on, wade into these waters alone, armed only with my innocence and the heavy topic you would have me wield.

"Don't Shoot the Messenger" ---- Please!

Let me start off by dipping my toe into the waters and asking, as meekly as possible: Does this title refer, in some way, to Federal budgets for our Nation's Fisheries?

Well, then, I'll wade a bit deeper: Is there, in the title, a wholesome castigation of the fishery resources? Or, is there at least some hint, some nudge of the elbow, that says maybe our national fishery responsibilities and roles really do need some re-evaluation and redirection from time to time?

Obviously, I sensed the latter.

1/ Keynote address presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-25, 1984.

2/ G. Ray Arnett is Assistant Secretary of the Interior for Fish and Wildlife and Parks, Washington, DC.

I accept the invitation to speak to you because I saw this as an opportunity to meet with friends and some of the finest sportsmen/conservationists in this country -- folks concerned about the quality and future of our sport fisheries -- and folks who have sense enough to meet in a place like West Yellowstone during this grand season.

Let me say right now that I truly am grateful for this opportunity, and would like to offer my sincere thanks to all the symposium's sponsors and organizers for the great work they have done to bring all this together.

This, of course, is the third Wild Trout Symposium. And I am honored to be a participant -- just as I know my two Assistant Secretary predecessors were.

Ten years ago, Nat Reed gave some very good counsel to the participants of this symposium -- he advised that there would indeed be some tough challenges and decisions in the years ahead. He was right.

Five years ago, Bob Herbst encouraged this same gathering by emphasizing that there was a great need for cooperation to achieve better, more stable and lasting fisheries. He was right too.

Both of these gentlemen made some very important and worthwhile contributions to their fellow anglers in this land, and all interested and concerned fishermen owe them a healthy measure of thanks.

During my tenure as the Interior Department's policy honcho for our fisheries, I've come to recognize and appreciate the challenges that Nat Reed spoke of, and to endorse Bob Herbst's plea for teamwork. But I'm here right now to address some tough dollars and cents questions about fisheries funding over the past few years.

That "Don't Shoot the Messenger" topic first offered seemed to imply that some awful deeds were done to our fisheries. Well, wading out a bit deeper, I will allow that, yes indeed, there were some tough and unpopular budget cuts 2 and 3 years back. There were reductions in personnel and production at a few facilities, merging of others, and transferred management of some hatcheries to a few States and the Bureau of Indian Affairs.

Some research efforts were halted or redirected, and some of the fishery assistance field stations were closed. A few folks got "RIF'd" -- that's Federalese for laid off. Others retired, a few folks quit. And that was unfortunate -- because they really should have had a bit more patience, and faith.

The majority of our professional fishery staffs, though, were transferred into new (and let me underscore that word new) fishery efforts. Despite the juicy rumors of 1981 and 1982, the Potomac River didn't run red with the blood of slaughtered bureaucrats. Our goal wasn't bloodletting. It wasn't even major surgery. I prefer to consider it necessary and better management of taxpayer dollars to help bring about the economic recovery President Reagan had promised the American people who were fed up with double-digit inflation, double-digit unemployment, 21% interest rates, run-away taxes, and a burgeoning bureaucracy.

Our intent -- despite what you have read or heard -- was to make the fisheries program more economical ... more efficient ... more stream-lined ... and more responsive to the States. But unfortunately, most of the reports you've read, and probably none of the rumors you heard, ever got down to the reasons of why these difficult financial reductions had to be made. It was too easy for those who wanted to keep the pot boiling to simply say Reagan is anti-environment.

Well, in that kind of climate, our reasoning for the changes in the fisheries program and other government programs scarcely had a chance to emerge.

Let me state, briefly and in passing refutation, that all the unfounded rumors and allegations you heard may have had some entertainment or newspaper-selling or fund-raising value for the vocal minority, but -- they had no foundation in fact.

We weren't out to "get" anybody or anything other than better management with fewer taxpayer dollars. We weren't trying to ugly stick the bass guys. We weren't out to put some of our premier salmon angling into a grocery store tin.

President Reagan wanted -- the Interior Secretary wanted -- I wanted -- effective fisheries research, and good strong fisheries program. In fact, I wanted 'em darn good. And to get to that -- a few sacrifices had to be made.

I want to follow up quickly here with an admission that, yes indeed, some of the folks and programs we trimmed were good, up-to-snuff, and quality efforts. BUT -- and here's a very big reason -- they were efforts that, for the most part, can, should, or were already being done by the States.

As far as I was concerned, the Federal fisheries effort needed to be rigorously soul-searched to determine if it was really on target with a genuine Federal fishery effort based on law, Congressional mandates, and demonstrated public need.

Why? Well, that's where I think we all ought to spend a few moments in history class. I'll start you off with this pop quiz:

Do you know how many U.S. fish hatcheries have been created in the last 113 years? Answer: 289.

Do you know how many are still in existence? Answer: 73. Let me hasten to add: No! We didn't cut out 216 hatcheries in 3 years.

Hatcheries, like almost any other government facilities, can outlive their need. Over the past 40 years, many hatcheries became obsolete, or their usefulness shifted more to State than Federal management goals and thus they were transferred.

Now for a couple easy history questions -- so you can get a passing grade:

What Federal outfit was poisoning "trash fish" in the Colorado River system during the 1960's? What outfit was curtailing its trout stocking efforts in that same river system in the 1970's? And what outfit was accused of using the Endangered Species Act to protect the squawfish, chub, and carp, the so-called trash fish it used to poison, in order to stop water projects in the Colorado basin in the late 1970's and early 1980's.

That was a multiple choice question, by the way. If you answered Bureau of Sport Fisheries and Wildlife or Fish and Wildlife Service you would have been right.

And, for our last question, another easy one:

What agency first imported carp into the U.S.? Answer: The U.S. Bureau of Fisheries, more than a hundred years ago. At the time, just about everyone was convinced it was just the fish the U.S. needed. Well, throughout much of this century, the old Bureau of Fisheries offspring, the U.S. FWS, has spent countless dollars and manhours trying either to eradicate the carp or trying to convince folks what a terrific but under-used resource it is.

The general drift of all the questions is that things change. They come and go. Styles change. The certainties of one age become the follies of another.

I won't stand here and try to tell you that our efforts have been the perfect course or the only course. That's probably the very sort of certitude that torpedoed so many of our past fishery efforts at the Federal level.

But I will stand my ground and tell you that our actions were based on a high degree of assurance that something had to be done to sort out and improve the Federal role in fisheries -- even if, in the short term, it looked like we were setting the fishery effort back.

I believe the course we elected to follow offers the greatest promise in the long run -- for anglers and for the resource -- and for the U.S. taxpayer.

The single greatest lesson of history we took into consideration was the unassailable, undeniable, and absolutely astounding growth of professional expertise and potential available to manage resident fish at the State level.

There has been a tremendous increase in the ranks of professional fishery biologists in State agencies from the 1940's, through the 1960's, til the present.

There are many important reasons for this growth, to be sure: Dingell-Johnson since the 1950's ... the success of the Coop Units in cranking out graduate fishery biologists since the 1940's ... the steady increase in the number of anglers ... the growing role sport fishing plays in recreational economics, and so on.

But the facts don't lie. The States were -- and are -- getting better and better at addressing the whole range of in-State fishery issues ... from hatchery management, to farm pond stocking, to urban fishing efforts.

We were faced with two untenable situations -- a blurring of fishery roles and a duplication of efforts at the State and Federal level. On one hand, many states were trying to assert their valid prerogative to manage their own in-state fisheries. But the funding they needed wasn't consistently available -- or, at times, the States were faced with some vexing jurisdictional issues, posed by a variety of Federal laws or programs.

On the other hand, parts of the Federal estate were too fat, overgrown, of questionable value, aimless, and long-overdue for performance appraisal. It was not an easy or pleasant situation to address, but it was necessary. Our guiding principle was to be fair and effective.

As you all know, the Reagan Administration thrust is, and has been, that States can, should, and will have a greater role in resource management decisions. And that's what we've been carrying forth. We've been doing what we see as an overriding Federal priority: sorting out what Federal and State roles and efforts should be in fishery management and responsibility.

One of our very first efforts was to develop and initiate a new Departmental Fish & Wildlife policy ... and the States solidly supported it. Now, a few "environmental" groups hated it -- because it gave States and sportsmen their rightful role and weakened the adversarial groups' ability to manipulate its will on centralized Congressional Committees.

But, in my view from the Potomac, I would say that the States supported the new Departmental policy because they saw <u>their</u> needs being addressed fairly and realistically. Indeed, things are looking up for their fishery management efforts:

The expanded Dingell-Johnson, or Wallop-Breaux, Bill is one good reason to be encouraged. This new tax effort sends along some very serious new dollars (nearly $55 million, in fact) to the States, with very little Federal folderol. We're confident that it will turn out to be an extremely effective and successful State grant-in-aid program along the lines of the old, familiar D-J. In other words, an effort where the States, with their professional expertise, and with input from concerned sportsmen, will make the ultimate decisions on resource management goals that best fit their needs.

And this is as it should be.

Wild trout and wild trout waters certainly can be and have been proclaimed from the halls of Congress, or from the bowels of Interior and Agriculture, for that matter. But, in the long run, what value or lasting worth do such grand emanations have without the support of the affected State fishery agency?

In the long run, we see it as essential, effective, and wise, to encourage the people -- the State Fish and Game agencies, the sportsmen -- to come up with new and creative ways to address the issues of protecting and managing what is wild and free. The combined savvy of interested and dedicated people can do far more good than some grand language printed in the Federal Register.

It's my belief that the future of honest-to-goodness wild trout waters in this country is brighter today than when Nat Reed was here at the first symposium in '74 or when my good friend Bob Herbst was here in '79.

I know that may sound like blasphemy to some young environmentalists somewhere out there who were weaned on the notion of loss, gloom, and doom, but I base this belief on the fact that in the last 5 to 10 years the State agencies -- with support from groups like the Federation of Fly Fishers, TU, and local sportsmen's organizations -- have made enormous strides in cleaning up, fixing up, and managing quality trout waters. There weren't a whole lot of Federal subsidies involved either. It has been a labor of love. It has been people acting out of the concern and commitment they had for the wild trout resource. It has been dedication, at the State and private levels. Applied work. Hard work. Commitment.

In the past 10 years a lot of trout fishermen have received four-star political educations at the county court house, at the State General Assembly, at Congressional Committtee hearings, and in the murk and maze of Washington. Some might call this active participation in the legislative process by sportsmen as lobbying. I like to think of it as just good old-fashioned advocacy for our natural resources. Concerned citizens learned "the system" and made it work for them.

I have great admiration for those folks. Their dedication to quality trout waters took them away from the fish and the waters they loved and into some downright polluted habitats. But they emerged victorious, and so did the resource.

Because of your efforts -- as sportsmen, as interested citizens, and as State fishery managers -- quality waters and quality fishing have gained a greater and deeper hold among the general fishing population. And it's through your work at the local level that local fishing quality improves. It takes commitment on the scene; or, as the old expression goes: charity begins at home.

But to bring this back around: what indeed is the Federal role? Is the Fish and Wildlife Service going to be a contributor to better fishing -- or just a cheerleader to State and private efforts?

Well, the Service will indeed be supportive of State and private fishery efforts. Very much so, I promise you. But moreover, it will have the leadership role in several key areas that are germane to the continued success of State efforts -- and I'll mention these in just a moment.

The Federal goal will be to keep fishery responsibilities where they should be. We don't want them blurred. We want to keep things logical, simple, and fair.

The Fish and Wildlife Service has just completed a rigorous exercise to delineate what the Federal government can, should, and must do to perservere in its worth to States, diversified users, and the resource:

-- The first and foremost reponsibility of the FWS will be to facilitate restoration of depleted, nationally significant fishery resources -- for example, the Atlantic salmon restoration effort, the Great Lakes fisheries work, and the increasing projects on behalf of striped bass.
-- Second, the Service will seek and provide for mitigation of fishery resources impaired by Federal development initiatives.
-- Third, the Service will work to enhance the status of currently and potentially endangered and threatened fishes, together with associated aquatic communities.
-- Fourth, FWS will assist with management of fishery resources on Federal and Indian lands, such as this magnificent area of Yellowstone National Park.
-- Fifth, FWS will maintain a Federal leadership role for scientifically based management of fishery resources. The Service's legacy of excellence in fishery research will continue.
-- Finally, the Service will enhance public awareness of the Nation's fishery resources.

As I hope you can see, we are not only redefining and refining the Federal framework, we are in a very real way saying: here is a solid foundation on which State and private fishery efforts can build their future.

We've laid a solid foundation, and it isn't intended to go away. We hope it'll grow and get stronger for you, and for your fishery endeavors.

If you want to know about my view from the Potomac, it would be this: The policies that issue from Washington should be regarded as the bedrock, the cornerstone, the poured foundation. The quality of the new structure depends -- as it always has -- upon the vision, the work, and the will of the people.

For a decade now, trout anglers in this great land have been building an important legacy for themselves and future generations. They've been working and building to ensure quality wild trout fisheries for the ages to come. Perhaps they weren't aware of that. Perhaps they thought they were biding their time 'til some Great Spirit from Washington swooped in to cleanse all streams and fatten all trout. But that wasn't so. It was their very own sweat, toil, and, at times, anguish that won the day and saved the stream.

The Federal government should do what it does best: set broad and sound guidelines for resource conservation. It can fund long-term research. It can take the time to do the background work no one else can afford. And, in this regard, the Fish and Wildlife Service and other agencies of the Federal government can be of great and lasting service to you. But you -- the trout fishermen -- your task is to be the activists on your own behalf, to be guardians of your own cherished waters and fishes.

You can't hire surrogates for that. You can't demand a Congress or an agency of the Executive branch to know and love and protect your interests in your stead. It cannot work. It never has and never will. You are the eyes and the ears and the voices of wild trout in this country.

You've done an extraordinary job for wild trout in the past 10 years. Keep up your good work. I know it's natural in symposia such as this to emphasize the negative -- that's what some motivation efforts are all about. But take a moment to giver yourselves credit, to reflect on what's been gained. You haven't done badly at all. In fact, the record of achievement in the past decade is encouraging...very encouraging. I would just issue the reminder that, while pleas and demands upon Washington are always good sport in their own right and always in season, don't get confused into thinking that Washington can ever do more than provide an essential and solid foundation ---- the real work and the real achievments in your endeavor will always remain the work of trout fishermen, dedicated folks willing to give of their hands and their hearts.

Thank you, and good fishing.

Multiple Use, Multiple Disciplines, and Limited Funding[1]

John B. Crowell, Jr.[2]

Abstract.--Fisheries on the National Forest System will continue to be managed in a multiple-use context. The challenge is to develop and refine analyses that compare the total benefits from each resource. Decisionmakers could decide whether to choose the best investment, or whether the situation warranted making expenditures which are not best financial investments.

When Dr. Loveless offered it, I welcomed the opportunity to address you today because I don't very often get the opportunity to state to an audience of your persuasion my views regarding multiple use management of our national forests. My humorously assigned title, "Come Down From Your Tree, John Crowell," is either an allusion to my avocation of bird watching--or a call to end my reputed preoccupation with emphasizing fuller utilization of national forest timber resources in a cost-efficient manner. I suspect the latter, and therefore particularly welcome the chance to speak to you as a group interested in resource conservation and wise use of all national forest resources.

Whether and how far we should collectively "come down from the tree" is a problem we must face because realistically one simply cannot ignore the fact that returns to the Treasury are important to the country and to this Administration which is dedicated to cost-efficient government. I saw a bumper sticker the other day which said, "I support President Reagan. I can't afford anyone else." Whether you like it or not, that really seems to be at the very core of the electorate's support for the President which the polls tell us is out there.

The basic reason the nation is now having to struggle with efforts to reduce annual Federal budget deficits and their accumulated carrying costs is because too little attention has been paid in the last 25 years, as Federal programs and expenditures have ballooned out of control, to how they would be paid for and to whom would make the payments. It's been too easy to enjoy now, and worry about paying later. Now we've come to "later," and the scramble is on (1) to stick somebody else with paying for the share of deficits our favorite programs have accumulated and (2) to preserve those favorite programs from being cut back or even to preserve them from no longer being expanded.

Whether we are administrators or taxpayers, we must recognize that the timber resource seems to be the single most valuable resource of the national forests. Properly managed, it can provide very large economic benefits. Properly managed, it can also provide many incidental or corollary benefits.

By emphasizing the value of the timber resource, I'm not saying that the other National Forest resources are not of great value also. Fish, wildlife, water, wilderness, recreation, minerals, forage and timber are all valuable products and amenities that go into the multiple use management options considered for each forest. What I am saying is, as we come to recognize that costs of programs are important and that good management does require evaluation of benefits obtained in return for costs expended, program priorities will evolve. As yet, however, we have only imperfect means for reducing the benefits of multiple use amenities to the common denominator--dollars--necessary for making valid comparisons and evaluations between uses.

The Multiple-Use Sustained-Yield Act of 1960 directs that the National Forests be managed for multiple use. The law with considerable prolixity, defines this as:

"...the management of all the various renewable surface resources of the national forests so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic

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1/ Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24, 1984.

2/ John B. Crowell, Jr. is Assistant Secretary of Agriculture for Natural Resources and Environment, U.S. Department of Agriculture, Washington, DC.

adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination of uses that will give the greatest dollar return or the greatest unit output."

FEDERAL GOVERNMENT OWNS ONE-THIRD OF U.S. LANDS

It surprises many people to learn that the American people own nearly three-quarters of a billion acres of Federal land--roughly one third of the total land area in the U.S. That amounts to each of you owning more than 3 acres of public land. The Forest Service manages 191 million acres, or 25% of the federal land ownership.

Other agencies manage Federal landholdings under different mandates than does the Department of Agriculture. For example, the Department of Interior's Bureau of Land Management administers 398 million acres of public domain and other lands under various laws which generally embrace the multiple use concept. On the other hand, under some dominant use mandates, the National Park Service administers 68 million acres and the Fish and Wildlife Service administers 43 million acres. Another 41 million acres are overseen by the military and other agencies.

NATIONAL FORESTS--DIVERSE ASSETS

The 191 million acres in the National Forest System are divided into 155 National Forests and 19 National Grasslands. These lands contain 128,000 miles of streams and 2.2 million acres of lakes that support more than 15.5 million 12-hour fisherman days per year. In addition, National Forest management affects fish habitats and many other water-related values downstream of the forests. In fact, concern for watershed protection and for future timber sources were the two original reasons why the Forest Reserves, which later became the National Forests, were first established.

Other assets of the National Forests include:

--85 million acres, or 18 percent of the Nation's total of commercial forest land, on which stands today fully one-half of the Nation's sawtimber supply, that is, trees over 12" in diameter.

--Grazing for about 1.5 million head of cattle and 1.6 million sheep each year under special permits granted to ranchers.

--An estimated one-fourth of the country's potential energy supply and a significant amount of our mineral resources.

--Wildlife habitat, which supports many species of wildlife, including some threatened or endangered species, and perhaps 50 percent of our Nation's big game.

--The source of roughly three-quarters of the water supply in the Western states, on which more than 1,000 communities and 20 million acres of crop and pastureland are dependent.

--The largest Federal source of outdoor recreation in the U.S., providing 230 million recreation visitor days per year--twice as much as the National Park System.

--Almost 28 million acres of wilderness, or 86 percent of the National Wilderness Preservation System in the lower 48 states.

NATIONAL FOREST RESOURCES ARE VERY VALUABLE

In fiscal year 1983, the revenues generated from these resources were $966 million--far less than could be generated and far less than a fair return on the value of the assets represented. This included: About $748 million from timber sales; $132 million from mineral assets (minerals, coal, oil, and gas); $28 million from recreation fees; $10 million from grazing fees; and $48 million from a variety of other uses.

I give these figures to show the immense value of these resources. They are becoming more valuable each year because, the demands on them are escalating. Applying the concept of multiple use to these lands is becoming more difficult because as demands increase, so does the likelihood of confict between uses. Obviously, multiple use cannot be applied to each acre at the same time.

A major consideration in determining uses of national forest land, of course, is the capability of the land itself to support timber production? Is it underlain by mineral resources? Is it scenically attractive? Does it offer superior opportunities for one particular resource, whether it be blue ribbon trout fishing or production of a scarce mineral? The answers to these and many other questions define the realm of possible uses.

At the same time, local and national publics demand a varied mix of uses. Major considerations by these publics may include: Distance from population centers, accessibility to wood processing plants on which there is local economic dependence; or availability of water for uses in arid areas or for cities.

Added to all of this is the reality that Federal expenditures and potential returns from those expenditures have to be carefully evaluated and assigned priorities in order to deal with Federal budget outlays in a rational way.

DETERMINING MULTIPLE USE MIX IS COMPLEX

Given all these considerations, land management planning--the process by which the mix of multiple use is determined on each national forest and grassland--becomes a very complex process. To integrate this mix of uses, the Forest Service relies on a gamut of specialists --foresters, engineers, hydrologists, soil scientists, recreation managers, range conservationists, and wildlife and fishery biologists, among others.

The agency currently employs about a hundred fishery biologists and dedicates nearly 20% of its total wildlife budget of $35 million to management of the fisheries resource. Not all of the specialists' input comes from Forest Service employees, however. In the case of fisheries especially, state cooperators make significant contributions in terms of fish populations and effects of regulation.

The major goals of the fisheries program are:

1. To achieve allocation of various uses so as to ensure that development projects are compatible with maintaining fish habitat; and

2. To ensure good coordination of potentially conflicting uses to minimize harm to fisheries.

We have problems integrating certain uses in some areas. In some cases on western rangelands, livestock grazing conflicts with the objectives of good fish and wildlife habitat and high water quality. This conflict is particularly evident in riparian areas along streams.

Riparian areas in arid zones are particularly tenacious problems because they are so fragile, and yet attractive to livestock, wildlife, fish, and people. These areas have the lushest forage and browse, easy access to water, cooler temperatures, flat ground and shade. Yet when livestock are permitted to "camp out" in these areas, streambanks are broken down, soil is compacted and stream-shading vegetation is removed. The result is that fish and wildlife habitat is degraded. Research shows that range management systems and grazing methods <u>are</u> available that will allow livestock to use riparian forage without degrading the areas for other potential uses. But to impose those systems and methods requires investment, primarily in fencing--which is not cheap.

FOREST SERVICE RIPARIAN POLICY

The Forest Service policy is that use of riparian areas by cattle may occur as long as riparian-dependent resources are not degraded. Policy is one thing; implementing it when implementation requires substantial investment takes time, particularly when the new, more stringent policy affects the livelihood of long-established ranchers neighboring the national forests.

EXAMPLE OF FISHERY DOMINANCE

In the context of multiple use, no one use is controlling, but usually one is dominant in a particular area as dictated by land capability, demands, and costs. The Rock Creek watershed on the Lolo National Forest near Missoula, Montana, is an example of the recognition of a key value which subsequently determines dominant use in the area.

Rock Creek is a blue ribbon trout stream that enjoys a national reputation. The watershed also contains various excellent wildlife habitats, is very appealing esthetically, and is heavily used by recreationists. The watershed consists of 183,000 acres, 108,000 of which are suitable for timber production--yet forest managers have planned only 38,000 acres for timber management, which is scheduled to ensure that there will be no risk of harming the fishery. The remaining five-sixths of the Lolo National Forest lands in the drainage are being managed specifically to conform to the needs of the Rock Creek fishery. Prevention of harm to an excellent fishery resource in a multiple use context is the guiding objective.

In some areas where fish habitat resource damage has occurred because of natural events or human activities, the Forest Service is making investments to restore habitats. For example, the goal for anadromous fish habitat on the Six Rivers National Forest in Northwestern California, is to restore salmon and steelhead populations to near historic levels. Miles of spawning and rearing streams were damaged by the 1964 flood that left a path of destruction behind all-time high peak flows. The damage was abetted by a history of logging, and road construction on several ownerships along Northern California Coast streams that did not take adequate account of fishery needs.

The cumulative effect of people and nature resulted in large amounts of soil and debris entering the streams, which in turn caused the loss of bank stability and streamside shade canopy. Since 1979, Six Rivers Forest personnel have built 136 structures to increase the spawning habitat of 15 streams. The structures have been found to support from 30 to 90 percent of the salmon and steelhead spawning populations in the project streams. Rearing habitats have been enhanced by placing large rocks, logs, and gabion structures in stream sections that lack the necessary habitat.

Evaluations of these project areas have shown a two- to seven-fold increase in yearling fish as a result of the work. Barrier removal, watershed restoration, and biological enhancement to supplement natural fish production round out

A total of $1.5 million in State and Federal funds has been invested since 1979 and an additional $1.75 million is planned for the next five years.

In making such investments, costs and benefits in cash terms cannot be ignored. It was estimated that each year the projected work would increase annual production by 53,000 commercial pounds and 1600 fish user-days. Given that project benefits will accrue for 10 years and using values developed for the Resources Planning Act program, it is claimed that these project activities yield benefit/cost ratios of three to one.

ECONOMIC ANALYSIS IS IMPORTANT

We need to be careful, though, about how we figure economic values. Obviously, the best investment, in resources or anywhere else, is the investment which yields the greatest returns. If we have a number of alternative investments, we need to compare those investments to see which one yields the greatest return and therefore is the soundest investment. This is not to say that forest planners always have to choose the investment which yields the greatest return. Sometimes, the returns may not be as high, but can be important enough to meeting public needs and demands, that they justify making the expenditures or investments anyway.

However, we need a universal basis for comparing the returns on investment. Timber returns money directly to the U.S. Treasury; so do oil, gas, and mineral development. Grazing and even recreational use have the potential for providing net returns, or of at least covering costs incurred.

In the case of fisheries, often we do not know whether investments are sound or not because the only way to know if an investment is sound is to recover costs from it. Since we do not recover costs from fisheries on the National Forests, we do not have a good idea of what value they offer, or how those values compare with values which can be generated from alternative uses of the land.

In the last few years, economists have made an effort to assign values to resources such as fisheries, wildlife, and recreation. I for one do not believe that we have come far enough in this area. Often, attempts are made to compare the indirect returns from a resource such as fisheries with the more direct returns from a resource such as timber. If you are going to count all economic benefits traceable to a fishery you have to do the same for other resources. Also I believe that at times unrealistically high values have been assigned to some of the more intangible resources. In effect, what should be a fairly straightforward economic analysis has ended up comparing apples and oranges, in a manner that is not logically consistent.

The best we have been able to do credibly is to look at foregone opportunity costs so as to estimate what we can be pretty sure we are not getting as a result of managing for an output like wilderness or fish. Management of the Rock Creek drainage on the Lolo National Forest in Montana, which I alluded to earlier, is a good example. There, the Forest Service is managing only 38,000 acres for timber production out of the 108,000 acres in the drainage which potentially could be so managed. The 70,000 acres from which timber management is being foregone in favor of the fishery are 110 square miles! If each acre supports, or is capable of supporting, 15,000 board feet, and if each one thousand board feet is worth $50 on the stump, the stand on these 70,000 acres, on the stump, is worth $52,500,000. An annual net return of 6% to the owners of that asset value, the people of the United States, would be $3,100,000.

We simply don't know whether it would be possible to manage the Rock Creek drainage for that kind of return from fisheries and recreation, because it's never been tried and the Forest Service does not at present even have the legal authority to try it by collecting charges from the users. I hasten to add also that the Forest Service has never shown either that it actually could manage those 70,000 acres of timber for a net return of $3 million annually (or whatever figure actually was justifiable, since the figures I've used are only for purposes of example). The Forest Service simply is not required by law to manage profitably any of the resources in its charge. In fact, the Multiple-Use Sustained-Yield Act implies that it need not, or at least that it need not in every instance.

We ought, then, to have a better basis for economic comparisons. If we could compare the total benefits from each resource, giving realistic, not inflated, values to each resource, then we would have a basis for determining what are sound investments in resources. From that point, decisionmakers could decide whether to go with the best investment, or whether the situation warranted making expenditures which are unlikely to be the best financial investments.

BELOW COST TIMBER SALES

Speaking of cost recovery and economics, I'd like briefly to mention the issue of so-called "below cost" timber sales by the Forest Service, which has been getting some attention lately. Critics have pointed to individual sales in which they contend expenditures exceed revenue. It should be remembered that land management, and particularly game management, is vegetation management--very often there are multiple benefits from vegetation management.

First, it should be noted that many sales which are criticized as money losers really are not if proper accounting techniques are applied. Second, there are a number of sound reasons to conduct sales that may actually lose money. These reasons include: improving the quality of the remaining timber in an area; investing in future improved long-term timber growth by thinning; salvaging timber killed by fire, insects, or disease; reducing fire hazards; providing local community stability; or improving wildlife habitat. You can readily appreciate that sales made for these reasons provide long-term economic, environmental, and social benefits. Having the flexibility to offer "below cost" timber sales allows the Forest Service more effectively to manage for all uses in an area and to make investments for the future.

It should also be noted that as a whole, the National Forest timber sale program, before sharing 25 percent of gross revenues with counties in National Forests, turns a profit. Over the past six years, from 1978 to 1983, the timber sale program cost $2.9 billion. During that same period, the value of the timber sold was $8.4 billion, measured by the prices bid; the value of the timber actually harvested was $4.3 billion.

In summation, fisheries will continue to be managed in a multiple-use context on National Forests. The challenge is to develop and refine procedures for economic analysis to make sure that resource tradeoffs can at least be fully considered. In the meantime, cooperation and tolerance among user groups will make it much less difficult for the Forest Service to meet society's needs from National Forest resources than if multiple use decisions must be made in a rancorous and competitive atmosphere where logic and analysis are rejected. Your help in the efforts to develop analytic procedures for ensuring balance in the multiple-use mix of resources on the National Forests is important. By working together, we can truly meet the greatest number of renewable resource needs of present and future generations.

The Worth of a Wild Trout[1]

Dan Abrams[2]

An ancient Chinese proverb states:

"If you wish to be happy for one hour, get intoxicated.
If you wish to be happy for three days, get married.
If you wish to be happy for eight days, kill your pig and eat it.
If you wish to be happy forever, learn to fish."

And I never cease to give thanks for wild trout and for the wild places they live. . .these wonderful fish and streams which have certainly expanded and enhanced my own enjoyment of life.

There have been those who have not been very optimistic about the future of such fish. In 1881, the Rev. Myron H. Reed, an enthusiastic angling clergyman ventured this prediction:

"This is probably the last generation of Trout fishers. The children will not be able to find any. Already there are well-trodden paths by every stream in Maine, New York and Michigan. I know of but one river in North America by the side of which you can find no paper collar or other evidence of civilization; it is the Nameless River.

"Not that Trout will cease to be. They will be hatched by machinery, and raised in ponds, and fattened on chopped liver, and grow flabby and lose their spots. The Trout of the restaurant will not cease to be. He is no more like the Trout of the wild river than the fat and songless reedbird is like the bobolink. Gross feeding and easy pondlife enervate and deprave him.

"The Trout that the children will know only by legend is the gold-sprinkled, living arrow of the Whitewater - able to zig-zag up the cataract, able to loiter in the rapids - whose dainty meat is the glancing butterfly."

In the hundred years that have come and gone since that lament, the human race has continued to sin greatly against this earth on which we live.

We seem to possess a perverse genius for finding new ways to foul our streams and to destroy the treasures of wild trout they hold. And while there were moments when it looked as if the good Rev. Reed's pessimistic prognostication was right on target, I thank God for voices of protest which have joined in a chorus of outrage against these transgressions. I thank God for people like you who know the worth of a wild trout.

When I speak of the worth of a trout, I do not talk of the economic numbers attached to revenues derived from the fifty-one million American people who go fishing each year. There are a lot of bucks generated from this pastime when one considers the license sales, tackle, travel, food and lodging related to it. But somehow the worth of a wild trout seems to transcend those figures, impressive though they are.

<u>How can you put a price tag on something so valuable as the healing of the stresses and pressures of our hectic lifestyles?</u>

"A wild trout can do that?" you ask.

Dr. Jerome L. Singer, Professor of Psychology at Yale University, wrote:

"Today's busy American lives in a world in which dozens of daily pressures mount up to create an atmosphere of tension and harassment. The interruptions from the telephone, a memo to be read and answered with a short deadline, home chores and repairs to be arranged. . .all accumulate to a powerful sense of desperation that can lead to dangerous psychological or physical stress reactions."

Dr. Singer asks, "What can you do to reduce the dangers of such regular pressures?"

Then he answers his own question very simply. "My answer as a psychologist is: go fishing!"

A good friend of Izaak Walton, Sir Henry Wotton, summed up the therapeutic effects of angling as "a rest to his mind, a cheerer to his spirits, a diverter of sadness, a calmer of unquiet thoughts, a moderator of passions and a procurer of contentedness."

What medicine can compare with that?

Is it any wonder that when Simon Peter was going through a particularly difficult time, when confusions and discouragements were a heavy burden, he turned to his fellow disciples and said, "I go afishing."?

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24-25, 1984.

[2] Dan Abrams is an angler, author, and Minister of the First Baptist Church in Jackson Hole, WY.

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r Sir:
t last report it seemed likely t Wisconsin would increase resident fishing license fee m $2 to $3 and issue a special ut stamp for $1.

Sportsmen seem to accept thout a whimper the rising sts of fishing equipment, gaso- e, lodging and all that goes to a fishing trip.

And while they complain that nservation departments are ot doing enough, they yelp at e first hint of an increase in cense fees.

I got a kick out the way the roblem of increased fees was pproached by Thomas S. Jenks, utdoor writer for the La Crosse Wisconsin) Tribune.

In his column, "The Inside on the Outside," Jenks opined that a $2 license is so cheap it's almost ridiculous, a $3 license is a steal, a $5 license a bargain, and a $10 license would be an honest value.

Here's why in Jenk's words:

"Fishing is one of the few sports in which you can participate all year — and pay for only once — and one of the few that yields anything beside exercise.

"Take golf. Eighteen holes of golf cost about $3 for an afternoon of exercise.

"Take bowling. Three lines of bowling cost about $1 and, unless in a group, lasts about an hour.

"Take skiing. A day's skiing costs about $3.

Movie goers spend about 85 cents for two hours of entertainment.

"The same guy that grumbles about a $3 fishing license thinks nothing of spending a couple bucks at the corner pub on the way home.

"Many fishermen enjoy their day even if they don't catch anything. If they do catch something, then this becomes gravy.

"I spent $2 this week on a fishing license and I'll be spending about half of Monday trying for the big one. If I get any fish, fine. If I don't I got $2 worth of fun trying.

"And, after Monday, there are many, many days left that I can have fun on my two bucks."

All I can add to Jenk's remarks is amen.

Yours truly,
A Stamp Buyer

BOOK CORNER

Dear Ken:

It is no idle threat when we say that trout fishing, as it has been in the past, will cease to be in the next generation. As Ted Trueblood has written in the April, 1961, Field and Stream, "This is probably the last generation of trout fishers. The children will not be able to find any."

The trout that our children will know will not be the wild rainbow that now dances on its tail and sends our pulses pounding with his desperate effort to evade our nets. Nor will it be the wiley brown, deep running, cunning and stubborn against being taken.

Instead, we will have to be satisfied with listless trout, reared in production hatcheries and ponds, and fattened on liver and artificial pellet substitutes. They will, as they do now, lack the native feeding instinct, as well as the ability to survive the swift streams and the predators. Oh yes, we will have our trout, but the sport will be gone forever.

This is a painful outlook. And it is even more painful to observe the complacency of thousands of anglers who have eyes, but see not, and ears, but hear not. They are satisfied to leave things as they are and are the first to villify the efforts of all dedicated trout fishing conservationists.

Scientific efforts by the U.S. Fish & Wildlife Service as well as by state conservation commissions and private clubs have proven that we can, through proper research and study, have better trout fishing. Pennsylvania, Wisconsin and Michigan, to name a few, have achieved notable success in bringing back to full use many streams.

The time has come when anglers everywhere must adopt a realistic attitude toward the sport of trout fishing and the efforts of men who are dedicating their lives to the preservation of their greatest sport interest. Without their understanding support, legislators and commissions cannot hope to put through bills regulating water use and control, pollution, watershed protection and beneficial conservation measures. They want your unprejudiced and honest help.

May we quote from Arnold Gingrich's publisher page in the May, 1961 Esquire.

.... writes: "Maybe human na-

It comes as no surprise that 90% of all fishermen surveyed by the United States Fish and Wildlife Service mentioned RELAXATION as the number one reason for going astream.

Is there anyone here who has never had frayed nerves soothed by the laughter of a dancing riffle where you knew a red-sashed rainbow held?

Is there anyone here who has never had the cares of the day washed away by the pull of a gentle current against your waders as you cast to a rising brown trout in a meadow stream?

I, for one, would not trade one wild trout for all the Valium in California.

How do you slap a price tag on a dream?

Once while fishing the Madison River not far from the Varney Bridge, an angler from Mississippi hooked a very large brown trout just downstream from me. He fought it well and finally brought it to net.

By that time, I had waded on down to admire his trophy. By the way he was gently handling the fish, it was obvious he planned to return him to the stream, so I asked if he wanted me to weigh the fish.

He seemed reluctant, but I pressed on, "Look, I've got this scale made in France. Accurate to the half-ounce. We can weigh him in the net and it won't hurt him at all. He'll probably go over six pounds."

Well, he patiently glared me back from the fish and just shook his head.

He worked him back and forth in the current while the trout gained his strength. He was a superb fish, and so I asked the man if he wanted me to measure it before it swam away.

"I carry this little tape measure to keep me from exaggerating. That brown will go 25 inches for sure!"

But the man declined with another shake of his head.

By now the fish was nearly ready to be on his own again, so I asked this guy if he wanted me to take a picture of him and his trout.

"It's something you can show your wife and fishing buddies and it'll only take a second."

His response was to give one last push to the trout which swam deliberately and strongly into the Madison River current.

Then the man straightened up and explained in his soft Mississippi drawl:

"You see, I've got this picture in my mind of how big this trout is. And I'll carry that picture with me all through the Mississippi year. And during the hot, sweltering days of summer, I'll remember this place and this cooling breeze. And I'll remember the smell of the sagebrush and the sound of wind-rustled leaves in those cottonwoods behind us. And I'll remember this big Montana sky. And I'll remember this fish.

"And I don't want this lovely picture cluttered with the statistics of a scale or a tape measure, or even with the gracious offer of your photograph. It could never be as nice as the one I carry here." (And he pointed to his head.)

And as I waded back upstream, I realized there was a dream no money could buy.

What do you mark on the price tag of a hope?

Don McLeod was an old-fashioned country doctor who served three generations of the residents of Jackson Hole, Wyoming.

For ten years, Doc and I made plans each summer to saddle up a couple of his horses and pack in to his special lake - the one bearing his name.

And every year, he stoked our plans once again with descriptions that nurtured an anticipation and a hope for the possibility of one of life's great moments.

"Dan," he would say, "You'll love it! It's incredibly lovely there. And there are trout. Big cutthroats. And we will catch a couple and broil them along the shore of the lake, and then just sit back and relax as our eyes feast on some of God's prime real estate."

Well, summer schedules had a way of crowding out some of these more important arrangements, and for one reason or another, we never did go.

But I still harbor a hope that someday I'll go up Granite Creek and take the trail to McLeod Lake. And perhaps I'll be fortunate enough to catch two trout.

I will broil one along the shore and eat it as my eyes feast on that patch of the Creator's prime real estate. That, you see, was always part of the plan.

And the other, I will hold for a moment and behold the brilliant colors and admire the scarlet blazes under the gill plates, and then let him go to swim the cold, clear waters of McLeod once again. That one would be for Doc.

But if the interruptions to my plans persist and I never do get there, no one in this room has enough money to buy away the remembrance of those hopes and plans Doc and I shared about the wild cutthroats of McLeod Lake.

How can you assess the price tag of an experience that closes the chapter of a man's fishing life?

For several years, Bud Lilly had guided Horace Stevens to the trout waters of the West Yellowstone area.

Time and the pressures of business had exacted their toll on the health of Mr. Stevens. He was well past seventy years of age, and he had difficulty in moving about. Vision was failing somewhat. Breathing the thin mountain air was a labor and he carried a cannister of oxygen wherever he went.

It was a warm, sunny, windless day in early July when Bud took Mr. Stevens to a spring creek where he knew some stoneflies were hatching. Not far from the car Bud spotted a fine brown trout feeding in a slick of that gin-clear spring water.

He helped Horace to the water's edge and aligned him in the direction his cast should go. This was a study in guiding in its fullest sense.

"Cast about five feet upstream, Horace."

"O.K. Now about three feet further across this time."

"There, it looks good."

"He's moving toward the fly now! There. . . he took it. Strike!"

And, somehow, the hook held. And perhaps the old veteran trembled more from excitement than infirmity as the fish was finally netted.

And the two men looked at the heavily-spotted four-pound fish before returning it to the water.

And Horace Stevens squinted at the fly and asked what kind of a fly it was.

"It's a stonefly, Horace."

And he clipped it and stuck it to the wool patch on his vest.

And he squinted, trying to focus on the end of the leader. And he asked what size tippet it was.

"That's a 4x leader, Horace."

And he clipped the leader off where it joined the line and carefully rolled it in neat loops and put it in his vest pocket.

He reeled in the line and turned to his friend and said, "Bud, that's my last trout. Ever."

Now, you tell me how much that wild trout was worth.

And I'm sure each one here has his own story of his own fish. The point is that the importance and worth of a wild trout goes far beyond nostalgia and sentimentalism and winter dreams.

I'm glad that Rev. Myron Reed's century-old assessment that his was the last generation of trout fishers was dead wrong. But the reason it did not turn out as he predicted is there were people who cared about trout and trout streams. People who realized their worth. People who did not merely lament what used to be, but people who dreamed what could happen.

And while we argue about special regulations as management tools, or debate the merits of one kind of stream improvement over another, or wait to hear from Washington as to whether acid rain is really anything to get excited about, the future of wild trout will always hang in the balance.

And as our planet's waters continue to recede or become sterile, we are suddenly struck with the realization that they aren't making any more trout streams these days. God, give us wisdom and a commitment to hang onto and enhance what remains.

Everyone in the village held the wise old man who resided there in high esteem.

Everyone, that is, except the brash young kid who ached and yearned to impress others of his own cleverness by embarrassing the wise old man.

One day he hit upon a scheme which he felt would accomplish just that.

He caught a little bird and, cupping his hands around it, planned to go to the wise old man and put the question to him whether the bird in his hand was dead or alive.

If he said, "alive," the smart-alecky kid would squeeze the life out of the bird and open his hand revealing a dead bird. If he answered, "dead," the boy would open his hand and let the bird fly away. Either way, the wise old man's answer would be wrong.

So he came to the wise old man and challenged him.

"Old man, hidden in these cupped hands of mine there is a bird. Tell me, is he dead or alive?"

The wise old man studied the situation a moment and, keeping his reputation untarnished, looked the young fellow in the eye and said, "It's in your hands. It depends on what you want it to be."

We have gathered here for two days to talk about wild trout. Tomorrow, you will head back to your tasks as fish biologists, as government officials who make decisions about trout and trout waters, as members of Trout Unlimited and the Federation of Fly Fishers. People who care, or you wouldn't be here.

As we go, we consider all the information shared, the challenges set before us, and the visions of what can be. But, the level of our commitment to do anything about these things will be determined by one factor, by one question - WHAT IS THE WORTH OF A WILD TROUT TO YOU?

It's in your hands, and it depends on what you want it to be.

Wild Trout in Alaska — Now and In the Future[1]

Norval Netsch and Robert E. Putz[2]

Presented by Jon Nelson

Abstract.--Alaska has an abundance of pristine water and indigenous trout. Developmental activities have and will continue to impact fish habitat. Recent legislation has significantly impacted land ownership and has led to increased conflicts between users. Public opinion can influence decisions that determine the protection given to Alaska's wild trout for future generations.

INTRODUCTION

Alaska is sometimes referred to as the "Last Frontier" - with good justification. Nowhere in the United States are there more waters containing more wild trout than are found in Alaska. Ten million acres of inland waters and 33,000 miles of shoreline are a water base of staggering proportions.

These waters support a statewide total of 21 species of trout (family Salmonidae). Of these, 20 species are wild trout indigenous to Alaska. The brook trout is a non-native which was initially introduced to southeastern in 1920 and is now naturalized (MacCrimmon and Campbell, 1969). Fishermen pay up to $3000 per week for world-class trophy fishing in a relatively uncrowded setting available in Alaska. All of the indigenous species have healthy self-supporting populations in many separate waters which have never received introductions or transplants by man. Compared to many areas elsewhere, this part of the wild trout situation in Alaska is obviously good.

The most popular and widely distributed are rainbow trout (Salmo gairdneri), Arctic grayling (Thymallus arcticus), Arctic char (Salvelinus alpinus)/Dolly Varden (Salvelinus malma), and five species of Pacific salmon. Also, cutthroat trout (Salmo clarki) are abundant in southeast Alaska, lake trout (Salvelinus namaycush) occur in most regions of the State, and inconnu (Stenodus leucichthys) are found in western and interior Alaska and are called the tarpon of the north by some fishermen.

However, there are factors that result in impacts to fish populations and habitat which may cause Alaska wild trout resource to follow the same dismal history of many areas in the "Lower 48". The foremost of these is the development of the energy, mineral and renewable resources found in Alaska along with the indirect impacts associated with population growth and the inevitable spinoffs.

Another factor which has a bearing on the future of wild trout in Alaska are the many faceted public attitudes in a last frontier atmosphere. Vast areas of untapped resources and pristine areas offer many choices of what is done, how things are done, and what is not done. Federal legislation and reactive State decisions over the past 15 years have significantly changed Alaska. Public opinion can and must influence future changes which may be even more significant than past activities. There are many parallels between development in Alaska now and what happened in the "Lower 48" a century ago. The difference is that Alaska still has the time and opportunity to avoid some of the mistakes of the past - if it will.

PRESSURES ON WILD TROUT IN ALASKA

Habitat

The perception of habitat degradation problems in Alaska usually differs with the observer's experience and point of view. To some, the fact that Alaska still enjoys extensive pristine areas is reason enough not to be concerned with habitat modification when it does occur. Others have the view that since Alaska is the last place where large areas are still pristine, it should be kept that way and little or no habitat destruction should be tolerated. These opposing positions have served as a balancing mechanism and reality, in terms of actions taken, is somewhere in between.

Virtually all developmental activities impact aquatic habitat regardless of the site of immediate direct disturbances. The water cannot be separated

[1]Paper presented at the Wild Trout III Symposium, Mammoth, Wyoming, September 24-25, 1984.

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from the watershed. Specific data on the amount of aquatic habitat that has been or will be impacted is currently unavailable. However, it is anticipated that over six million surface acres will be impacted by seven categories of developmental activities for the period 1983 to 2003 (Table 1).

The amount of water within this 6 million plus acres which may be impacted is unknown. The only way it can be described at present is that a lot of fishery habitat will be involved. How these activities can impact fishery habitat has been described elsewhere, but some of special concern in Alaska are:

1. Gravel Removal. Few developments in Alaska can be done without gravel. Most roads, drilling pads and construction sites require three feet or more gravel to insulate against thawing of the underlying permafrost. Offshore islands commonly used in the Beaufort Sea are entirely built from gravel. Simple cut and fill cannot be used in most of the State and hundreds of millions of cubic yards of gravel is required. Some upland sites are available, but the common practice of mining in river flood plains is likely to continue indefinitely. The impacts of this have been studied in Alaska (Woodward-Clyde Consultants, 1980).

2. Siltation. Many activities cause siltation, but none in Alaska has the immediate and obvious impacts as placer mining. During early 1984, the U.S. Environmental Protection Agency received about 450 applications for draft National Pollutant Discharge Elimination System (NPDES) permits for mines which have a sluce loading capacity in excess of 20 cubic yards per day. These permits were expected to be issued in final form by June 1984, and will be good for a three-year-period. Since there is an unknown number of miners operating without a permit, and smaller mines do not need permits, the total number of mines actually in operation and the total sluce capacity of all placer mines is unknown. An indication of the significance, however, is that in 1981, over 27,400 new mining claims were filed and exploration expenditures were $65-76 million annually during the 1979-1981 period (Tuck, 1984).

It is well known that some mines cause considerable amounts of silt to enter streams. Studies recently completed by the Alaska Cooperative Fishery Research Unit at Fairbanks concluded that mining caused as much as 1900 tons per day of additional sediment in Birch Creek during periods of high flows (Van Niewenhuyse, 1980). In addition, these studies confirm findings reported in other areas that, compared to unmined streams, mined streams have higher settleable solids, higher specific conductance, lower alkalinity, lower hardness, more cementing of the bottom materials which interferred with intra-gravel flows (in Birch Creek the groundwater was nearly devoid of dissolved oxygen), and lower microinvertebrate densities. It was found that fish moved out of stream areas receiving mine effluents, thus eliminating from use much stream habitat.

TABLE 1. Anticipated surface areas impacted by selected categories developmental activities in the period 1983 to 2003 in Alaska. From data assembled by the Habitat Resources Program, U.S. Fish and Wildlife Service, Region 7, and is based on various published and unpublished reports and professional judgement.

	Surface Acres	
Activity	Direct Impacts	Direct plus Indirect Impacts
Oil and Gas	654,000	1,635,000
Minerals	508,550	1,474,800
Urbanization	396,600	1,293,600
Agriculture	600,000	720,000
Forestry	375,600	676,100
Transportation	98,600	325,380
Hydropower	91,600	146,600
Total Acres	2,697,950	6,271,480

3. Water Withdrawals and Flow Changes. While Alaska has a summertime appearance of an abundance of water, some areas could be classified as desert. Most of southeast Alaska receives more than 200 inches of precipitation annually, Anchorage receives about 20 inches and the North Slope receives less than 10. In some areas, surface runoff ceases entirely during the winter and, in many watersheds, there are few or no subsurface sources to provide a base flow. This becomes most acute in the Arctic where ice typically becomes 6 feet or more thick. By late winter, many rivers have liquid water only in deep isolated pools and some streams are frozen solid. Isolated springs frequently become critical overwintering areas for fish. Energy exploration and other activities require liquid water and also depend on the scarce supplies available. Domestic water supplies in several areas of Alaska are not sufficient to meet current or projected demands. Several villages have experienced water shortages during winter for many years, and the rapid population growth of Anchorage is causing a demand that will soon exceed the present supply. A detailed discussion of water problems in the Arctic is found in Wilson, et al, 1977.

The hydroelectric potential of Alaska staggers the imagination of even the most zealous engineer. Several huge projects have been proposed (and defeated) including the Rampart Dam on the Yukon River which would have created an impoundment about the size of Lake Erie.

Under active consideration is a two-dam complex on the upper Susitna River to supply power to south central Alaska and Fairbanks. This proposal would significantly modify the flow regime of the Susitna River and studies are underway to predict what the impacts on the fishery and other resources may be. Through careful site selection, several completed dams have not impacted any significant fisheries. Some dams are upstream of salmon migrations thus avoiding creation of a barrier. In one case, Terror Lake on Kodiak Island, detailed instream flow assessments were made and flow recommendations to protect fish were incorporated into the final designs - an example of good management which involved the cooperation of developers, environmentalists and Government.

4. Wetland and Streamside Encroachments. Alaska is blessed with an abundance of wetlands and streams. As developments occur, it is impossible to avoid encroachment and as the human population grows, the problem becomes magnified. Drain and fill of wetlands is occuring at a rapid pace in the populous southcentral area. Alaskans love the outdoors and recreational cabins are very popular. In those areas where waterfront property accessible by road, streamside "urbanization" is rapidly spreading. Private lands along the most popular river in Alaska, the Kenai, is literally lined with cabins and some permanently occupied houses. Many of these structures are on the streambank and have developed dikes, docks, levies, and canals to protect or enhance their property. If this continues, man will gradually destroy the very thing he wants to enjoy - the river and its tremendous fishery.

Harvest

As human population increases, more people in more user groups are placing more demands on a finite fishery resource. Managers and the public must realize that the quantity harvested or qualities associated with the fishery, or both, will change. An essential factor in the management equations is the capability of Alaska waters to produce resident fish. The fact that some places may at times produce a fish every cast and there are areas where 10 pound rainbow trout are common creates a dangerous illusion of universal abundance and productivity. Many of these are relatively small areas where fish are concentrated for feeding, spawning or overwintering.

Much of the abundance illusion is due to the presence of salmon, which make spawning runs of relatively short duration, can involve tremendous numbers of fish, are frequently very concentrated and obtain their growth in the ocean - not freshwater. Many of the freshwater hotspots for rainbow trout and some other resident species are areas that are supported by salmon as a food (including nutrient) base.

Many game fish species concentrate to feed on salmon eggs, flesh from salmon carcasses and/or juvenile salmon. Decomposed salmon carcasses then add nutrients to feed the entire system. Waters fed by this salmon food base are generally very productive for resident species compared to waters that do not have salmon. Also, overall production of inland waters of Alaska that do not have salmon is relatively low when to compared waters elsewhere which have higher temperatures and longer growing seasons. In nearly all cases, growth rates of fish in Alaska are slow and most species are long lived. For example, grayling may be 16 years old (Craig and Poulin, 1975), lake trout as old as 35 (Bendock, 1982) and rainbows up to 13 years old years old (Russell, 1974).

Commercial Fishing

Commercial fishing has been an important part of Alaska's economy for over 50 years. The 1981 catch was over 113 million salmon which collectively weighed 612,463,000 pounds for which fishermen were paid over $398 million (ADFG, 1984). The value and tradition of the commercial fishing industry has led to a powerful lobby to protect their interests.

The State of Alaska has established escapement goals for salmon on most major streams and carefully monitors the catch and escapement to adjust regulations to meet these goals. The North Pacific Fishery Management Council manages the fishery outside State waters to the 200 mile limit. Although most fishery managers consider most Alaska salmon stocks in good shape, there are unresolved problems between the United States and Canada particularly on chinooks.

The documented commercial take of trout and char in Alaska was 22,000 pounds in 1981. The incidental catch of steelhead is of particular concern to anglers, but no reliable figures are available as to the magnitude of the problem. Unconfirmed reports indicate that incidental harvest of steelhead could become a problem in a few cases where there is active commercial fishing near stream mouths when steelhead begin their runs.

Sport Fishing

In 1982, 293,011 anglers fished 1,623,090 days and harvested 2,828,706 fish in Alaska (Mills, 1982). Since 1977, the first year of statewide sport fish surveys, the number of anglers have increased at an average annual rate of 8 percent. However, between 1981 and 1982, the number of resident anglers increased 18 percent and non-resident anglers increased 17 percent. Overall, 72 percent of the anglers are residents.

Compared to fishing pressure in many other areas, this is relatively light on a statewide basis. In fact, there are many areas which are seldom if ever fished, and some that are subjected to very heavy pressure. The latter situations usually occur in areas accessible by road from Anchorage where about half of Alaska's population resides. Of the statewide totals, 70 percent of the angler days were expended in the southcentral region and one river alone, the Kenai River, supported 14 percent of the State total. A series of streams in this populated area frequently have elbow to elbow fishermen - not quite the picture of Alaska fishing sometimes seen in magazines.

The monetary value of sport fishing in Alaska is unknown, but actual expenditures by sport fishermen on the Copper River (a tributary to Lake Iliamna) converted to an average cost of $40.04 per trout caught and $243.01 per trout retained in 1972 (Siedelman, Cunningham and Russell, 1973).

Subsistence Fishing

Subsistence fishing has long been an important part of the life style of many native Alaskans as well as others living in remote areas. Since early statehood, Alaska has demonstrated its concern for continuation of subsistence opportunities (Kelso, 1981). In anticipation of the Alaska National Interest Lands Conservation Act (ANILCA), a statuatory priority for subsistence uses of Alaska's fish and game resources was enacted in 1978.

Federal concerns about continuation of the opportunity for subsistence uses were reflected in Title VIII of ANILCA which was passed in 1980. Section 804 of ANILCA provides that "...the taking on public lands of fish and wildlife for non-wasteful subsistence uses shall be accorded priority over the taking on such lands of fish and wildlife for other purposes." The act does recognize the need to manage fish and wildlife under "sound management principles," but it is clear in this law as well as the Alaska subsistence law that subsistence needs will be the highest priority of consumptive uses. Fish make up about 80 percent of the subsistence harvest.

Although there are numerous reports of subsistence use by individual villages or regions, precise information on a consolidated statewide basis is unavailable. In upper Cook Inlet, where the most serious controversies have developed, there were 1,331 subsistence salmon permits issued in 1980 with a reported catch of 14,775 salmon (Braund, 1982). Implementation of these laws is an extremely complex political, social, cultural and biological problem and is discussed by Kelso (1982) and in an undated compilation of papers by Langdon.

Growing Conflicts between User Groups

For many years, Alaska enjoyed the luxury of enough fish to keep most people happy with the exception of low cycle years of salmon. As population and demands for more fish increased, scattered incidents of discontent began to develop, particularly in the upper Cook Inlet area. Sport fishermen began a battle for a larger share in the allocation of salmon with commercial and subsistence fishing interests. The 1983-84 Fishery Board meetings provided a forum for the most heated exchanges between user groups ever held for allocation of fish in Alaska. The Fishery Board (consisting of seven people appointed by the Governor) proceeded to set annual regulations, some of which are being challenged in court. Sport fishing groups challenged the Governor's appointments to the Board, arguing that sport fishermen were under represented (initially one member of the seven represented sport fishermen; this was subsequently increased to two).

Major Federal legislation has greatly impacted the future of Alaskan waters. The first was the Alaska Native Claims Settlement Act (ANCSA) of 1971. This act provides for the transfer of 44 million acres of Federal land to private ownership by the various Native village and regional corporations.

The land selected by the Natives included lands around their villages, and these were often located at premium fishing sites. Once conveyed to the Natives, these lands are now under their control which means they may regulate access and use. Many lodges now pay fees for the privilege of fishing in waters once in public ownership. One prime example is the world renown Karluk River, on Kodiak Island. This famous steelhead, chinook, sockeye, and coho stream is totally owned, including the streambed, by the Koniag Regional Corporation.

Of major importance, ANCSA was responsible for ANILCA which set aside approximately 125 million acres of land in Alaska as National Parks, Wildlife Refuges, and Wild and Scenic Rivers. It also provided wilderness areas and other protective designations. However, as with all complex legislation there were many compromises in ANILCA. One of the most controversial is Title VIII, which gives subsistence uses priority over other consumptive uses of fish and wildlife in Alaska. The controversy will continue for years as many Alaskans feel they have the "right" to obtain at least some of their food from the natural occurring fish and wildlife resources. The definition of subsistence users has undergone much debate and is still not clear. Conflicts have occurred in several areas involving steelhead, chinook, and sockeye salmon. Specific subsistence and personal use fisheries have been established but much remains to be done, and the problem grows.

Titles X and XI of ANILCA also cause concern among fishermen. Title X provides for oil and gas leasing and development on Federal lands in Alaska including National Wildlife Refuges. On refuges these activities must be compatible with the purposes for which the refuge was established. Title XI deals with hydro electric projects, transportation corridors, and access on conservation system units. The actual impact on fishery resources depends on many factors, but the fact that these provisions are in the leglislation has caused continued outcries from some environmentalists.

Hatcheries

Commercial fishing for salmon in Alaska began in the late 1800's and by 1900 several salmon processing companies had built hatcheries to enhance production. The real momentum for development of hatcheries however, came in the early 1970's during several years of low salmon runs and a pending "boom" in wealth brought about by the discovery of oil at Prudhoe Bay. In 1971, the Alaska legislature created within the Department of Fish and Game a Division of Fisheries Rehabilitation, Enhancement and Development (FRED) to plan and implement a program that ensures the perpetual and increasing production and use of Alaska's fishery resources.

Appropriated funds and bond issues approved by the voters provided for rapid development of an ambitious program. In 1983, FRED had 20 salmon and trout hatcheries in operation, released nearly 260 million fish, and had a return of nearly 2.3 million fish (McMullen and Hansen, 1984). In addition, FRED administers permits associated with a private nonprofit hatchery program representing seven regional aquaculture associations which, in 1983, had 17 hatcheries in operation that released over 170 million fish.

Although the bulk of the above production is made up of five species of Pacific salmon, there were 1,250,600 rainbow trout, 57,400 steelhead and 1,355,500 Arctic grayling planted in 1983. During that same year, sport fishermen caught an estimated 18,800 fish which resulted from FRED activities.

THE OUTLOOK

There is little question that pressures on Alaska's fishery resources will increase. The national need for energy and minerals will necessitate further development of non-renewable resources, remote areas will be made accessible by new roads, expansion of agriculture will occur in spite of early questionable economics, more logging will take place, commercial salmon fishing will continue to be an important part of the economy and will expand to other species. All of this will cause population growth which will result in accelerated urbanization and increases in the number of sport fishermen. Reduced dependence on foreign energy sources, concerns about National and State economies and the relative health of local economies in the "Lower 48" compared to Alaska will all play a role in the determination of how quickly these and other developments will take place.

Several significant recent pieces of legislation will continue to have a profound influence on Alaska's wild trout and the fishermen who enjoy them. Land ownership patterns and access to prime areas will change as more lands are conveyed to private ownership. Battles over subsistence priority provisions are likely to continue for many years. The question of Native sovereignty is still being debated. Public use policy and regulations on the 125 million acres of National parks, preserves and wildlife refuges in Alaska will vary with different interpretations made by different administrations. Differing opinions by special interest groups will result in lawsuits leaving many management decisions decided by the courts, not professional land and resource managers. This is one of the reasons why Alaska reports the highest number of lawyers per capita in the Nation outside of Washington, D.C.

Other signs for wild trout and their habitat are promising. Authorities already exist for the appropriate State and Federal agencies to mitigate habitat degradation - provided they are capable, willing, and have the resources to do so. The many agencies which have responsibilities for habitat protection have a good track record of working together in an attempt to reach acceptable solutions to problems. A special task force made up of many special interest groups and governmental agencies made recommendations to the Governor which resulted in legislation intended to resolve the complex problems facing the Kenai River - and to preserve its priceless fishery. Another example of successful cooperative effort was the formulation of a joint fish and wildlife advisory team which monitored construction of the Trans Alaska Oil Pipeline and was used as a case study by Morehouse, Childers and Leask (1978).

Recognition of the high value of the sport fishery and interests in maintenance of "quality" fishing is increasing. Andrews (1980) described some important concepts for wild trout management and discussed the 1966 establishment of special regulations for quality fishing in selected waters in the famed Bristol Bay area. Those basic ideas have since progressed and have been expanded by several organized sport fishing groups which are finally gaining sufficient strength and momentum to influence policy and regulations. The Alaska Department of Fish and Game has formed a sport fish planning group made up of individuals and representatives of several sportsmen's groups to develop a rainbow trout management policy for submittal to the Board of Fisheries for approval.

Ideas relatively new to Alaska, such as drastic reductions in bag limits, artificial lure only regulations and catch-and-release, which didn't have a chance of widespread acceptance even three years ago, were adopted for several accessible waters at the 1983-84 Fishery Board meetings. Many of the high quality fishing guides and lodges have a catch-and-release policy for most resident species and steelhead. Most now realize that providing quality fishing on a continuing basis is more important than allowing their clients to take home a lot of fish meat.

Although Alaska has and will continue to have a significant hatchery program, concerns about genetic integrity and protection of wild stocks are increasing. The FRED Division has on-going efforts to study proposed new hatchery sites, to determine best egg sources, to evaluate results, to protect genetic diversity and to protect against spread of parasites and diseases. Early uses of out-of-state egg sources has changed to strictly Alaska sources and in many cases, eggs come from same system where stocking will occur. Management problems associated with mixed wild and hatchery stocks are potentially serious in some cases and will be difficult to resolve. Several agencies are conducting research, but answers may be years in the future. The misconception that hatcheries are the solution to fish shortages is changing to the realty that hatcheries are but one tool which must be properly applied to fisheries management.

Alaska is a challenging and exciting place. In spite of some areas of serious habitat degradation which started in the gold rush days and continued degradation resulting from mining, logging, energy development, and other activities since, the biggest challenge is yet to come - protecting the remaining huge amounts of pristine waters and the wild trout they can support for future generations. The excitement is knowing it is very possible. The future of wild trout in Alaska rests with public opinion and the responsiveness of the appropriate governmental agencies and landowners.

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Atlantic Salmon in Iceland's River Grimsa[1]

Sigurdur Fjelsted[2]

The Grimsa lies about 70 miles west of Iceland's capital Reykjavik, and flows for about 30 miles from its mountain lake origin to its confluence with the Hvita, a glacial river, which empties into the Atlantic a few miles down stream.

The land through which the Grimsa flows is owned by a number of sheep and dairy farmers. Under Icelandic law, the river waters and the fish in them are the property of the adjoining landowners. In 1885, Grimsa became the first Icelandic river fished with a fly for salmon by foreign and Icelandic anglers.

Prior to the late 1960's, each farmer permitted angling on his stretch of water as he saw fit -- fishing with rod and reel by the owning family or invitees, with or without fee. There was no management of the river as a whole except for hatchery support. In the late 60's, the Icelandic government, by agreement with landowners, determined that each salmon river must form an association to provide unified management of the river, its habitat, and its rod and reel harvest of salmon.

Except for a few gill nets in the mouth of certain glacial rivers, no commercial harvest of wild salmon is allowed in Iceland's salt or fresh waters. Icelanders love salmon, and the local market is largely filled by rod and reel salmon caught and sold by anglers to partially cover the heavy expense of their fishing.

To the river owning farmers now, the salmon is an important cash crop, constituting about 25% of annual income. The river is cared for like their fields and the crop is harvested by anglers, both foreign and domestic. Many rivers built angling houses or lodges to accommodate their angling guests. At Grimsa, a new lodge opened in 1973, was financed by American anglers under a unique arrangement whereby the investors were reimbursed by fishing time on the river.

Quality angling and spawning escapement are achieved by limiting the number of anglers, regulating the fishing hours and the length of the season. On Grimsa, by agreement between government biologists and the landowners association, only eight anglers per day are allowed during the thirteen week season. While it is daylight almost twenty-four hours, fishing is only permitted twelve hours per day. The entire river is divided into "beats" or sections, and the anglers rotate from one beat to the next with each fishing session so that all have an equal chance to fish the entire river.

Over the past dozen years, rod and reel catch has varied between 700 and 1900 salmon per season and it is estimated that this represents at least 50% of each year's total run. The average catch over this period is well above that for prior years. It is important to note the efficiency of rod and reel harvest. Eight rods per day fishing, only 13 weeks - a total of 728 rod days - annually takes over half or more of the total annual run.

Unified management has brought restoration of pools, control of erosion and bank damage due to livestock grazing. It has brought the establishment of a small enchancement hatchery on the banks of the river where a unique experiment is in progress. On the theory that large fish breed large fish, and that rising to the fly may be an inbred characteristic, only large, wild, fly-caught salmon from Grimsa are used as brood stock. While production is now limited to about a 100,000 fingerlings, it is hoped that the next decade will see the return of an increasing percentage of large, fly-caught fish. On Grimsa, as on all of Iceland's salmon rivers, each salmon caught is meticulously logged at the lodge so that we know size, sex, location and time of catch, method of angling utilized (including pattern and size of fly). There is no man-made pollution, (volcanic eruptions have caused some temporary problems on some Icelandic rivers) there is no poaching, and the in-river variables are under control to the greatest degree possible. Biologists regularly sample certain river sections by electro-fishing to determine spawning success. They report that the available spawning habitat is fully utilized and that the number of smolts going to sea each year has remained fairly constant. It is our strong belief that the ups and downs in returning runs over the past 12 years are due to conditions in the high seas, not to conditions in the river.

In 1978 and 1979, over 600 fly-caught Grimsa salmon were tagged and released, proving that catch and release angling for Atlantic salmon can be successful, and that the same fish can be caught and released a number of times during the same season and still return to fight another year. This was reported in a paper presented to the American Fisheries Society (Rocky Mountain Branch) Catch and Release Symposium in February 1980. Because the in-river variables are so constant and the catch records of the past are so well maintained, the Grimsa is an excellent place to do certain types of research on the Atlantic salmon.

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-25, 1984.

[2] Sigurdur Fjeldsted is a Rivermaster on the Grimsa in Iceland.

The Evolution of Salmonid Stream Systems[1]

Burchard H. Heede[2]

Abstract.--Evolution of salmonid stream systems is described in light of terrestrial history. The last ice age was responsible for the macro land forms in high mountain areas, the location of most salmonid streams. Hence, more powerful land-forming agents were at work then than now, and they inherited land forms they had no role in creating. Adjustments were required to carve suitable streambeds and to develop channel characteristics benefitting salmonids. In terms of man, long time spans were required to create a quasi-equilibrium condition within the stream systems as well as with other systems. Interaction with other systems is demonstrated for small salmonid streams running through forests by the incorporation of fallen logs into the channels, providing additional adjustment to overly steep stream gradients. If not disturbed by man, the interaction between the systems is harmonious, and quasi-balance prevails.

Before I discuss stream systems important for salmonids in detail, let us first look at terrestrial developments from a greater distance. This approach may help us to consider these systems in the context of global evolution, and thus enhance our understanding of their integrated existence. Such a view is of increasing importance in a world of rapid technologic development; an era that is not accustomed to accepting long time spans and is therefore not attuned to the mood of our terrestrial history. In this history, speed was not the driving force; time was plentiful for the attainment of systems that, in and among themselves, represented a harmonious entity. That is not to say that weaker systems did not disappear to make room for stronger ones. But evolution, not catastrophy, was the real driving force toward harmony--a harmony which, for example, allowed waterflows to find their bed and fish their home. In other words, this world was created so that each entity, may it be of physical or biological nature, attained its own niche.

As we learn from paleo-magnetism, the Americas separated from the Euro-Asian and African continents 180 million years ago (Alexander 1975), and geophysicists tell us that the continental plate on which you and I are sitting or standing at this moment, is still moving a few centimeters per year (Carr and Coleman 1974, Irving 1977), an imperceptible distance during our symposium. How very much in agreement is this rate with overall global evolution, and how merciful it is with us human beings.

Evolutionary developments also took place at times we are inclined to judge as catastrophic. I think here of the Ice Ages. There were many ice ages on this globe, but average temperatures dropped by only a few degrees. Ice ages thus developed slowly, and disappeared slowly. This allowed vegetation and animals, and later man, to evade the glaciers and hostile environments. Many plants and animals migrated east and west around the Alps to warmer areas in Europe, and more directly to southern regions in the Americas. Between these ice ages, warming occurred to even tropical conditions to give relief from the impact of hostile environments.

The last ice age ended only 8,000 to 10,000 years ago. It lasted for some 1.5 to 2 million years, and like the former ones, was interrupted by warming periods. In high mountains, glaciers carved wide, U-shaped valleys. On the lowlands, continental ice masses plowed the earth surface, and in areas surrounding the frozen land, increased waterflows put their imprint on the land. Thus, in spite of many millions of years of land-forming processes, it was this last ice age that molded the shape of much of our land. The Pleistocene age, as we call the last ice age, is responsible for the present macro landforms in many regions.

This last statement has implications for salmonid stream systems, since the majority of them are located in mountainous land. If we compare our present mountain streams with the immense landforming agents of the ice age, for

[1]Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-25, 1984.

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example, the glaciers or the large meltwater streams of the warming period, it becomes obvious that the modern streams are comparative dwarfs. These "dwarfs" had to find their bed in an environment not shaped by them but by the large ice agents. Examples of this inherited environment are wide valleys, or narrow incised valleys with steep slope gradients, or tributary valleys not connected with the main valley but ending at a valley side slope where they form so-called hanging valleys. Many small streams could not find a direct connection with the master stream, and thus formed beautiful waterfalls. Insufficient time has elapsed since the warming of the ice age to carve a bed through the valley side slope for a hookup with the master stream.

Mountain streams on wide valley bottoms were in a better position to find a suitable bed than those in hanging valleys. Also, in nearly all cases, the wide valley bottoms left by glaciers were too steep for our small streams to find an equilibrium condition within the inherited environment. These streams had to work for equilibrium; they had to adjust.

Figure 1.--Upstream view of a typical mountain stream meandering on a wide valley bottom.

I should insert here that, because of the relationship between flow energies and sediment loads, the slope gradient of a stream is determined by its sediment load (Heede 1980). Higher loads require steeper gradients and vice versa. Generally, small mountain streams carry only small loads. Therefore, a disequilibrium condition existed because of the inherited steep gradients, and adjustment was required to obtain a balance between stream and valley. As stated before, balance or harmony, is the objective of the evolutionary terrestrial developments to allow coexistence between different systems.

To obtain equilibrium, the wide valley streams adjusted their bed to a lower slope gradient. This could be achieved either by downcutting of the bed in the upstream reaches and by deposition in the lower reaches, or by increasing stream length by meanders. Since the latter type of adjustment takes less energy than downcutting, the streams on wide valley bottoms meander, often like pig tails (fig. 1).

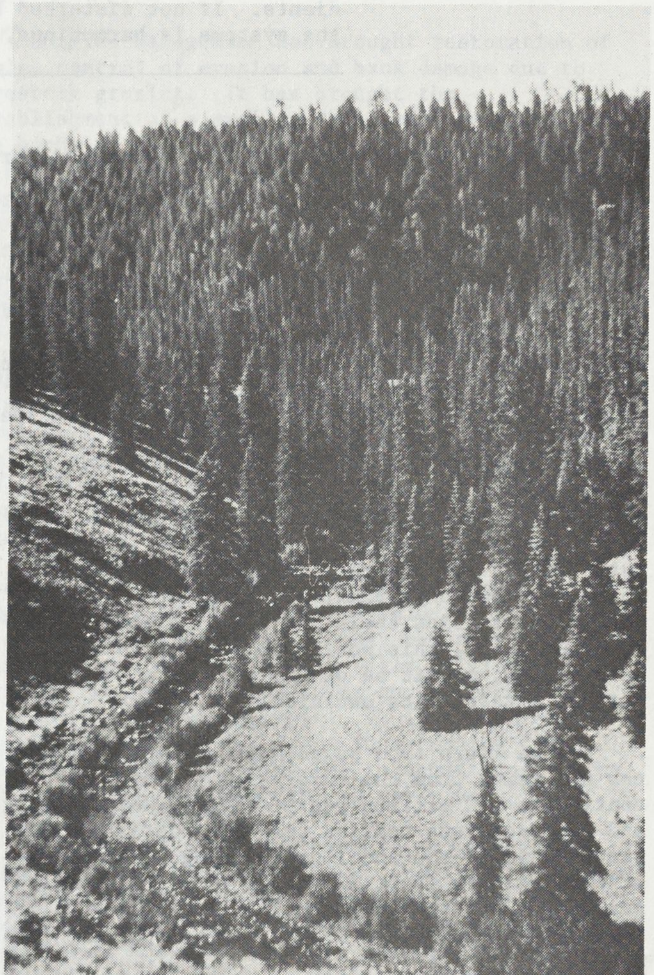

Figure 2.--Narrow valley bottoms and steep sideslopes do not allow the formation of stream meanders, except those created by protruding mountain spurs, as seen in the foreground.

In mountain streams that inherited steep, narrow valley bottoms, types of adjustments are restricted because there is not sufficient bottom width for meanders to develop (fig. 2). These streams are in a "straight-jacket." They are restricted in downcutting, because soils in narrow valleys are usually shallow, and frequently bedrock protrudes on the valley floor. Downcutting to attain a shallower slope gradient would therefore be a Herculean task. This means that channel slope must be adjusted on the existing bed.

Again, we marvel at the ingenuity of nature to find an evolutionary and not a catastrophic solution. By moving gravel and boulders on the bed, which we call bedload movement, bars oriented transverse to the streambed are formed (fig. 3). These are like small dams. Upstream from them, the waterflow is slowed down; at the waterfall over the bars, flow energy is dissipated, and some distance is required before flow energies are regained. Furthermore, the transverse gravel bars break up the original smooth and steep profile of the streambed. A stepped profile is formed. Thus, the water is stepped down from the upstream to the downstream reaches, and the slope gradient is effectively decreased. These processes are so efficient that I found a significant inverse relationship between the distance from bar to bar and the channel slope gradient (fig. 4); the steeper the original slope, the more transverse bars developed and the shorter the distance between them (Heede 1981).

The adjustment processes in V-shaped (narrow) valley streams also create other beneficial effects. We noticed that gravel bars slow water velocities, which leads to sediment deposition upstream from the bars. The depositions have much flatter gradients than the original bed. Flatter gradients cause additional decreases in flow velocities and thus less demand for sediment transport. The impact of the water falling over a gravel bar causes the development of a scour hole below the bar, and water leaving the hole must regain velocity. Where transverse gravel bars are more frequent, these combined developments cause a drastic change in streamflow: a highly turbulent, energy-laden flow becomes a more tranquil one. Thus, a small salmonid stream that inherited an environment out of balance with its essential needs, molded its own bed and, undoubtedly, this ultimately benefitted the salmonids for which it is now host.

When we looked back into terrestrial history, we found that the attainment of harmony between systems, often seemingly unrelated to each other, appears to be the overall objective of global evolution. If we investigate salmonid stream systems in context with other systems, we discover that the global objective of harmony also directed their evolution. Many, if not most, salmonid stream systems are located in forests. We have long known about the beneficial cooling effect of tree canopies for man as well as fish. Only now we know that salmonid stream and forest systems are also interacting within the stream adjustment processes we discussed earlier, and that forests are helping the stream system attain balance with the environment. This aid is in the form of trees and large branches that fall across channels and are incorporated into the stream hydraulics by forming log steps--small dams, if you wish (fig. 5) (Heede 1975). My investigations show that, where log steps are formed, gravel bars are not required. This was demonstrated by the fact that only a few gravel bars existed where many log steps were available, and vice versa. When log steps rot out, they will be temporarily replaced by newly formed gravel bars until other trees fall into the channel, and create new log steps.

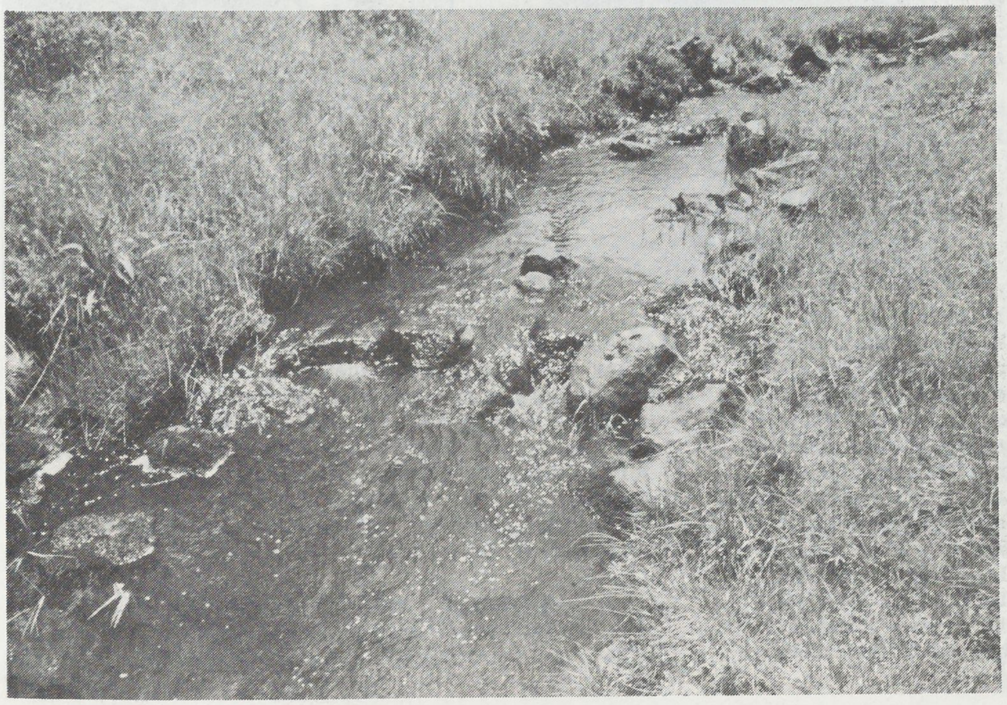

Figure 3.--Upstream view of a transverse gravel-boulder bar.

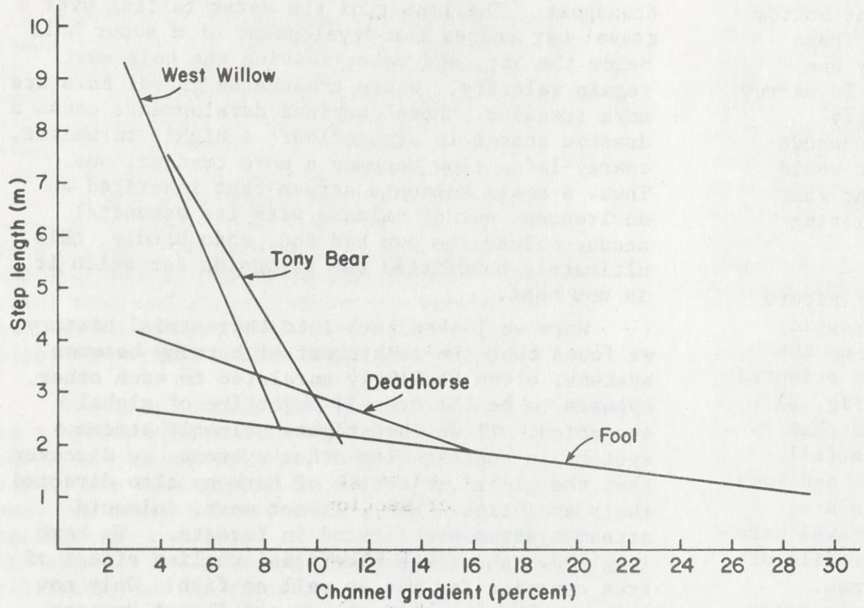

Figure 4.--West Willow Creek and Tony Bear Creek are located in the Arizona White Mountains, while Deadhorse Creek and Fool Creek are Colorado Rocky Mountain streams. All streams show a significant inverse relationship between frequency of transverse bars and channel gradient.

Figure 5.--Upstream view of a fallen tree incorporated into the stream hydraulics and forming a log step. Note the still water upstream from the log step and the flow energ dissipation caused by the waterfall (white water).

Gravel bars are created by the downstream movement of gravel and boulders on the bed. When the large particles move, fine sediment is also set into motion. The fines go into water suspension and hence the flow will carry them downstream into other reaches. At higher sediment concentrations, water quality decreases. Higher concentrations not only may hamper salmonids in finding food (and attractive lures), but may also degrade the fish environment. Thus, log steps decrease sediment transport and aid salmonids by keeping a healthier environment. In this sense, forests form an interactive relationship with salmonids.

In contrast, where streamside forests, or dead and dying trees of streamside forests, are removed, water quality decreases until gravel bars take over the adjustment. Studies in the Pacific Northwest (Sedell and Luchessa 1981) and in northwestern California (Keller et al. 1981) showed that removal of large organic debris, intended for stream improvement, resulted in substantial water quality decreases.

I have shown, in a 5-year experiment in a virgin coniferous forest in which I removed all existing log steps and prevented new ones from forming, that 74% of all removed log steps were replaced by gravel bars.[3] This is a relatively fast development, but we do not know how much more time will be required until a new balance between stream and environment will be attained. The studied stream systems--a control stream was also involved--and the forest systems were not affected by any other management action.

This experiment demonstrated some of the detrimental environment effects man can cause if he does not recognize that natural systems are interwoven. The systems I studied existed in harmony with each other--until I interfered.

Within the salmonid stream system we could differentiate between the biologic system of salmonids and the physical system of the stream. By now, it will not surprise us that the evolution of both systems led to harmony between them--if not disturbed by man. In pursuit of this principle, it is of great interest to evaluate stream dynamic processes in terms of fish biology. Although I am not a fishery biologist, I will make an attempt. While doing this, it appears the more profoundly we investigate, the stronger a certain aspect prevails. What professionals in the hydraulic sciences judge to be consequences of physical developments, adhering to the laws of physics, could also be interpreted as adherence to biologic requirements. Or, if you will, could be judged as adjustment processes between both systems. An example follows:

We discussed stream meandering as a slope adjustment process in salmonid stream systems where valley bottoms are wide. As you know, stream bottoms are not flat or smooth, but topographic undulations are the rule. There is also order in most undulations. In meandering streams, deep water holes, or scour holes, exist where the flow crosses over from one meander into the next, and also where the flow hugs the outside bank of the meander belt. Vertical water circulations, called secondary currents, appear within the meander belt but not outside of it. Hydraulicians try to explain this phenomenon with different variables, but none are sufficient to yield a solid answer. Variable microhabitats result, ranging from deep pools to shallow riffles that possibly are requisite for salmonid survival. We have no scientific explanation of biologic activities of salmonids that could have had a hand in such development, yet without question evolution of the stream towards balance with its environment also benefitted the habitat of salmonids.

In summary, we can state that the evolution of salmonid stream systems, after inheriting an ice age environment that was certainly not made for their needs, was smooth and benefitted streamflow requirements as well as the biological requirements of the salmonids. Forest systems entered actively into the adjustment processes required for the attainment of a harmony between all three systems by delivering trees and branches into the channels. We could extend the number of systems important for, and related to, salmonid systems such as the climatic system. But I believe the three systems considered in this treatise--stream, salmonid, and forest--already show the basic terrestrial trend of development: evolution, not catastrophy. From this, man should learn and understand that natural evolution is slow and deterministic, and that human interference in the relationships among the systems will rupture the harmony. Examples are: cutting of streamside forests, straightening the alignment of meandering streams, or gravelling streambeds with particle sizes in conflict with the hydraulic requirements.

On his short time scale, man cannot create or heal what natural evolution has brought about. More about this and in greater detail will be presented in later sections of this symposium.

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Wild Steelhead Trout Populations in Idaho[1]

Russ Thurow[2]

Abstract. Wild, indigenous steelhead trout populations are unique in Idaho. A small number of drainages have been identified for wild stock production. Fisheries investigations were conducted in the Middle Fork Salmon River to assist management of wild stocks. Considerations for future management of wild stocks are discussed.

INTRODUCTION

Historically, large runs of wild steelhead trout (Salmo gairdneri) returned annually to Idaho's abundant, free flowing rivers. The construction of dams within Idaho has eliminated nearly 3,000 miles of the steelhead trouts' original habitat by totally blocking anadromous runs in the Boise, North Fork Clearwater, Payette, Upper Snake, and Weiser rivers (IFG 1984)

As a result of hydroelectric projects and associated hatchery mitigation programs, only three major drainages (Middle Fork Salmon, South Fork Salmon and Selway rivers) and a small number of mainstem Salmon River tributaries sustain wild steelhead trout populations unaltered by non-indigenous stocks (IFG 1984). These areas have been managed for the production and preservation of wild stocks. The remainder of the states' steelhead waters have been supplemented with hatchery-reared steelhead. Initial, large steelhead hatcheries were constructed in the 1960's.

Annual smolt releases from the Dworshak National and Pahsimeroi River/Niagara Springs hatcheries have increased hatchery steelhead returns. These facilities currently release between 3 and 4 million smolts. Hatchery-reared steelhead currently support most of the statewide steelhead harvest. (Partridge and Pollard 1983)

During the last two decades, dams on the Columbia and Snake rivers have severly reduced survival of migrating Idaho steelhead which currently navigate nine dams. As an example, catastrophic losses of juvenile steelhead occurred during the spring 1973 outmigration, which resulted in a net survival to Bonneville Dam of 4-5% (Raymond 1979). Consequently, escapements of wild steelhead diminished and drainages managed for wild stocks were closed to steelhead fishing. (Middle Fork Salmon River in 1974, Selway River in 1975, South Fork Salmon River in 1968) in an attempt to sustain the wild stocks.

Very little data was available on wild steelhead in the Salmon River drainage so preliminary work was conducted in 1980. From 1981 to 1983 the Idaho Department of Fish and Game conducted an intensive investigation of the Middle Fork Salmon River (Middle Fork).

The work was expanded to the South Fork Salmon River in 1984. Both research programs were designed to evaluate the current status of wild steelhead and to provide information which would assist future management of the steelhead resource.

Specific objectives of the Middle Fork research were to: 1. document principal steelhead spawning areas and assess adult escapements 2. characterize steelhead spawners 3. assess the age class, distribution and abundance of juvenile steelhead 4. genetically characterize steelhead from the Middle Fork and compare them to other Idaho steelhead stocks 5. evaluate the timing and movements of Middle Fork steelhead in the Salmon River drainage 6. assess the harvest of wild steelhead in the mainstem Salmon River sport fishery.

In this paper I will review the status of wild steelhead in the Middle Fork Salmon River (Thurow 1984) and discuss future management considerations for wild steelhead in Idaho.

[1] Paper presented at Wild Trout III. [Mammoth, Yellowstone National Park, September 24,25, 1984.

[2] Russ Thurow is a Senior Fisheries Research Biologist with the Idaho Department of Fish and Game, McCall, Idaho

RESULTS

Habitat

The Middle Fork Salmon River drainage is located in a remote area of central Idaho and for most of its length, lies within the Frank Church River of No Return Wilderness. As a result, most of the drainages and its aquatic habitat lie in a pristine wilderness condition. However, human activity has significantly altered sections of several tributaries. Most habitat degradation has been caused by precious metal mining and excessive grazing by livestock. Efforts are warrented to restore degraded habitats.

Stock Characteristics

The Middle Fork sustains a wild, unaltered stock of steelhead. We found no evidence of dilution by nonindigenous populations. Middle Fork steelhead are an inland stock of summer run fish which migrate nearly 800 miles from the Pacific Ocean. They appear to be most similar to B Stock steelhead which, by definition, pass Bonneville Dam after 25 August and are predominately 2-salt fish. Middle Fork steelhead average 32 to 33 inches and 12 to 13 pounds, ranging to 40 inches and 20 pounds.

Electrophoretic analysis suggests that Middle Fork steelhead are similar to other inland Snake River steelhead stocks. (Wishard and Seeb 1983) Results further suggest that unique, locally isolated steelhead populations exist, as evidenced by heterogeneity among the tributary populations we examined.

Spawning

Tributaries provide the principal spawning areas for steelhead in the Middle Fork. We observed an abundance of suitable habitat in most tributaries. Current escapements of adult steelhead are not sufficient to seed the spawning habitats.

Spawning activity occurred between 15 April and 30 May with most spawners and redds observed between 1 and 20 May. Many of the spawners we observed constructed redds in small (5 yd^2) graveled areas isolated within sections of unsuitable substrate.

Rearing

Young of the year steelhead begin emerging in July. Most steelhead parr rear for two years in the drainage prior to smoltification and a spring outmigration to the ocean.

Tributaries provide the principal rearing habitats for steelhead parr in the Middle Fork. Fewer steelhead parr rear in the mainstem Middle Fork because there is less usable habitat than in tributaries. Habitats with abundant "roughness elements" (boulders, woody debris) appeared to be preferred steelhead rearing habitats.

The Middle Fork drainage could support larger densities of juvenile steelhead with larger adult escapements. Full seeding of rearing areas would ensure maximum smolt production.

Movements

The life history and movements of Middle Fork steelhead are complex and variable. Differences in time of entry into the mainstem Salmon River and seasonal staging are likely influenced by environmental and genetic factors.

A portion of the steelhead destined for the Middle Fork ascend the Salmon River in fall, while the remainder over-winter in the Snake River. Some fish stage in pools below the Middle Fork while some wander widely above and below the Middle Fork. Most wild steelhead begin moving above the South Fork Salmon River after mid September. A segment of the run enters the lower 10 miles of the Middle Fork in fall. Many of the fish which ascend the Middle Fork in fall do not overwinter there but re-enter the mainstem Salmon River. Beginning in March, large numbers of steelhead begin entering the Middle Fork. These fish rapidly ascend the Middle Fork and proceed to spawning streams.

Sport Fishery

Wild steelhead destined for the Middle Fork remain in the mainstem Salmon River for several months prior to ascending the Middle Fork. These fish were formerly susceptible to an intensive sport fishery in which exploitation rates approached 50%. Prior to 1982, anglers were asked to voluntarily release wild steelhead. The program was unsuccessful and nearly 80% of the anglers who caught wild steelhead killed them.

Since increasing numbers of hatchery fish were ascending the Salmon River with wild stocks, a "mixed stock" fishery occurred. Biologists searched for a means of differentiating wild and hatchery fish. Data illustrated that wild and hatchery-reared steelhead could be accurately differentiated based on a 2.25 inch dorsal fin measurement. Approximately 96% of the wild steelhead exhibited a dorsal fin exceeding 2.25 inches and 96% of the hatchery-reared steelhead exhibited a dorsal fin less than 2.25 inches.

In the fall, 1982, the Idaho Department of Fish and Game initiated an innovative regulation based on the dorsal fin measurement. Anglers were allowed to harvest hatchery steelhead and required to release wild steelhead. Initial concerns over excessive handling of the fish have been alleviated somewhat by the ability of most anglers to correctly identify wild fish. The regulation has allowed anglers to harvest a maximum number of hatchery steelhead while releasing wild steelhead to aide the restoration of the Middle Fork steelhead population.

DISCUSSION

It is a goal of fishery managers in Idaho to restore sport fishing opportunities for wild steelhead to the Middle Fork Salmon, South Fork Salmon, and Selway rivers. Restoration of these populations and eventual re-opening of sport angling opportunities will be dependent on three factors:

First, continued regulation of the mixed stock fishery in Idaho and in sections of the Columbia and Snake rivers. Beginning in 1984, all hatchery-reared steelhead will receive an adipose fin clip for ease of identification in the fishery. Regulations which maximize the harvest of hatchery fish while increasing escapement of wild stocks will aide restoration of the populations.

Second, maintenance of abundant, quality habitat for resident and anadromous fish. An aggressive stance is warrented to insure that remaining wild steelhead stocks have access to the best available habitat. Populations will further benefit if corrective measures are applied to restore aquatic habitats which have been degraded.

Third, striving for continued improvements in fish passage through the Snake and Columbia river dam complex. With better smolt survival rates, adult escapements could improve dramatically and accelerate the restoration of wild steelhead populations.

Idaho is fortunate to sustain some remaining populations of wild steelhead. A committment has been made to restore wild stocks in several key areas. Consequently, the Middle Fork Salmon, South Fork Salmon and Selway rivers will continue to be managed for the production and preservation of wild, indigenous steelhead (IFG 1984) These remaining wild stocks are of inestimable value, not only because they are best adapted to local conditions, but also because they offer a variety of management options.

Existing wild steelhead escapements in the Middle Fork are far less than escapements required for full seeding. Consequently, it could be several years before a consumptive fishery is feasible. Fishery managers have the option to consider non-consumptive fisheries until full seeding is attained.

Due to the uniqueness of its wild steelhead stocks, its remoteness, and quality and picturesque habitat, the Middle Fork may lend itself to quality type regulations emphasizing low angler densities.

Our challenge is to maintain wild steelhead stocks for future generations of both anglers and nonanglers.

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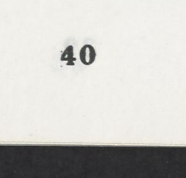

Wild Summer Steelhead Trout in California[1]

Terry D. Roelofs[2]

Abstract.--This paper reviews the current status of wild summer steelhead stocks and their habitats in California. About 3,000 adult fish comprise the average annual escapement. The fish occur almost exclusively in wilderness areas. Both habitat and resource management by federal and state agencies provide protection for these fragile populations.

INTRODUCTION

Summer steelhead (Salmo gairdneri) (fig. 1) share several attributes with the renowned Atlantic salmon (S. salar): their life histories are similar, spending one or more years rearing in streams before migrating to sea where they may range up to thousands of miles from their natal streams; unlike Pacific salmon (genus Oncorhynchus) they can repeat spawn in successive years; their futures are clouded by habitat destruction, and in some instances over-exploitation; and both are prized by anglers for their willingness to strike a fly or lure, as well as for their stamina, speed, and beauty. Summer steelhead, together with the special river systems they depend on, provide a rich legacy of angling tradition on the west coast rivaling that of the east coast salmon streams. Famous summer steelhead rivers include the Klamath, Rogue, North Umpqua, Deschutes, Klama, Stillaguamish, Dean, Kispiox, and Babine Rivers.

This paper describes the current status of summer steelhead stocks in California[3], the southern most populations in North America. While we know much about the current distribution and abundance of these fish in California and elsewhere, there remain large gaps in our knowledge about the life history and habitat requirements of these great gamefish:

> It may not be out of place here to call attention to the well known fact that stream fishing for trout, a major sport in California, is rapidly entering a critical stage. The extension of roads easily negotiated by the automobile, the building of high dams, the netting of steelheads in the rivers, water pollution, the use of water for irrigation, and many other things incident to a rapid growth in population, are causing a marked and sudden depletion in the number of fish. It has been said that intelligent conservation must depend largely on our knowledge of the natural history of the species, and nowhere else is this more applicable. Very often our attempts at conservation serve among other things to bring to the surface our lack of definite knowledge of the habits and life history of the very fish that we are striving to protect. It is to be hoped that active support will be given to the Fish and Game Commission in every effort at careful investigation along this line (Snyder 1925).

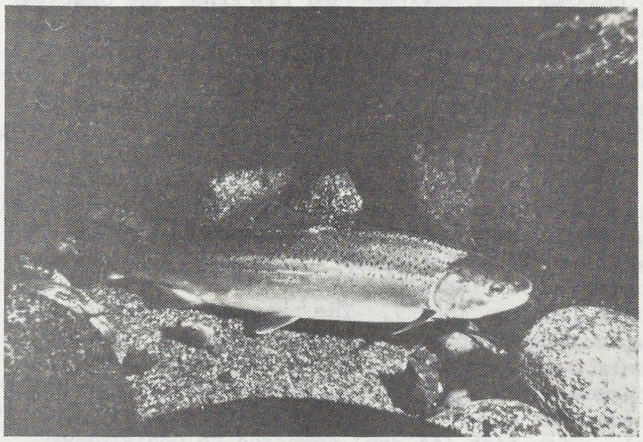

Figure 1.--California summer steelhead trout (photo by Lincoln Freese).

Written nearly sixty years ago, the paragraph above describes too well the problems currently facing summer steelhead in California and elsewhere, as well as would-be managers of these fishes. All of the problems "incident to a rapid growth in population" mentioned by Snyder still impact or

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[1]Paper presented at Wild Trout III Symposium. Yellowstone National Park, September 24-25, 1984.

[2]Terry D. Roelofs is Professor of Fisheries, Humboldt State University, Arcata, Calif.

[3]The California streams that currently have populations of wild summer steelhead in most cases are poorly known to the angling public. In order to protect these fragile populations, I will not be naming these streams in this paper, except for those streams where special angling regulations are in effect to safeguard the fish.

threaten summer steelhead. Our knowledge about their life history and habitat requirements has increased only slightly in sixty years. Many key questions remain unanswered: where and when do these fish spawn ?; what is the relationship, if any, between summer and winter steelhead ?; what is the role of the so-called "half-pounder" (see Kesner and Barnhart 1972; Everest 1973) in the life history of some steelhead populations ?; how can juvenile summer steelhead be distinguished from winter steelhead and resident rainbow trout ?; and so on.

The lack of past records on the distribution and abundance of summer steelhead in California makes it impossible to place the current status of the stocks in any kind of historical context. Descriptions by Snyder (1925) of steelhead in the Klamath and Eel Rivers during late summer and early fall, and mention of a steelhead in a Klamath River tributary in June 1934 by Shapovalov (1935 as cited by Shapovalov and Taft 1954) are among the oldest published accounts. Annual summer steelhead counts of adult fish in the Middle Fork Eel River during the past twenty years and on other streams in recent years, provide information on population trends.

The USDA Forest Service in Region 5 currently classifies summer steelhead as a "sensitive species" in California[4]. This designation reflects the uncertain status of these fishes, and a particular concern about the Middle Fork Eel River population (Dean Carrier, 1983[5]). The present distribution of summer steelhead in California certainly reflects their sensitive nature, with nearly all known populations being found in wilderness areas. Watersheds that are roaded and logged extensively support only a few fish (if any) compared to undisturbed watersheds. Perhaps summer steelhead in California, being at the southern limit of their range, are particularly susceptible to habitat alterations.

[4]In 1984 a Forest Service proposal to drop the summer steelhead senstive species designation was protested by California Department of Fish and Game. The Forest Service countered that with the exception of special angling regulations on the Van Duzen and Middle Fork Eel Rivers, the Department had made little effort to restrict angler harvest of these fish. The Department is now proposing to the California Fish and Game Commission that beginning in 1985 there be a limit of one fish per day greater than 15 inches on all Klamath and Trinity River tributaries (Gerstung 1984[6]). (If adopted, these regulation changes will apply to all Klamath and Trinity River tributaries without identifying those streams containing summer steelhead).

[5]Carrier, Dean. 1983. Personal Conversation. Wildlife Specialist. Region 5, USDA Forest Service, San Francisco, Calif.

[6]Gerstung, Eric. 1984. Personal Conversation. Fisheries biologist. Inland Fisheries Branch, California Dept. of Fish and Game, Rancho Cordova, Calif.

DISTRIBUTION AND ABUNDANCE

Summer steelhead are known to exist in twenty-two northern California streams. As previously mentioned, nearly all of these streams are in wilderness areas (the 1984 California Wilderness Bill providing significant additional protection for several streams). Elton Bailey in an October 6, 1966 California Department of Fish and Game memorandum to E.P. Hughes stated:

> In most instances they [summer steelhead] are found in the more remote areas of certain streams such as ..., Middle Fork Eel River ..., VanDuzen River, etc. Perhaps this remoteness is responsible for their presence just as much as stream conditions.

In 1983 I summarized the distribution and abundance of summer steelhead in California and made recommendations for resource and habitat management in a report to Region 5 USDA Forest Service[7]. The total number of adult summer steelhead counted in all California streams systems in 1980 was about 3,000, with nearly half of these in the Middle Fork Eel River. Only seven streams have average annual counts exceeding 100 adult fish.

Annual adult summer steelhead counts for the Middle Fork Eel River have ranged from a low of 198 in 1966 to a high of 1,600 in 1981 (fig. 2). Large yearly fluctuations primarily are due to hydrologic conditions (floods and droughts). In many years sections of the Middle Fork Eel become intermittent, trapping the adult summer steelhead in large, thermally-stratified pools (fig. 3) where they are vulnerable to legal and illegal angling. Angling closures in the summer holding areas were instituted in 1966 to protect these fish (Jones and Ekman 1980).

STREAM HABITATS USED BY STEELHEAD

Adult Fish

Dunn (1981) and Freese (1982) characterized the pools used by adult summer steelhead throughout the summer and fall in three California streams. Pool volume, pool surface area, presence of ledges, percent of pool bottom covered by gravel, and upstream gradient all influenced the number of adult summer steelhead in thirty-three study pools (Dunn 1981). In another stream studied shade and cover were the significant determinants of fish numbers while there was little apparent relationship existing between steelhead numbers per pool and pool dimensions, upstream or downstream gradient from the pool, or distance to the first downstream pool (Freese 1982). At one time many federal and state agency biologists in California speculated that

[7]Roelofs, T. D. 1983. Current status of California summer steelhead (Salmo gairdneri) stocks and habitat, and recommendations for their management. Unpublished report submitted to Region 5 USDA Forest Service. San Francisco, Calif. 76pp plus appendices.

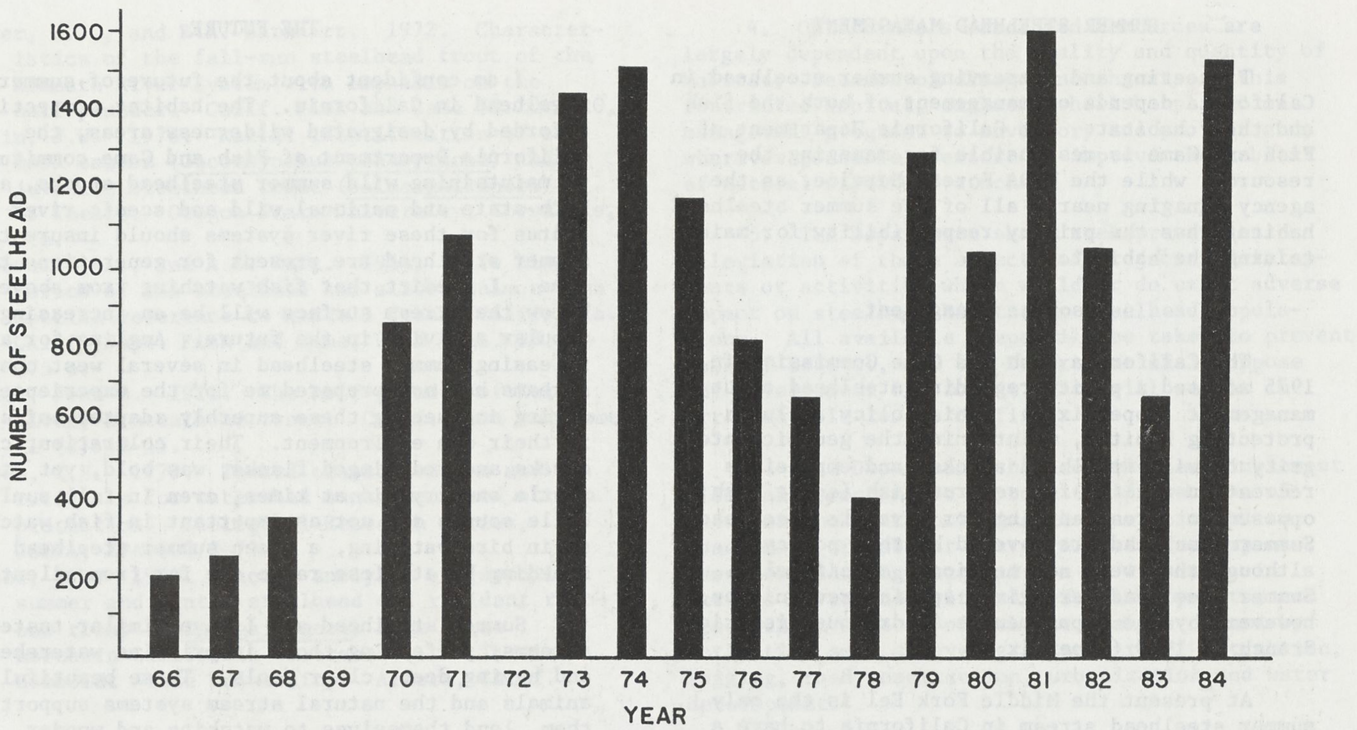

Figure 2.--Number of adult summer steelhead counted in Middle Fork Eel River, 1966-1984. (1966-1980 data from Jones and Ekman 1980; 1981-1984 data from Gerstung, pers. comm.[6]).

summer holding habitat in fact might be limiting summer steelhead in California. It should be noted that there was no indication in either of these studies (Dunn 1981; Freese 1982) that summer holding habitat was limiting to adult summer steelhead.

Little is known about the time and, of particular interest, place of summer steelhead spawning in California. Spawning by summer and winter steelhead in Oregon's Rogue River was separated both in location and time (Everest 1973): summer steelhead spawned an average of two months earlier, and almost exclusively in small, intermittent

Figure 3.--Adult summer steelhead in a Middle Fork Eel River pool, August 1981 (photo by author).

streams. If California summer steelhead also spawn primarily in intermittent streams, our past neglect and abuse of these streams may well explain the current distribution of the fish being limited mostly to wilderness areas.

Past logging practices gave little or no attention to protecting intermittent streams. Many dry streambeds have been used as skid trails, their riparian cover has been stripped, and huge amounts of slash and other debris left in the channel. Finally, road crossings (culverts and temporary bridges) were not designed with fish passage in mind. The end result is that these fragile, small streams have lost their ability to sustain summer steelhead, and some strains of these fish have been lost.

Juvenile Fish

Because of our present inability to distinguish with reasonable certainty individual juvenile fish from the three possible races (summer steelhead versus winter steelhead versus resident rainbow trout) (Martin 1978; Winter 1983), little can be said about habitat preferences or segregation by the various races. If, as is the case in the Rogue River, California summer steelhead spawn earlier and in different areas than winter steelhead, potential competition for rearing area may be avoided or reduced.

SUMMER STEELHEAD MANAGEMENT

Protecting and preserving summer steelhead in California depends on management of both the fish and their habitat. The California Department of Fish and Game is responsible for managing the resource, while the USDA Forest Service, as the agency managing nearly all of the summer steelhead habitat, has the primary responsibility for maintaining the habitat.

Resource Management

The California Fish and Game Commission in 1975 adopted a policy regarding steelhead trout management (Appendix A). This policy includes protecting habitat, maintaining the genetic integrity of wild steelhead stocks, and emphasizes recreation angling for sea-run fish (adult fish as opposed to stream angling for juvenile steelhead). Summer steelhead are covered by this policy, although they were not mentioned specifically. Summer steelhead were given special recognition, however, by the Department's Anadromous Fisheries Branch in 1980 (Appendix B).

At present the Middle Fork Eel is the only summer steelhead stream in California to have a specific management plan designed to protect and enhance these fish. The plan includes angling closures, vehicle restrictions, land management guidelines, and a river patrol started in 1979 to collect biological and physical data, as well as to enforce the angling closures (Jones and Ekman 1980). I recommend that similar stream-specific management plans for summer steelhead be adopted on the other six streams having annual runs exceeding 100 fish.

Stream-specific management plans can address the threats facing certain populations. For example, I share the concern expressed by Freese (1982) that summer steelhead in some Trinity River tributaries are threatened by the activities of gold miners. These threats include: 1) the impacts of fine sediments released and stream channel modifications that accompany operation of portable suction dredges; and 2) illegal harvest of adult summer steelhead.

Habitat Management

Nearly all the remaining summer steelhead habitat in California is within the boundaries of declared wilderness areas. This guarantees protection for these essential stream environments. This is most fortunate, because as Warren (1979) points out, stream physical habitat may require geological time to recover from human-caused alterations, while biological communities require only biological (successional) time. Threatened resources (such as summer steelhead) are best protected by maintaining the entire natural system upon which they depend. Summer steelhead in California appear to have this protection.

THE FUTURE

I am confident about the future of summer steelhead in California. The habitat protection afforded by designated wilderness areas, the California Department of Fish and Game commitment to maintaining wild summer steelhead stocks, and both state and national wild and scenic river status for these river systems should insure that summer steelhead are present for generations to come. I predict that fish watching from above and below the stream surface will be an increasingly popular activity in the future. Angling for and releasing summer steelhead in several west coast streams had not prepared me for the experience of diving and seeing these superbly adapted animals in their own environment. Their coloration, crimson cheeks and red-tinged flanks, was bold, yet still subtle and cryptic at times, even in full sunlight. While sounds are not as important in fish watching as in bird watching, a dozen summer steelhead speeding by at close range are far from silent.

Summer steelhead and I have similar tastes in streams, preferring those in pristine watersheds, and having deep, clear pools. These beautiful animals and the natural stream systems supporting them, lend themselves to watching and wonder. As more people make this connection, people including non-anglers will enjoy California summer steelhead.

ACKNOWLEDGEMENTS

I would like to thank the following people: Gordon Reeves for helping write the first research proposal; Randy Bailey, Willis Evans, and David Gibbons of USDA Forest Service for funding; Eric Gerstung, Wendy Jones, and David Rogers of California Department of Fish and Game for their dedication to protecting and promoting summer steelhead in California; Phillip Dunn, Lincoln Freese, Mitch Lorenz, and Brian Winter, students who dove and walked hundreds of stream miles over three summers; Erica Upton for editing this paper; and finally Delores Neher for typing the paper.

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Appendix A.--The California Fish and Game Commission adopted the following policy on steelhead rainbow trout on August 15, 1975:

1. The steelhead rainbow trout in California is recognized as a valuable resource with strict environmental requirements and a limited range. Steelhead waters include all streams or stream sections accessible to steelhead in the North and Central Coast Regulation Districts and in the Sacramento River drainage above the Delta, and such other waters as the Commission may designate.

2. The greatest fishery value of this resource is its potential to provide recreational angling for sea-run fish. Management shall be directed toward providing such angling and maintaining a vigorous, healthy resource. Angling for juvenile steelhead will be restricted only to the extent necessary to insure optimum spawning stock and angling opportunity for sea-run fish.

3. Resident fish will not be planted or developed in steelhead waters. Resident fish will not be planted or developed in drainages of steelhead waters, where, in the opinion of the Department, such planting or development will interfere with steelhead populations. Programs on threatened or rare and endangered species, within the species natural range, are excepted.

4. California's steelhead resources are largely dependent upon the quality and quantity of habitat. Because of damage and threats to this restricted habitat, emphasis shall be placed on management programs to inventory and protect and, wherever possible, restore or improve the habitat of natural steelhead stocks.

5. The Department shall seek prevention or alleviation of those aspects of projects, developments or activities which would or do exert adverse impact on steelhead habitat or steelhead populations. All available steps will be taken to prevent loss of habitat, and the Department shall oppose any development or project which will result in irreplaceable losses of fish.

6. The Department shall develop and implement plans and programs to improve the protection of steelhead habitat including, but not limited to, assessment of habitat status and adverse impacts, land use planning, acquisition of interests in streams threatened with adverse developments, and research on effects of habitat changes caused by activities such as over-grazing, gravel extraction, logging, road construction, urbanization and water development.

7. The Department shall develop and implement programs to measure and, where appropriate, increase steelhead population size and angler use and success, consistent with the objectives of providing quality angling and maintaining a healthy resource.

8. Artificial propagation of steelhead, except for mitigation, shall be for the purpose of improving angling for sea-run fish, and should include strains or varieties of steelhead which have the greatest potential to contribute to recreational angling. Artificial production or rearing and stocking programs shall be managed so as to produce minimal interference with natural salmonid stocks, and such programs shall be periodically reviewed to assess their effects on these stocks.

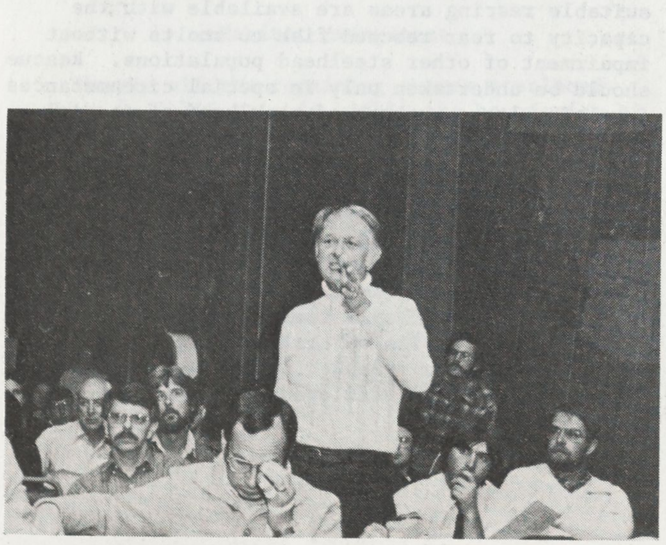
9. Juvenile steelhead rescue shall be limited to instances where habitat conditions are temporarily inadequate to maintain fish life and when suitable rearing areas are available with the capacity to rear rescued fish to smolts without impairment of other steelhead populations. Rescue should be undertaken only in special circumstances involving large numbers of steelhead of special significance.

Item 10 deletes some stream sections from the steelhead waters described in paragraph 1 of the policy, and item 11 allows for the addition of streams or sections thereof.

Appendix B.--The Anadromous Fisheries Branch of the California Department of Fish and Game outlined the following intentions regarding spring-run (summer) steelhead in a report of March 31, 1980 to the State Fish and Game Commission:

It is the intention of the Department to maintain identifiable native spring-run steelhead populations, to preserve the genetic integrity of the populations, and where feasible, to restore certain of these populations to levels capable of supporting significant summer fisheries.

It is also the intention of the Department to provide and maintain summer steelhead fisheries, using artificial rearing programs, in certain California waters which contain no wild, native spring-run steelhead populations.



The Department intends to continue efforts to identify wild native stocks and to monitor their abundance.

To help protect the genetic integrity of wild, native spring-run stocks, the Department will avoid the future planting of spring-run exotics in the Klamath River system, the Eel River system, and other waters found to support distinct wild native populations.

The future planting of artificially-reared spring-run fish in areas supporting native populations will be limited to the endemic strains, and will be done only when other management measures are judged to be impractical or ineffective.

PANEL: Where the Trout Are[1]

Bruce Shupp[2]

The seven panelists and I have been trying to relate the title of our panel to the reality of their presentations. In the broadest sense, the title could be, "Why the Trout Are Where They Are or Where They Will Be," because this panel is going to discuss trout management--the cause of trout being where they are.

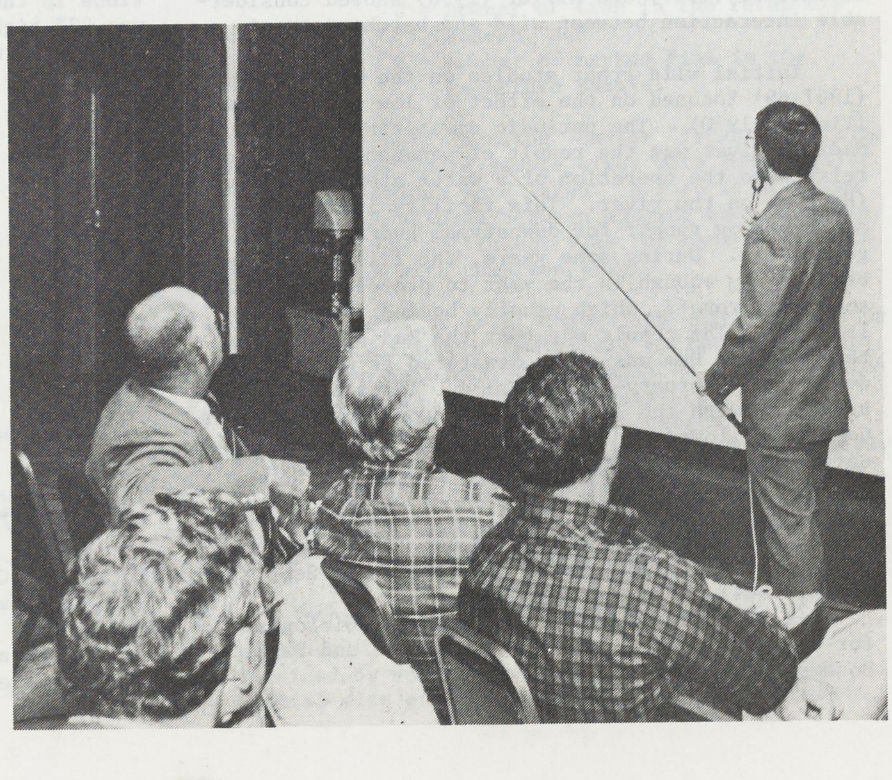
Our first four papers review statewide trout management programs in Missouri, California, Washington, and Pennsylvania. They include approaches to both improve wild trout management or simply to provide "trout" angling.

We have a fine paper describing effects of using a slot-length limit to rectify growth problems of a wild trout fishery in the AuSable River, Michigan.

Finally, we will enjoy two papers which, on the surface, appear to have conflicting results from detailed evaluations of competition between wild and hatchery trout in Montana and Idaho. This should lead to some interesting questions and challenges!

Five of the seven papers have a very strong common theme--reshape anglers' philosophy about, and use of, wild trout angling and wild trout management. In some cases, the results of the transformation attempts have been less than gratifying.

All of these seven papers certainly reflect the positive influence of "Wild Trout I and II" in generating interest and enthusiasm among managers and scientists to improve wild trout populations through enlightened management. We look forward to "Wild Trout IV" and the progress achieved between now and then.



[1]Discussion leader's introductory remarks of the Session Where the Trout Are at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24, 1984.

[2]Bruce Shupp is Chief, Bureau of Fisheries, New York Department of Environmental Conservation, with offices located at Albany, NY.

Effect of Stocking Hatchery Rainbow Trout on Wild Stream-Dwelling Trout[1]

E. Richard Vincent[2]

The purpose of this study was to determine what effect, if any, long-term stocking of catchable-sized hatchery rainbow trout had on a resident, stream dwelling, wild trout population. The cessation of stocking in the Varney section of the Madison River in 1970 after 15 consecutive years of stocking resulted in a 162% and 133% increase in two-year-old and older wild brown trout numbers and biomass, respectively, and a 809% and 1,016% increase in the number and biomass of two-year-old and older wild rainbow trout, respectively. It took two years of no stocking to fully expand the wild brown trout population and at least four years for the wild rainbow.

INTRODUCTION

The use of catchable-sized (8-12 inch) hatchery rainbow trout to supplement existing wild, stream-dwelling trout populations has been an accepted fisheries management practice. Hatchery trout were stocked in streams either to increase angler catch rates or to maintain trout numbers where wild trout were perceived to be below carrying capacity. In using hatchery-reared trout to supplement wild trout in streams, little concern was given to the impact(s) stocking had on existing wild trout populations, although investigators such as Shetter (1947) and Miller (1958) showed considerable interaction between wild and hatchery trout.

Initial wild trout studies on the Madison River (1967-69) focused on the effect of low stream flows (Vincent 1970). The periodic dewatering of the Madison River was the result of management practices related to the operation of a water storage reservoir (Hebgen) on the river. This facility is used to store spring runoff for downstream hydroelectric generation. During some years, the filling process began early enough in the year to precede significant snow melt runoff, which usually begins in mid to late May. The result was that the Madison River below Hebgen Dam was often dewatered as much as 50% during the February-April period. In late 1967, an agreement with the local dam operator (Montana Power Company) allowed for the delaying of the Hebgen fill until runoff was sufficient to keep flows above natural December-April levels. Using wild trout population estimates from two study sections on the Madison River below Hebgen Dam, the estimated total biomass of two-year-old and older brown and rainbow trout was compared with the minimum mean monthly flows for the December-April period (fig. 1). Spring (March-April) estimates from the Norris section show that as the minimum mean monthly flows increased, the total pounds of wild trout increased. However, estimates from September for the Varney section showed no biomass increases for the 1967-69 period. Factor or factors other than the minimum flow must have been controlling wild trout populations in the Varney section. Since angling pressure was 22% higher for the Norris section, the over-harvest of wild trout was ruled out as one of the

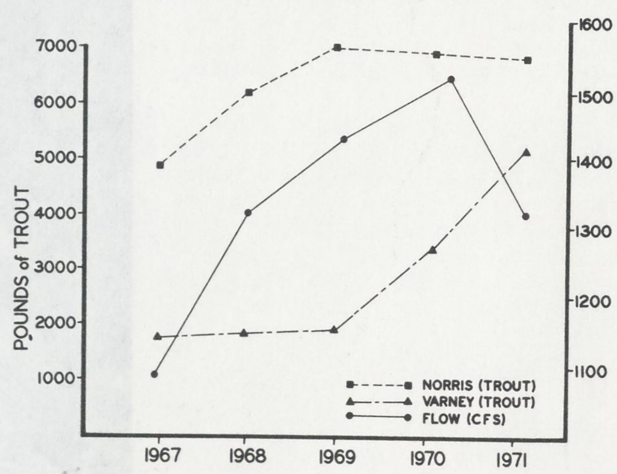


Figure 1. Comparison of total two-year-old and older wild trout biomass (lbs.) between the Norris and Varney study section on the Madison River and minimum mean monthly discharge (cfs) for the December-April period.

[1]Paper presented at Wild Trout III Symposium (Yellowstone National Park, Mammoth, Wyo., Sept. 24-25, 1984).

[2]E. Richard Vincent is a Fisheries Biologist for the Montana Dept. of Fish, Wildlife and Parks, Bozeman, Montana.

factors (Vincent 1969). One major difference was that catchable-sized hatchery trout (8-12 inches) were being stocked in the Varney section (1955-69) while no stocking had occurred since 1960 in the Norris section.

The purpose of the wild trout-hatchery trout study was to determine what effect, if any, the stocking of catchable-sized hatchery rainbow trout had on a wild trout population in a stream environment. Primary objectives of the study were: (1) to determine if changes occurred in wild trout numbers when stocking occurs and (2) to determine which sizes of wild trout would be the most affected.

DESCRIPTION OF STUDY AREA

The Madison River originates in Yellowstone National Park at the junction of the Gibbon and Firehole Rivers, entering Montana through the northwest corner of the Park. Upon entering Montana, the river flows approximately 120 miles in a northerly direction before joining the Gallatin and Jefferson Rivers to form the Missouri River (fig. 2).

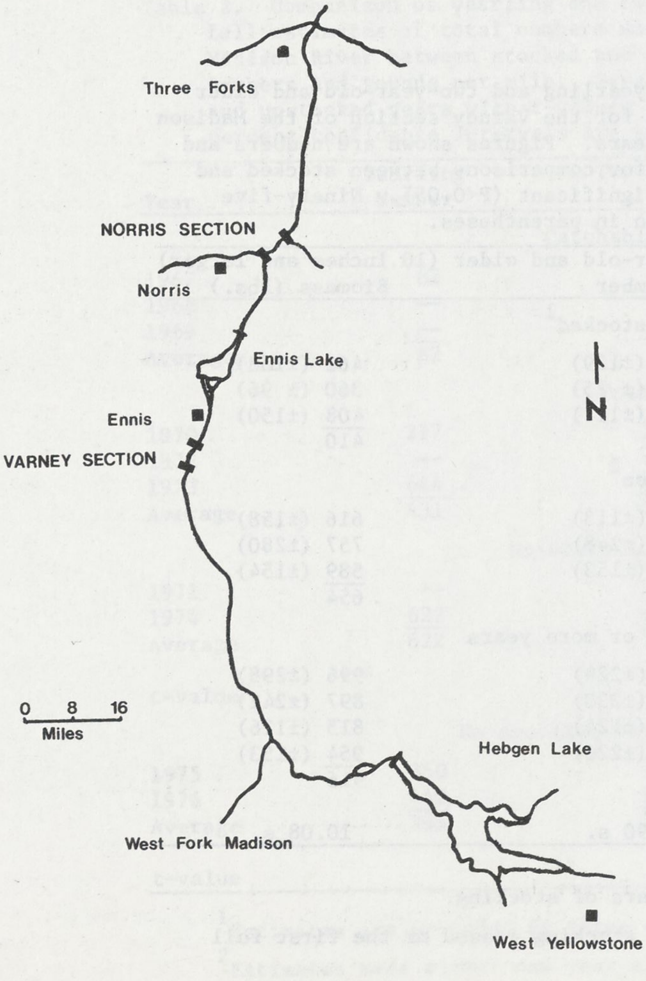


Figure 2. Map of the Madison River drainage and study sections.

The primary gamefish in the Madison River are brown trout (Salmo trutta) and rainbow trout (Salmo gairdneri) which were introduced more than fifty years ago and have been perpetuating themselves through natural reproduction. Little additional stocking occurred prior to 1948. From 1948 through 1954, stocking was limited to subcatchable-sized (2-5 inch) brown and rainbow trout originating from wild stocks taken in spawning traps. The first catchable-sized rainbow trout of hatchery origin were planted in 1955.

The four-mile Varney study section is located on the Madison River approximately 51 miles downstream from Hebgen Dam. Here, the river has a predominately braided channel with long riffles interspersed with fast runs and a few pools. Stream gradient averages 30 feet per mile. In this reach, the average annual discharge is approximately 1,400 cfs, with peak flows in June of near 5,000 cfs and low flows near 900 cfs during the December-April period (U.S.G.S. 1967-75). This study section was stocked with 1,200-1,600 catchable-sized rainbow trout annually from 1955 through 1969. Stocking was officially discontinued in 1970. However, an unauthorized plant of an unknown quantity of catchables occurred in 1972. From 1973 to the present no stocking has occurred.

METHODS

Wild trout population estimates were made in the fall (Sept.) for each year from 1967 through 1976 using a Petersen mark-and-recapture method with the following adaption of Ricker's (1958) formula number four:

$$N = \frac{(M+1)\ (C+1)}{R+1} - 1.$$

where: N = population estimate,
M = number of fish marked,
C = number of fish in the recapture sample, and
R = number of marked fish in the recapture sample.

Two or more "marking" and/or "recapture" trips were required where sample sizes were small and/or trout populations were large. A 7 to 14 day time interval was allowed between marking and recapture trips to allow sufficient time for marked trout to randomly mix with unmarked trout.

Estimates of total number and weight were made through summation of individual estimates made for size groups selected on the basis of uniform catchability and adequate marked recaptures (Vincent 1971). Ages of wild trout were determined from scale samples taken during electrofishing. Hatchery trout were identified by presence of eroded dorsal, pelvic and pectoral fins. Confidence intervals at the 95% level were calculated for total number and weight using the following formula:

$$\text{C.I.} = \pm 2 \sqrt{\text{variance}}$$

Variance for the total number and weight were obtained by summing variances computed for each initial size group using Seber's (1973) formula:

$$\text{Variance} = \frac{(M+1)\ (M-R)\ (C+1)\ (C-R)}{[(R+2)\ (R+1)]^2}$$

Wild trout were sampled through the use of electrofishing gear mounted in a fiberglas boat. The boat contained the following: (1) a stationary negative electrode fastened to the bottom of the boat, (2) a mobile positive electrode, (3) a portable 2,500 watt AC generator with a rectifying unit which converts alternating current to direct current, and (4) a live box to retain captured fish. Captured fish were weighed to the nearest 0.02 lbs., measured to the nearest 0.10 inch, marked with a partial fin clip and then released into the study section.

The student t-test was used to test null hypotheses of no difference between stocked and unstocked years using means of total number and weight. Normal distributions were assumed in all comparisons. In no instance were t-tests used where a heterogenous variance was detected as determined by the F-test (Snedecor 1956). All levels of significance were at $P \leq 0.05$.

RESULTS

Brown Trout

Fall brown trout population estimates showed immediate increases in the number of two-year-old and older trout following the first summer no catchables were stocked (table 1). After two consecutive years of no stocking, the number of two-year-old and older browns had increased 141% over the 1967-69 stocking years' average. Upon stocking of catchables again in 1972, the number of two-year-old and older declined 12% with total biomass declining 24% over 1971 levels. With the cessation of stocking in 1973, wild brown trout numbers again increased to 1971 levels in two years.

Fall brown trout population estimates were placed into three categories based on the length of time from the last years of stocking or no stocking. The categories are: (1) catchables stocked - where stocking had occurred for at least two consecutive years prior to the estimate, (2) transition - where only one year of either stocking or no stocking preceded the estimate, and (3) no stocking - where at least two consecutive years of no stocking preceded the estimate. Comparison of fall estimates for two-year-old and older brown trout show both numbers and biomass to be significantly different between stocked and unstocked years with unstocked years averaging 156% higher in numbers and 123% more in biomass. The averages of biomass and numbers for transition years lie between those of stocked and unstocked years with differences from stocked years significant.

Table 1. Comparison of fall estimates of yearling and two-year-old and older brown trout numbers and total biomass for the Varney section of the Madison River between stocked and unstocked years. Figures shown are numbers and pounds per mile. T-values are shown for comparisons between stocked and unstocked years with t-values >2.57 significant ($P<0.05$). Ninety-five percent confidence intervals are shown in parentheses.

Year	Yearling Number	Two-year-old and older (10 inches and larger) Number	Two-year-old and older (10 inches and larger) Biomass (lbs.)
	Catchables stocked[1]		
1967	395	355 (±129)	462 (±168)
1968	1,060	280 (± 75)	360 (± 96)
1969	788	317 (±117)	408 (±150)
Average	748	317	410
	Transition[2]		
1970	997	439 (±113)	616 (±158)
1972	753	670 (±248)	757 (±280)
1973	902	587 (±153)	589 (±154)
Average	884	565	654
	No stocking for two or more years		
1971	924	764 (±229)	996 (±298)
1974	1,003	851 (±230)	897 (±242)
1975	1,209	799 (±124)	815 (±126)
1976	1,969	831 (±220)	954 (±153)
Average	1,276	811	916
t-value	1.69 n.s.	17.90 s.	10.08 s.

[1]Estimates preceded by two or more years of stocking.

[2]Estimates made either one year after stocking ceased or the first fall after stocking began.

Yearling brown trout numbers appeared not to be affected by the stocking of catchables and no significant differences could be detected between stocked and unstocked years, although unstocked years averaged 71% higher than stocked years. Most of this difference was due to low numbers of yearling brown trout estimated for Sept., 1967. It appears that the yearling brown trout numbers relate more to previous Dec.-April water flows than to stocking. The lowest yearling number for the 1967-71 period corresponded to the lowest mean monthly flow for the same period.

Rainbow Trout

Fall wild rainbow trout population estimates showed immediate increases in the number of two-year old and older fish following the first summer of no stocking in 1970 (table 2). After two years of no stocking, the number had increased 332% over the 1967-69 stocking years' average. The 1972 stocking of catchables resulted in a 63% decline in wild trout numbers over 1971 levels. When stocking again ceased in 1973, the wild rainbow trout numbers again began to increase. By 1976, two-year-old and older numbers had increased 809% with total biomass increasing 1,016%.

Since wild rainbow trout populations did not stabilize even after four years of no stocking, it was necessary to separate estimates into four categories based on the length of time from the last year of stocking or no stocking. They are: (1) catchables stocked - where stocking had occurred for at least two consecutive years prior to the estimate, (2) transition - where only one year of either stocking or no stocking preceded the estimate, (3) no stocking for two consecutive years, and (4) no stocking for at least three consecutive years prior to estimate. Significant differences in total number and weight of two-year-old and older rainbow trout are shown between the stocking years and both categories of no stocking. Fall yearling numbers appeared to be depressed by stocking although lack of estimates during some years made statistical evaluations impossible.

DISCUSSION

The introduction of hatchery-reared, catchable-sized rainbow trout into resident wild trout populations in the Madison River caused a significant decline in the number of larger sized wild trout. The degree of decline varied by species and the number of consecutive years catchables were stocked.

Table 2. Comparison of yearling and two-year-old and older wild rainbow trout fall estimates of total numbers and biomass for the Varney section of the Madison River between stocked and unstocked years. Figures shown are numbers and pounds per mile. T-values are for comparisons between stocked and unstocked years with t-values >3.18 significant ($P<0.05$). Ninety-five percent confidence intervals are shown in parentheses.

Year	Yearling Number	Two-year-old and older (10 inches and larger) Number	Biomass (lbs.)
		Catchables stocked[1]	
1967	82	35 (± 22)	29 (± 18)
1968	--	92 (± 65)	96 (± 68)
1969	--	67 (± 40)	66 (± 47)
Average	82	65	64
		Transition[2]	
1970	217	231 (± 95)	210 (±104)
1972	--	105 (± 43)	135 (± 58)
1973	644	114 (± 47)	131 (±108)
Average	431	150	159
		No stocking for two years	
1971	--	281 (±104)	296 (±104)
1974	622	434 (±166)	322 (±107)
Average	622	358	309
t-value		4.79 s.	9.14 s.
		No stocking for three or more years	
1975	350	727 (±174)	569 (±136)
1976	440	591 (±269)	714 (±325)
Average	395	659	642
t-value		10.80 s.	9.71 s.

[1] Estimates are preceded by three or more years of no stocking.

[2] Estimates made either one year after stocking ceased or the first fall after stocking began.

Other investigators have also shown decreases in wild trout numbers when stocking of hatchery fish occurred. McMullin (1982) found that when the stocking of catchables was discontinued in the Big Hole River in 1974, wild brown and rainbow trout numbers increased 83 and 325%, respectively, over a six year period. Here, as in the Madison River, brown trout experienced the quickest recovery rate (two years) and rainbow trout the slowest (four years or more). Bachman (1982) found that when hatchery brown trout were stocked into a section of Spruce Creek, Pa., the previously stable wild brown trout population declined to levels below any previously observed. Thuember (1975) found that the number of wild brook trout nearly doubled in the North Branch of the Pike River and K. C. Creek, Wisc., when stocking of hatchery trout ceased. Snow (1974) reported that when hatchery northern pike were stocked in Murphy's Flow, where wild populations of northern pike existed, wild northern pike numbers declined, especially those exceeding 26.0 inches.

The actual mechanism(s) which cause the decline in wild fish numbers after hatchery fish are introduced is not totally understood, but there is some suggestion that disruption of the stable wild fish social structure may be a major factor. McLaren (1979) found that hatchery reared trout, when placed in a semi-natural stream environment, were more active, fed more frequently and exhibited a greater antagonistic behavior than the resident wild trout. Bachman (1982) showed that this elevated antagonistic behavior of hatchery trout disrupted the stable wild trout social structure, creating lengthy antagonistic encounters with resident wild trout which resulted in some exhaustion of the wild brown trout. The added stresses of increased social interaction and temporary over-crowding eventually leads to losses of the hatchery trout, as well as abnormal losses of resident wild trout.

The practice of using hatchery trout to supplement wild trout populations in streams has several serious drawbacks. One is the actual reduction of the number of larger wild trout available to the angler. Another is the expense of raising and stocking large numbers of catchables. Another even less studied effect is the possible genetic alteration of the wild trout through either interbreeding of wild and hatchery trout or the indirect selection of wild trout tolerant to the presence of hatchery trout. Kruegar and Menzel (1978) found that the long-term stocking of nine brook trout streams in Wisconsin altered the genetic makeup of the resident wild brook trout. Correlations were noted between the number of years a stream was stocked and the degree of genetic alteration. It was felt that these changes were not due to interbreeding, but selective interaction between the wild and hatchery trout. This may offer even more long-term problems for the wild trout than the direct losses described in this study. Management of trout fisheries in streams would be better directed to maintaining or enhancing stream habitat, maintaining adequate water flows and good water quality and when necessary enacting more restrictive angling regulations.

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Wild Trout Management in the Keystone State[1]

Delano R. Graff[2]

Abstract.--Wild trout management in Pennsylvania is based on criteria established after a statewide survey and inventory of trout waters. Wild trout waters were selected, stocking of these streams terminated, and special management options developed. Most angler concerns about and resistance to wild trout management were based on loss of traditional stocking and changes in special regulations which permitted artificial lures in programs previously limited to fly-fishing-only.

Trout management has been a part of fishery conservation in the Keystone State--Pennsylvania--for a very long time. The first state trout hatchery opened in 1873 and the first minimum length limit for trout was established nearly 80 years ago. Given such a long standing tradition of interest in trout management, one might reasonably assume that Pennsylvania has an old and well established wild trout management effort. That would be a reasonable but quite wrong assumption. Pennsylvania's first statewide wild trout management program went into effect on January 1, 1983. The development and implementation of this program has been accomplished; evaluation is yet to come. My purpose is to provide a description of wild trout management in Pennsylvania, including what preceded it; what resource supports it; some of the problems, disappointments, and rewards of developing wild trout management; and what we, who are involved in fisheries management decisions, see as the future of Pennsylvania's wild trout management.

The traditional approach to trout management in Pennsylvania was to concentrate on habitat protection and on the use of hatchery trout to provide recreation. The use of special regulations was widespread, primarily in response to social preferences of fly fishermen and on hatchery trout supported fisheries. Years and years of emphasis on trout stocking coupled with attendant publicity and promotion of the trout stocking program had produced a widespread expectation of and dependence upon trout stocking as the key to good angling. The allocation of hatchery trout was a matter of great interest to many sportsmen. Hatchery trout were allocated to counties; the percentage of total hatchery production that went to any particular county was calculated using a formula involving license sales, public land and water, and population of each county. There were some limits on the number of trout stocked per acre in any given water, but, essentially, the allocation of hatchery trout was based on a "county quota system" which gave no consideration to the quality of trout habitat within a county--as long as a water area met certain minimum criteria, it was stocked. This approach resulted in some fine wild trout streams being stocked in the same manner, at the same rate and frequency, as marginal trout waters of similar size. The county quota system also created a class of anglers/statisticians who annually compared county quotas and current year and past years' stockings to be sure they got their "fair share" of hatchery trout. When wild trout management was proposed in 1982, a number of anglers voiced concern over the loss of stocked trout in their favorite stream. This concern was expected and reasonable given the circumstances under which most of our anglers had been fishing for many years.

Pennsylvania's special regulations program for trout was, historically, closely tied to use of hatchery trout and to the tackle preferences of fly fishers. A few specially regulated streams--the Letort, Penns Creek, and Big Spring, for example--were managed for wild trout, but most were stocked. Fly-fishing-only and fish-for-fun areas made up most of the specially regulated areas on trout streams; both programs were developed around social objectives and utilized hatchery trout (some of the fish-for-fun areas were stocked as often as five times a year).

Prior to the implementation of resource-based fishery management in Pennsylvania we had a general angling public that was conditioned to associate good trout fishing with stocking of hatchery trout. We also had a user group that preferred specially regulated waters, a group that was accustomed to programs that were based on hatchery trout and developed around the tackle preferences of fly fishers. What people were used to and resistance to change were to be major factors in gaining public acceptance for wild trout management.

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The development of wild trout management in Pennsylvania was only one aspect of a major change in agency philosophy toward fishery management. The goal was to shift from a socially determined approach to fishery management to management which reflected both resource and social factors--essentially, management by resource category. This new approach to fishery management was designated Operation FUTURE (Graff 1982). Operation FUTURE was officially launched in 1981, but the beginning of Operation FUTURE and of wild trout management was established as early as 1976.

In 1976 the Pennsylvania Fish Commission embarked on a five year effort to survey all stocked trout waters in the Commonwealth. We would have preferred to do all trout waters; however, in the early stages of planning the statewide survey, it was determined that Pennsylvania might have as many as 10,000 miles of streams that could, in one way or another, qualify as "trout water," with the best of these streams supporting good populations of wild trout and the poorest having no wild trout but considered suitable for trout stocking. Since most of the unstocked trout waters were either small, headwater streams or in private ownership with public access denied, it was decided to survey all stocked waters and to develop a statewide system of resource categories upon which to base management decisions (Graff 1978).

In the very early stages of the statewide survey and inventory, it became apparent that Pennsylvania had a surprising number of streams supporting reproducing trout populations. It was also apparent that trout populations under special regulations varied from quite good in streams such as the Letort or Penns Creek to really poor in other areas where "fish-for-fun" areas had been established on streams that simply were not good trout water. At the same time, public interest in fish-for-fun areas was high and requests for expansion of the program were being made by anglers. At this point the Commission decided that it would be inappropriate to encourage or permit expansion of "fish-for-fun" as a socially oriented, hatchery trout supported program if--as evidence suggested--such regulations were better used as a wild trout management tool. Staff suggested that the entire special regulations program might be improved if biological objectives replaced social objectives. Consequently, a moratorium was declared on the establishment of new special regulations areas until resource data could be analyzed and new management objectives developed. This moratorium and the new approach to use of special regulations under resource-based management became one of the most controversial, emotional, and, to staff involved, disillusioning aspects of the entire experience of implementing wild trout management.

By 1978 there were sufficient data in hand to begin preliminary program development. Wild trout management options were not developed at this time, but we had made one major decision. No matter what combination or choice of regulatory tools might be used to manage wild trout streams, one management approach would be uniformly applied to all streams designated as "wild trout water": NO STOCKING. The agency began to prepare the angling public for this possibility by statements in a variety of public releases. A typical release was:

> "The Fish Commission needs angler support for acceptance of new trout management programs designed to achieve 'quality' by recognizing the value of wild trout. In some cases this may involve fish-for-fun or lure restrictions. It will definitely mean the end of stocked trout in some pretty popular streams." (Graff 1978)

Despite efforts to prepare anglers for a change in traditional stocking techniques, the cessation of stocking in what had long been heavily stocked waters proved to be one of the most difficult aspects of introducing wild trout management in Pennsylvania.

In 1982 it all came together. The resource survey data were available and analyzed, management programs were developed, and it was time to "go public." The public we were going to included people who were primarily interested in what was going to happen to their favorite stream--would it be stocked or wouldn't it be stocked?--and people who were interested in what, if any, proposals were forthcoming relative to use of special regulations. Total public concern went well beyond wild trout and special regulations for wild trout management, but the bitterest and most emotional response certainly centered on the combination of wild trout and special regulations.

A statewide trout management program was developed through analysis of information collected from nearly 1,900 stream sections and the creation of resource categories. One of the resource categories was "Class A" wild trout water. In establishing this resource category, it was necessary to answer two questions:

1. What is the definition of "wild trout" and "wild trout water"?

2. What management procedures are necessary to best manage for wild trout?

Seeking a definition of "wild trout" may seem strange for an agency charged with responsibility for fisheries management, but in the first symposium on wild trout it was made clear that "the beginning point in wild trout management is defining a meaning or meanings for the term 'wild trout'" (McNall 1975). In Pennsylvania a wild trout is, by definition, a stream-bred (naturally reproduced) trout. That seems simple enough, and it is. It provides a firm and clear definition and a basis for future management decisions.

The definition of "wild trout water" was not as simple. The mere presence of a naturally reproducing population of wild trout is not, for management purposes, sufficient to classify a stream as "wild trout water." A rather high percentage of streams examined during the statewide survey had some wild trout but generally too few to support a good fishery. It was decided to select only those streams that were clearly among Pennsylvania's best--in terms of wild trout populations--as "wild trout waters." In this way we were not only assured that proper recognition and management would be given the truly exceptional streams, but also even the most adamant opponent of wild trout management would have to agree that the selection had been careful, conservative, and clearly limited to waters where standing stocks of trout substantiated the claim that there were sufficient wild fish to sustain a fishery.

Waters identified as candidates for wild trout management all meet certain standards. Class A wild trout waters in Pennsylvania include all brown trout and mixed brook/brown trout waters supporting at least 40 kilograms/hectare (36 lbs/acre) of naturally reproduced trout and all brook trout waters supporting at least 30 kilograms/hectare (27 lbs/acre) of naturally reproduced trout. Other factors are considered in making final determinations, an example being stream width. Stream width classes used in making management determinations start at less than 4 meters and extend to greater than 30 meters or, roughly, less than 12 feet wide to more than 90 feet wide. The reason for considering width is obvious. A stream 30 feet wide offers a lot more fish and fishing per mile than one 10 feet wide even though both have the same rating in terms of trout per hectare. The important part of identifying waters for wild trout management is that the selection was based on a large number of samples of streams across Pennsylvania. Those streams selected for wild trout management constitute only 5% of all sections surveyed for brown or brook/brown trout populations and only 7% of the brook trout waters surveyed. The miles of streams involved in the wild trout management program come to about 5% of the total mileage of streams managed for trout. This small percentage of the Keystone State's total trout fishery is something special, something of exceptional value, and deserving of exceptional management.

The exceptional management options developed for Keystone State wild trout range from a basic program of no stocking with no other changes in state regulations or normal habitat protection to a program of lure restriction and zero harvest. The array of options selected for wild trout management includes:

BASIC WILD TROUT MANAGEMENT

The basic wild trout management program is intended to provide anglers with an opportunity to catch and harvest (if desired) wild trout from a population totally supported by natural reproduction. The basic wild trout option is proposed for stream sections which support populations of brown trout, brook trout, or mixed brook/brown trout capable of providing a fishery without stocking, but which may have limited potential (perhaps due to stream size) to produce an obvious biological response to the application of special regulations.

Biological objectives under this option are:

1. Protection of wild populations from effects of stocking.
2. Protection of wild populations from excessive harvest.

Regulations applied under this option are:

Minimum size limit:	Normal "statewide" size limit of 7 inches.
Creel limit:	Normal "statewide" creel limit of 8 fish daily.
Season:	Opening day to Labor Day. Extended season with reduced creel where applicable under current policy.
Gear/lure restriction:	None, normal "statewide" regulations apply.

WILDERNESS TROUT STREAM MANAGEMENT

Emphasis in this program is on the provision of a wild trout fishing experience in a remote, relatively natural, and "unspoiled" environment. The wilderness trout streams program, officially established in April 1969, is designed to protect and promote native trout fisheries, the ecological requirements necessary for natural reproduction of trout, and wilderness aesthetics. The superior aesthetic quality of these watersheds is considered an important part of the angling experience; and remote areas, where an individual can go to find a degree of relative solitude, are a valuable and necessary part of the life of modern man.

Biological objectives include:

1. Protection of wild trout fisheries in remote areas from the impact of human development, including industrial development, road construction, impoundments, and introduction of nonresident fish species.

Regulations applied under this option are:

Minimum size limit:	Normal "statewide" size limit of 7 inches.
Creel limit:	Normal "statewide" creel limit of 8 fish daily.
Season:	Opening day to Labor Day. No extended season.
Gear/lure restriction:	None, normal "statewide" regulations apply.

LIMESTONE SPRINGS TROUT MANAGEMENT

The limestone springs trout management option is an effort to provide anglers with an opportunity to fish in a traditional manner in recognition of the unique value and aesthetic qualities of limestone spring runs. Limestone spring runs, originating almost always in one or a few limestone springs rather than from headwater seeps or tributaries, constitute an important part of Pennsylvania's trout angling heritage. Those sections of spring runs that still maintain substantial wild trout populations merit special management and consideration, not only as valuable trout habitat but also in recognition of the importance such runs have gained in the traditions and values of fly fishing.

Biological/social objectives under this option are:

1. The recognition and conservation of the unique qualities of small limestone spring runs.

2. Reduction or elimination of angling mortality as a factor of population dynamics.

3. Restriction of gear to fly-fishing-only.

Regulations applied under this option are:

Minimum size limit:	Variable
Creel limit:	Variable, including limited harvest of trophy size to no-kill.
Season:	Open year around.
Gear/lure restriction:	Artificial flies or streamers, barbless hooks.

FLY-FISHING-ONLY

The fly-fishing-only option is an approach which can be applied to both wild and stocked trout fisheries. As used in wild trout management, the intent is to provide anglers with an opportunity to fish over a population of wild trout in a traditional fashion. The fly-fishing-only program is fundamentally a social tool. As such, biological objectives will not be addressed. Requests are received from interested anglers and are best handled at the area level. In situations where fishery management conflicts arise, decisions will be made in favor of biologically based management programs.

Regulations applied under this option are:

Minimum size limit:	9 inches
Creel limit:	3 per day
Season:	Open year around, except no harvest between March 1 and opening day of trout season.
Gear/lure restriction:	Artificial flies or streamers.

CATCH-AND-RELEASE

Catch-and-release management of wild trout is an effort to provide anglers with the opportunity to fish over an essentially natural population of fish where hatchery fish, harvest, and hooking-handling mortality are not factors in population structure. Catch-and-release or no-kill management is designed to permit trout populations to return to pristine densities and age/size composition.

Biological objectives under this option are:

1. Elimination of angling mortality as a factor of population dynamics.

2. High stock density management with accompanying high catch-and-release rate of trout.

Regulations applied under this option are:

Minimum size limit:	None
Creel limit:	None, no fish may be killed or had in possession.
Season:	Open year around.
Gear/lure restriction:	Barbless artificial lures.

TROPHY TROUT

The trophy trout option is intended to provide anglers with the opportunity to harvest trophy wild trout longer than 14 inches, with a high catch-and-release rate of 9 to 14 inch trout. Trophy trout management is utilized to achieve higher densities of wild trout in streams where 5% or more of the existing wild trout are 14 inches or greater in length. These streams have demonstrated potential for supporting a good wild trout population with fish achieving trophy size. Streams eligible for this management option are virtually all brown trout waters.

Biological objectives include:

1. Protection and stockpiling of older (age 4+) and larger trout.

2. Protection of multiple-aged spawning stocks.

3. Creeled trout significantly larger than the average 9 to 10 inch hatchery trout.

Regulations applied under this option are:

Minimum size limit:	14 inches
Creel limit:	2 per day

Season:	Open year around, except no harvest between March 1 and opening day of trout season.
Gear/lure restriction:	Artificial lures

The management options selected for wild trout are a blend of old and new. The wilderness trout program was simply a continuation of an existing program. The fly-fishing-only program was modified slightly to permit catch-and-release angling prior to the opening of trout season and the creel limit was reduced from 6 to 3 fish daily. The limestone springs option was really designed to fit a few, virtually individually managed waters, but it is clearly consistent with the concept of exceptional management for exceptional waters. None of these--wilderness, fly-fishing-only, or limestone springs--created much, if any, unfavorable public reaction and generated no controversy. The catch-and-release option was a dramatic departure from the fish-for-fun program; and two facets of this option, use as a wild trout management tool instead of on hatchery trout supported fisheries and inclusion of artificial lures rather than flies only, created bitter and emotional resistance among anglers accustomed to the old fish-for-fun approach. The trophy trout option was a brand new program for Pennsylvania. It was not well received by the general angling public, mostly due to cessation of stocking and the use of lure restrictions.

Social problems encountered in implementing wild trout management were based primarily on the natural resistance of people to change, whether it was a change in stocking or a change in regulations. It was stocking and regulations which caused almost all of the problems and controversy that were encountered in bringing wild trout management to Pennsylvania. The cessation of trout stocking in some well-known and popular streams created, as was anticipated, strong public opposition. It became obvious, after only a few meetings, that anglers weren't anti-wild trout, they were pro-hatchery trout. The meetings and public contacts on concerns about a stream being removed from the stocking list all struck on some common themes:

1. Anglers don't believe the biologist; his figures are wrong.

2. Anglers don't believe that fisheries managers can distinguish between hatchery trout and wild trout. ("Of course there's lots of trout, you stocked them.")

3. No one can catch wild trout, so there's no sense in fishing.

4. The local economy will suffer; sporting goods stores, restaurants and motels will be penalized.

5. Why change now? We've been stocking for 50 years and the wild trout are still doing well.

6. I don't care myself, but what about senior citizens and kids who can't drive to another stream?

7. Why weren't the people asked? You work for the people; you should give them what they want or you won't have a job.

After hearing these same comments or questions a number of times, the responses became practically standard. Those who questioned the ability or integrity of fishery biologists were cordially invited to accompany staff on a stream survey and to reach their own conclusions. The remaining questions were answered as diplomatically and factually as possible. We avoided argument, and if we didn't know the answer to a question, we admitted that fisheries is not an exact science and there's a lot we don't know. I have little reason to believe that any of these meetings or responses to public concern convinced anyone to change their mind, but I do believe our staff made a favorable impression for several reasons:

1. The streams selected were clearly very good streams. We represented them as the "top 5%," the last of the best, and people did recognize that these were exceptional streams.

2. There was no reduction in the total number of trout being stocked statewide. Anglers were getting just as many hatchery trout, they were just being stocked in other waters.

3. A promise was made that all wild trout streams would be reevaluated, the public would be invited, and if trout populations were not as good as we originally thought, then management changes would be made.

4. No concessions were made, even under pressure from elected officials. The agency's Executive Director was firmly committed to wild trout management, and anglers soon recognized his support for resource-based management was real, his support for staff recommendations was strong, and no exceptions were going to be made.

Based on the Pennsylvania experience I would recommend that anyone going into an adversarial meeting on wild trout management have three things in hand before the meeting: (1) complete conviction that you're doing the right thing, (2) confidence in your data, and (3) full support and commitment of the agency staff starting at the highest levels. We had all of those in Pennsylvania and it made our job easier. I think it was why we succeeded. Working with anglers and concerned public to establish the validity of a no-stocking approach to wild trout management was a rewarding experience, and we were able to achieve the management objective. Class A wild trout waters in Pennsylvania are not stocked. Working with anglers and concerned public to establish the validity of lure restrictions as a wild trout management tool was not nearly as rewarding, nor nearly as successful.

Changing Pennsylvania's special regulations program and establishing biological objectives as the basis for some special regulations to be applied to wild trout management was one of the most controversial and emotionally charged parts of the early stages of Operation FUTURE. Those who were interested in the application of special regulations as a trout management tool were, in many instances, ready to object to anything the Commission proposed even before they saw the proposals. Much of this attitude could be traced to a misunderstanding of the motives for the Commission's moratorium on establishment of special regulations areas. An attempt had been made to explain that the moratorium was only to allow the Commission to develop new fisheries management objectives and to determine if Pennsylvania should continue to have a purely social/hatchery trout oriented special regulations program or to change and use special regulations to achieve biological objectives in wild trout management (Graff 1977). Despite explanations offered by Commission staff, there was a widespread feeling that the moratorium was simply a prelude to doing away with all special regulations areas and this was a concession to spin fishers and bait fishers. Misunderstandings of the reason for the moratorium extended beyond Pennsylvania. A distinguished fishery scientist speaking to a meeting of the Colorado-Wyoming Chapter of the American Fisheries Society criticized the Pennsylvania moratorium and stated that "Moratoriums on special regulations at this time of need is analagous to declaring a moratorium on cancer treatment until we learn what can work best." (Behnke 1980). Perhaps, if we had done a better job of explaining that the moratorium was needed on proliferation of socially oriented, hatchery trout supported programs until we could gather sound biological information on which to base the application of special regulations, this gentleman and others might have been less disturbed by Pennsylvania's moratorium. In any event, the change in the special regulations program generated a very bitter and vocal response from a small group of anglers--most of whom were fly fishers.

It was in the change from "fish-for-fun," flies only, and hatchery trout to catch-and-release, artificial lures only, and no stocking that we generated the bitterest and, for me at least, most disillusioning controversy of the entire wild trout management effort. The abolishment of the old heavily stocked, flies only, fish-for-fun program in favor of the wild trout, artificial lures only, catch-and-release program struck at two areas very important to a substantial number of people using specially regulated areas. It eliminated some established fish-for-fun areas because they didn't support wild trout, and it allowed spin fishers to share specially regulated waters with fly fishers. Neither of these ideas was well received. It simply came down to the fact that Pennsylvania's "quality anglers" had historically had all of the specially regulated waters (except Penns Creek) restricted to fly-fishing-only, and that's exactly how many of them preferred it. Also they liked to catch fish, they liked to catch them on flies, and if they had to make a choice between fly fishing for hatchery trout or using catch-and-release for wild trout, they would rather have fly fishing for hatchery trout. A surprising number of people lost sight of the importance of the resource and were concerned only with who (or at least how) could fish in a specially regulated area.

Attempts were made to explain that the catch-and-release regulation was based on a biological rationale and that numerous studies had demonstrated there was little difference between hooking mortality from lures and that from flies (Wydoski 1979). Alternatives were offered to offset the loss of fish-for-fun areas on streams that had to be stocked to support a fishery. These alternatives included fly-fishing-only, delayed harvest with both an artificial lures or flies only option (delayed harvest is no-kill from March 1 to June 15, and thereafter a 3 fish daily, 9 inch minimum size limit until February 28), or on Class B streams with good physical habitat but not enough wild trout to make Class A, a hatchery supplemented (one stocking) catch-and-release program. Neither rational discussion of the merits of artificial lures in terms of hooking mortality or an emotional appeal relative to the value of wild trout had much effect.

The issue of flies versus spinners still isn't really resolved. I have a drawer full of hate mail from fly fishers. One of the two or three chapters of the Federation of Fly Fishers that we have in Pennsylvania wrote to our Director demanding my dismissal since I was obviously prejudiced against fly fishers. We still have a couple of specially regulated no-kill areas that are under a flies only regulation. The situation grew so heated and emotional that these areas were sort of "grandfathered" by special Commission action. This was an especially difficult experience for me because I have been a long time advocate of special regulations for trout management and a defender of the legitimacy of Pennsylvania's socially directed fly-fishing-only regulations. I had truly counted on "quality anglers" as staunch advocates of biologically based trout management and as enthusiasts for wild trout. It came as a genuine disappointment to me to find that many people were more concerned with denying spin fishers access to specially regulated waters and with having freshly stocked, relatively naive and gullible hatchery trout to fish for than with management of wild trout. I guess I can sum it up by quoting a distinguished member of the Pennsylvania Fish Commission who, after hearing a statement prefaced by, "I personally have nothing against spin fishermen . . . ," interrupted to say, "Wait a minute, all of you begin by saying you have nothing against spin fishermen, but that's not the message I'm hearing. What I'm hearing is that you don't like spin fishermen, you don't like their wives, you don't like their kids, you don't even like their dogs." That is the message we all heard and it was truly a negative experience.

Trophy trout regulations also proved to be a difficult program to establish. Originally we had selected five very good trout streams as candidates for trophy trout management. In each case, as a part of wild trout management, we terminated stocking. The combination of no stocking and lure restrictions was not well received on three of the five candidate streams. In one instance, one determined individual rallied local landowners in opposition to the lure restriction, and it became clear that if lure restrictions and trophy size limits were imposed, much of the streamside land would be posted against trespass and public access denied. On another stream similar concerns by a major landowner resulted in the same situation. On the other stream the combination of no stocking and lure restrictions resulted in town meetings, involvement of political representatives, pleas for the welfare of children and senior citizens, and threats of trespass postings. Rather than jeopardize a new program and public access, three of the five streams were removed from the proposal for trophy trout. In two instances it was made clear that the resistance was not because stocking was terminated (it's possible some landowners were pleased to see it end) but because landowners wanted children to be able to fish and to keep trout over 7 inches rather than be subjected to a 14 inch size limit and lure restrictions.

I've made it sound as if the issue of wild trout and special regulations was one big disappointment and that's not really the case. There's no doubt I was disillusioned and disappointed by the reaction of some of my fellow fly fishers, but I was also very encouraged and heartened by the support the Commission received from Trout Unlimited, an organization whose membership contains a high percentage of fly fishers. Trout Unlimited was an active promoter of the idea of resource classification and wild trout management and an early advocate of a statewide inventory of trout waters. When public opposition was building, Trout Unlimited, at the state council and chapter levels, officially endorsed the Commission's wild trout management initiative, including the use of artificial lures in catch-and-release areas. There's no doubt that many of their members did not agree with the Fish Commission's special regulations proposals, but the organization gave its full support to what was best for the resource, and that support was important and influential.

Despite the many concerns voiced by fly fishers and the horrible social conflicts some anglers envisioned as inevitable when fly fishers and spin fishers are permitted to fish together on a specially regulated water, the program is working. No fly fisher has suffered irreparable harm from fishing next to a spin fisher and no rash of unsportsmanlike conduct by spin fishers has been reported. Artificial lures caused a great deal of bitterness, but those anglers who have been exposed to the new catch-and-release areas seem satisfied that things will work out. Those who haven't and continue to fish those areas where fly-fishing-only regulations were "grandfathered" remain as vocal, biased, and opposed to artificial lures as before. They have no desire to be confused by reality.

Biologically it's too early to make a valid assessment, but we have resurveyed some wild trout waters and the results have been gratifying. The public--and some elected officials--have turned out to see the surveys. The wild trout are there, and while the public meetings and staff presentations may not have changed anyone's mind, the follow-up surveys have. Nothing is as convincing as seeing the fish. Wild trout management does work!

The future of wild trout management in Pennsylvania looks good. We've picked good streams to start with, and anglers are learning more quickly than I anticipated that wild trout fishing can be rewarding and that harvest and lure restrictions do make a difference. I look forward to an expansion of both the catch-and-release and trophy trout programs. As we have a chance to evaluate the results of such tools as not stocking and restrictive regulations, it is entirely possible that we will be removing some of our "Class B" waters from the stocking program and attempting to improve and enhance the populations so they can be "Class A" waters. I foresee the bitterness and emotionalism of the fly fisher versus the hardware fisher dying a natural death as more and more specially regulated areas include artificial lures and more and more people realize the wild trout is the basis for the fishery, not whether one fishes a lure or a fly.

Ten years ago, at the first wild trout symposium, Ralph W. Abele, Executive Director of the Pennsylvania Fish Commission, said, "The only realistic approach to wild trout management, at least in the Northeast, is to phase wild trout management in slowly and carefully. I think we must establish its validity and legitimacy as a part of fisheries management by developing good projects which win public support." (Abele 1974). I'm pleased to say that's exactly the approach he took and that wild trout management is now a reality in Pennsylvania. I'm very optimistic about the future of wild trout in the Keystone State.

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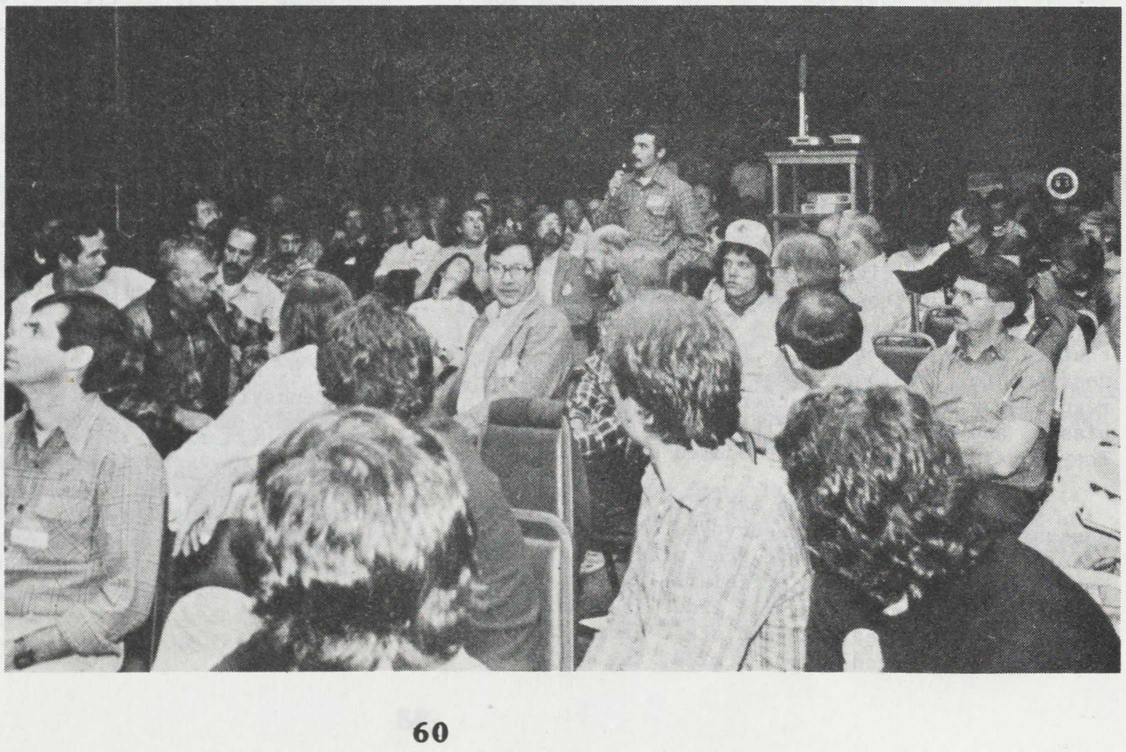

Summary of a Basic Fishery Management Strategy for Resident and Anadromous Trout Habitats, Washington State[1]

Paul Mongillo[2]

At its August 1983 meeting, the Washington Game Commission directed the Department of Game to develop a basic stream management plan upon which future fishing seasons and regulations could be based. The report entitled "A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington" was prepared by WDG's Fish Management Division in response to that directive.

The report acknowledges two important trends affecting Washington stream fisheries: First, as the number of anglers in Washington increases, overfishing is becoming more of a threat to many of the state's wild trout populations. The report cites studies showing that "adequate protection of wild trout populations in Washington is often dependent upon the amount of fishing pressure being applied, not the regulatory controls in effect." In addition, "most evidence seems to indicate that if suitable habitat is present, severe reductions in trout populations are normally caused by overfishing." Second, fishery managers have documented a growing preference among anglers in recent years toward catch-and-release fishing, even in areas where regulations don't require it. The report concludes: "The reasons for recreational trout angling in streams have clearly evolved to a point where the provision of food for subsistence use can no longer be viewed as a viable fishery management objective." It stresses the need to ensure that a majority of female trout have an opportunity to spawn one time before they can be legally killed in a fishery. The numbers of spawning fish in our state's waters must be increased if future fishermen are to have a resource to enjoy.

The strategy proposed in the report for dealing with the problem would be to separate the basic regulations for lake fishing from those governing stream fishing. Few lakes have self-sustaining natural trout populations. They are managed primarily as consumptive fisheries, to provide as much recreation as possible from artificially maintained fish populations. The state's streams support self-sustaining wild trout populations that must be protected. The report calls for these to be managed to provide as much recreation as they can sustain without subjecting them to overfishing. To accomplish this, proper minimum size restrictions are required to protect trout through at least one spawning cycle. Hooking mortality thus becomes an important issue. Research indicates that up to 50 percent of fish caught with bait die after release, while the death rate for fish caught on virtually any kind of artificial lure--whether with barbed or barbless hooks--is only 5 percent. In other words, if you fish with bait, as many as one out of every two fish you throw back dies. If you fish with artificial lures, only one out of 20 released fish dies. The report concludes that releasing fish is incompatible with use of bait. The same goes for minimum size limits, which amount to mandatory catch-and-release of undersized fish. The only exception to the high mortality rate associated with releasing bait-caught fish applies to steelhead. Studies show that steelhead caught with bait are generally not hooked in vital areas that would cause their eventual death if released.

In rivers, streams and beaver ponds, basic regulations would be made more restrictive by implementation of an eight-inch minimum size limit. This would help protect juvenile resident and anadromous fish and promote increased spawning by small, non-migratory resident fish. Bait fishing would be prohibited on a majority of these waters from late May through October. Conversely, basic stream fishing regulations would be liberalized by the use of possession limits instead of catch limits wherever bait is prohibited. This would provide new opportunities for legal catch-and-release trout fishing in streams, allowing unlimited non-consumptive fishing until the angler elects to keep his or her limit.

The eight- and five-fish bag limits would be retained, but only two could be over 12 inches. This would distribute the catch among a larger number of anglers and do away with the three-over-14 inches and two-over-20 inches regulations currently in effect.

A major objective to the Fisheries Management Division's strategy proposals is to make fishing regulations more consistent throughout the state. Where special problems or situations exist, they will be dealt with through special regulations, rather than by altering basic, statewide regulations to accommodate the exceptions. The report proposes ten categories of special regulations for rivers, streams and beaver ponds: (1) Designated stream zones managed for hatchery fish - for optimum hatchery trout management (normally no minimum-size limit and bait allowed and catch limits apply). For example, this would be applied to streams with artificially maintained populations along east-west mountain highways in the southern Cascades.

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[1]Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24, 1984. The full report can be obtained from the Washington Department of Game.

[2]Paul Mongillo is Resident Fisheries Program Manager, Washington Department of Game, Fish Management Division, Olympia, WA.

(2) Delayed season opening - for use in waters requiring additional protection for spawning trout, spawned-out adults or outmigrant smolt concentrations. (3) Bait allowed - for use in fisheries targeted on summer-run steelhead (catch limits apply). (4) More restrictive regulations for Dolly Varden or bull trout - (may also be implemented on individual waters, or throughout a Department of Game administrative region). For instance, a one-fish limit could be set for bull trout in streams throughout the department's Region Three. (5) More liberal regulations for brook or brown trout - (may also be implemented on a regional basis). These might include, for example, bonus limits in waters with stunted populations of eastern brook trout. (6) 12-inch minimum size limit - for most migratory-resident trout populations (those that migrate up- and down-river, or in and out of lakes, but do not go to sea) in mainstem areas, including lakes or reservoirs, if applicable; and to protect large steelhead smolts in the Columbia River mainstem. (7) Data-specific minimum size limit - for migratory resident trout populations in mainstem areas (including lakes or reservoirs, if applicable), where specific population data show that a minimum-size limit higher or lower than the 12-inch standard would be advisable. For instance, population data would dictate a need for a higher limit on the mainstem Yakima River. (8) No minimum size limit and bait allowed (catch limits apply) - for non-migratory resident trout populations with small individual fish (preferably on a geographic basis, not individual waters). This might be applied to alpine streams in Okanogan County. (9) 14-inch size limit - for sea-run cutthroat in marine waters and mainstem areas. About two-thirds of sea-run cutthroat females first spawn when they are between 12 and 14 inches long, and this regulation would restrict the harvest mostly to fish that have spawned at least once. (10) Catch-and Release - all trout caught must be released. This will be used for steelhead when there is no harvestable surplus and to preserve age class composition of resident trout populations similar to natural conditions.

Competition From Catchables — A Second Look[1]

C. E. Petrosky and T. C. Bjornn[2]

Abstract.--Competition from stocked catchable-size trout was not severe, and occurred only at high stocking densities. The highest stocking densities temporarily increased rainbow trout mortality in one stream and decreased cutthroat trout abundance in another. Stocking densities in Idaho generally average less than experimental densities where competition occurred.

INTRODUCTION

Ten years ago at the Wild Trout I Symposium, an important issue was raised but not resolved--does stocking of catchable-size trout depress wild trout populations? Do catchable-size hatchery trout compete aggressively for limiting food or spatial resources (Vincent 1975) or induce a stress in wild trout (Butler 1975)? Scientific evidence to answer these questions remains scarce. The popular viewpoint that competition from stocked trout has severe consequences to wild trout has never been demonstrated because potential competition has not been separated adequately from environmental factors or angling pressures which can influence population abundance.

We present here a summary of our studies in Big Springs Creek and the St. Joe River, Idaho, in which we tried to isolate competitive effects due to direct interactions between wild and catchable-size hatchery trout. In a three-year study in Big Springs Creek, a productive stream, we related effects of stocking hatchery rainbow trout, *Salmo gairdneri*, at different levels to changes in wild rainbow trout abundance, dispersal, mortality rate, growth rate, and condition factor. In a short-term study in the infertile St. Joe River, we related effects of stocking levels to changes in abundance of cutthroat trout, *S. clarki*, and observed behavior of wild cutthroat trout and hatchery rainbow trout.

We believed that potential for competitive interaction would be greatest under conditions of limited harvest. Few people fished Big Springs Creek during the study. We conducted the St. Joe River study in a special regulation (3-fish creel, 13-inch minimum-size limit) zone. Most wild cutthroat trout and all stocked rainbow trout were sublegal size.

METHODS

Big Springs Creek

We used 15 sections in Big Springs Creek, each about 130 m long. The sections were grouped by threes within five stream zones so that we had a control (unstocked) section within each zone, as well as sections that we stocked with hatchery trout at different levels.

We electrofished the sections each June, 1979-81, before stocking hatchery trout to estimate wild rainbow trout abundance (Seber and LeCren 1967). We recorded lengths and weights and jaw-tagged all rainbow trout larger than 160 mm. We stocked the sections in July and August with jaw-tagged catchable-size rainbow trout. In September or October, we repeated the population estimates in the sections to determine abundance of wild and hatchery trout. Tag recaptures enabled us to determine movements and growth rates of individual trout, relative to their initial stocked or unstocked sections. In 1979 and 1980, but not 1981, we trapped downstream migrants from Big Springs Creek using a weir at the mouth of the stream (Bjornn 1978).

The three-year study consisted of two separate experiments. In 1979 and 1980 we stocked four sections with 50 hatchery trout and four sections with 100 hatchery trout, keeping four sections unstocked. Stocking 100 hatchery trout approximately doubled the initial wild trout biomass in a section. In 1981, we increased the stocking level to 400 hatchery trout in each of five sections and used five unstocked sections as controls.

Approximately 12,000 rainbow trout fry inhabited Big Springs Creek in autumn 1979 and 1980, similar to previous years when no steelhead trout fry had been stocked in the stream (Horner 1978). In 1981, the Idaho Department of Fish and Game began to reintroduce steelhead trout, increasing the fall population of resident rainbow and introduced steelhead trout fry to 23,000.

We statistically compared population parameters of wild trout from stocked and unstocked sections

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[1] Paper presented at the Wild Trout III Symposium. [Yellowstone National Park, Wyoming, September 24-25, 1984.]

[2] C. E. Petrosky, Graduate Assistant, and T. C. Bjornn, Leader, Cooperative Fishery Research Unit, University of Idaho, Moscow, Idaho.

(Petrosky 1984). The parameters were autumn abundance of rainbow trout fry, changes in abundance during summer of yearling and older wild trout, proportions of wild trout migrants, summer and annual mortality rates, growth rates, and condition factors.

St. Joe River

In the St. Joe River, we sampled 22 pools, runs, or pocket-water reaches averaging 107 m long. Using wetsuit, mask, and snorkel, we counted the number of wild cutthroat trout inhabiting the sections in late July 1979. In August, we stocked seven sections with 50 catchable-size rainbow trout, seven with 150, and one with 500; we observed behavior of wild and hatchery trout primarily at this latter site. Seven sections were left unstocked. The number of wild cutthroat trout and hatchery rainbow trout remaining in the sections were counted weekly for three weeks after stocking occurred. We statistically compared short-term changes in abundance of cutthroat trout from stocked and unstocked sections. Habitat use, feeding behavior, and aggressive behavior (Hartman 1965) of wild and hatchery trout were also recorded.

RESULTS

Big Springs Creek

Stocking catchable-size rainbow trout did not affect autumn density of wild rainbow trout fry, but may have reduced fry density when both wild rainbow and introduced steelhead trout were present. In 1979 and 1980, densities of wild fry in sections stocked with 50 and 100 hatchery trout did not differ significantly from densities in unstocked sections (table 1; fig. 1). In 1981, when fry densities were artificially increased by steelhead introductions, stocking of 400 catchable-size trout apparently reduced the overall fry density in test sections, but the mean difference was not statistically significant at the 5% level ($F = 5.21$; $p = 0.08$). Interestingly, stocking catchable-size trout at this level did not reduce fry densities of resident rainbow and introduced steelhead trout to levels below previous years when only resident rainbow trout were present.

Abundance of yearling and older rainbow trout did not change significantly from June to autumn in response to stocking at any stocking level (table 1). Generally, the number of yearlings in the sections in autumn represented about 87% (antilog$_e$ -0.14; table 1) of the initial number in June, regardless of stocking level. Abundance of age 2 and older rainbow trout in autumn was about half that in June. By contrast, hatchery trout abundance decreased rapidly, leaving only about 20% of the number stocked by autumn and 1% by the following June.

Stocking hatchery trout did not cause wild rainbow trout to leave Big Springs Creek in either 1979 or 1980. Only 33 of 2,039 tagged wild rainbow trout were captured in the weir during the two years. About half (17) were caught in May 1980 before hatchery trout were stocked that year. Of the remainder, 5, 4, and 7 tagged wild rainbow trout originated from sections that were not stocked, stocked with 50 hatchery trout, and stocked with 100 hatchery trout, respectively.

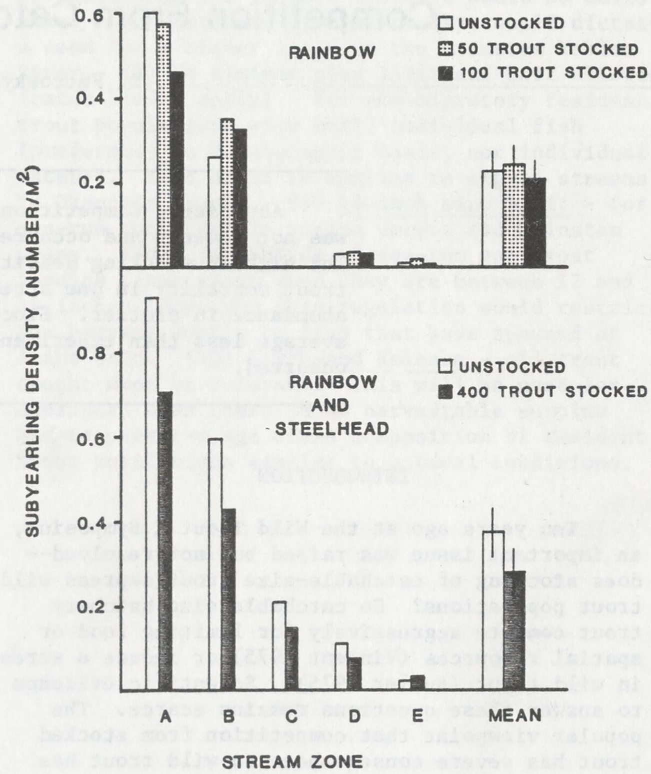

Figure 1.--Density of wild rainbow trout subyearlings (1979-80) and wild rainbow and introduced steelhead trout subyearlings (1981) in autumn in sections stocked and not stocked with hatchery rainbow trout, Big Springs Creek. Vertical lines represent ± 2 SE.

Hatchery trout did not displace wild rainbow trout from stocked sections to any measurable degree. About 10% of the wild rainbow trout tagged in June occupied areas outside their initial section in autumn, regardless of whether that initial section was stocked or not (table 1). Of the number of wild trout that we knew were alive in autumn, about 25% occupied areas outside their initial sections, regardless of the number of hatchery trout stocked in that initial section.

Only the summer mortality rate of tagged wild rainbow trout increased in response to stocking of hatchery trout, and only at the highest stocking level (table 1). In 1981, releases of 400 catchable-size rainbow trout in the test sections increased summer mortality rate of known survivors ($F = 16.35$; $p = 0.03$). Annual mortality rate was unaffected at all stocking levels. Based on mortality rates of known survivors, 25% fewer wild rainbow trout would be expected in autumn based on the 1981 stocking level (fig. 2), but no difference would be expected after a full year.

Growth rates of wild rainbow trout that remained in their initial sections were similar under stocked and unstocked conditions. The apparent dif-

Table 1. --Summary of estimated population parameters ± 2 SE for wild rainbow trout from stocked and unstocked sections of Big Springs Creek, 1979-80 and 1981 experiments. Asterisks (*) denote differences from unstocked sections significant at $p < 0.05$.

Population parameter	Test group	Experiment year	Not stocked	Sections: 50 trout stocked	Sections: 100 trout stocked	Sections: 400 trout stocked
Fry density in autumn	Resident	1979-80	0.23 ± 0.05	0.24 ± 0.05	0.21 ± 0.05	---
	Resident plus introduced steelhead[1]	1981	0.38 ± 0.06	---	---	0.28 ± 0.06
Change in abundance[2]	Small yearlings	1979-80	-0.08 ± 0.33	0.02 ± 0.33	-0.16 ± 0.33	---
		1981	-0.19 ± 0.32	---	---	-0.20 ± 0.32
	Large yearlings	1979-80	-0.17 ± 0.44	-0.33 ± 0.44	-0.17 ± 0.44	---
		1981	0.10 ± 0.25	---	---	-0.18 ± 0.25
	Older	1979-80	-0.60 ± 0.46	-0.57 ± 0.46	-0.69 ± 0.46	---
		1981	-0.81 ± 0.26	---	---	-0.83 ± 0.26
Proportion of migrants to initial number[3]	Tagged yearlings and older	1979-80	0.10	0.12	0.11	---
		1981	0.10	---	---	0.07
Proportion of migrants to known survivors[3]	Tagged yearlings and older	1979-80	0.21	0.29	0.23	---
		1981	0.23	---	---	0.21
Summer mortality rate[4]	Known survivors	1979-80	3.27 ± 0.40	3.23 ± 0.40	3.07 ± 0.40	---
		1981	2.80 ± 0.16	---	---	3.67 ± 0.16*
Annual mortality rate[4]	Known survivors	1979-80	2.20 ± 0.40	2.47 ± 0.40	2.16 ± 0.40	---
		1981	2.53 ± 0.16	---	---	2.52 ± 0.18
Instantaneous growth rate	Yearling nonmigrants	1979-80	0.32 ± 0.28	0.49 ± 0.33	0.58 ± 0.24	---
		1981	1.17 ± 0.31	---	---	0.87 ± 0.38
	Older nonmigrants	1979-80	0.20 ± 0.20	0.11 ± 0.26	0.20 ± 0.19	---
		1981	0.67 ± 0.14	---	---	0.58 ± 0.17
Autumn condition factor	Yearling nonmigrants	1979-80	1.00 ± 0.05	0.97 ± 0.05	1.01 ± 0.04	---
		1981	1.06 ± 0.05	---	---	0.99 ± 0.06
	Older nonmigrants	1979-80	1.03 ± 0.01	1.01 ± 0.01	1.04 ± 0.01	---
		1981	1.02 ± 0.03	---	---	1.05 ± 0.04

[1] Introduced steelhead fry could not be distinguished from resident rainbow fry.

[2] $\log_e$ (Autumn abundance/June abundance).

[3] Statistical analyses performed on transformed (arc-sine square root) proportions.

[4] Instantaneous rates, transformed by adding one to final and initial numbers before taking natural logarithms.

ference in growth between stocked and unstocked sections in 1981 was not significant (table 1). Of the three years of study, wild rainbow trout grew most rapidly in 1981, even in the presence of large numbers of hatchery trout.

Interactions with hatchery trout throughout summer did not affect condition factors of surviving wild rainbow trout in autumn. Condition factors for trout that stayed in unstocked sections did not differ significantly from those that stayed in sections stocked with 50, 100 or 400 hatchery trout (table 1).

St. Joe River

At the start of the 1979 experiment, unstocked and stocked sections contained similar numbers of wild cutthroat trout (fig. 3). Release of 50 and 150 hatchery trout in test sections temporarily doubled and quadrupled total trout abundance, respectively. In a single section, release of 500

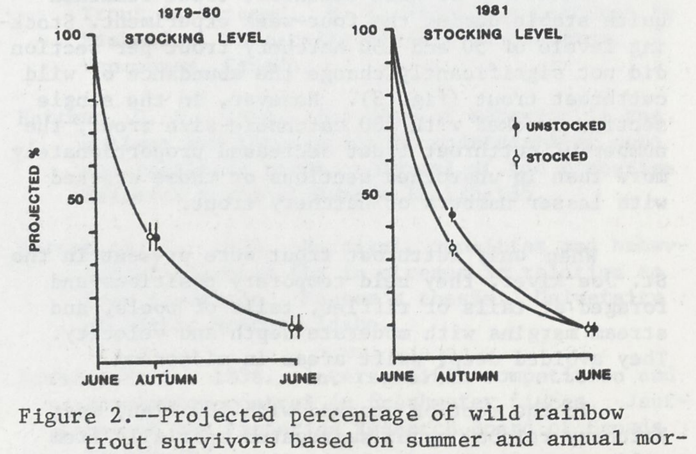

Figure 2.--Projected percentage of wild rainbow trout survivors based on summer and annual mortality rates of known survivors from stocked and unstocked sections, Big Springs Creek, 1979-80 and 1981 experiments. Vertical lines represent projections from ± 2 SE of mortality rates.

hatchery trout temporarily increased total trout abundance more than 11-fold.

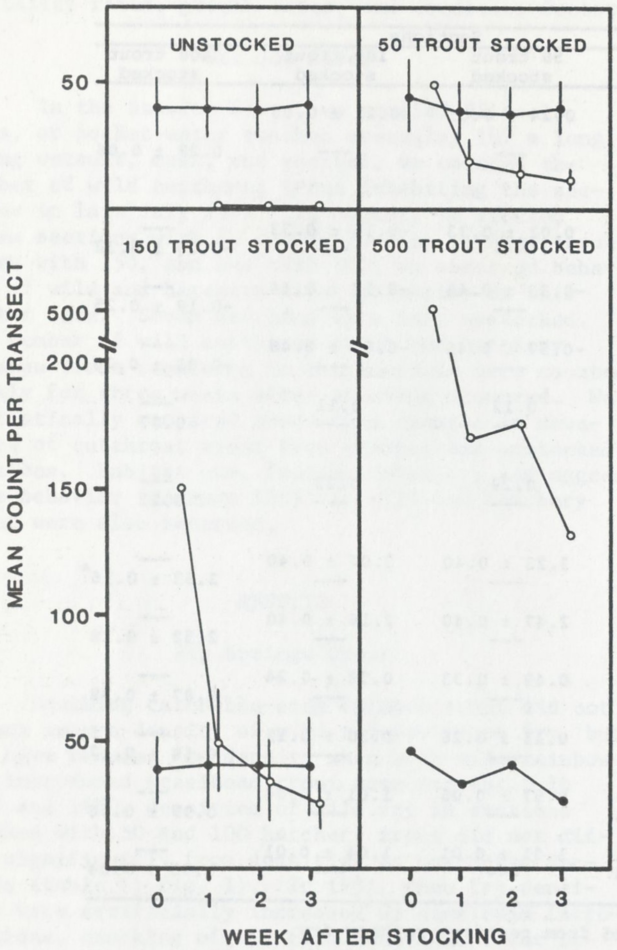

Figure 3.--Mean count of wild cutthroat trout (solid dot) and hatchery rainbow trout (open dot) in stocked and unstocked sections, St. Joe River. Vertical lines represent ± 2 SE.

Abundance of wild cutthroat trout remained quite stable during the four-week experiment. Stocking levels of 50 and 150 hatchery trout per section did not significantly change the abundance of wild cutthroat trout (fig. 3). However, in the single section stocked with 500 catchable-size trout, the number of cutthroat trout decreased proportionately more than in unstocked sections or those stocked with lesser numbers of hatchery trout.

When only cutthroat trout were present in the St. Joe River, they held temporary positions and foraged at tails of riffles, tails of pools, and stream margins with moderate depth and velocity. They avoided deep, swift areas in midstream.

In the section stocked with 500 fish, most hatchery rainbow trout segregated spatially from wild cutthroat trout. Upon release, hatchery rainbow trout formed aggregations in generally deeper and swifter water than that preferred by cutthroat trout. Most hatchery trout remained in groups throughout August (fig. 4). Although relatively few hatchery trout used habitat similar to that used by cutthroat trout, they outnumbered wild trout in some areas.

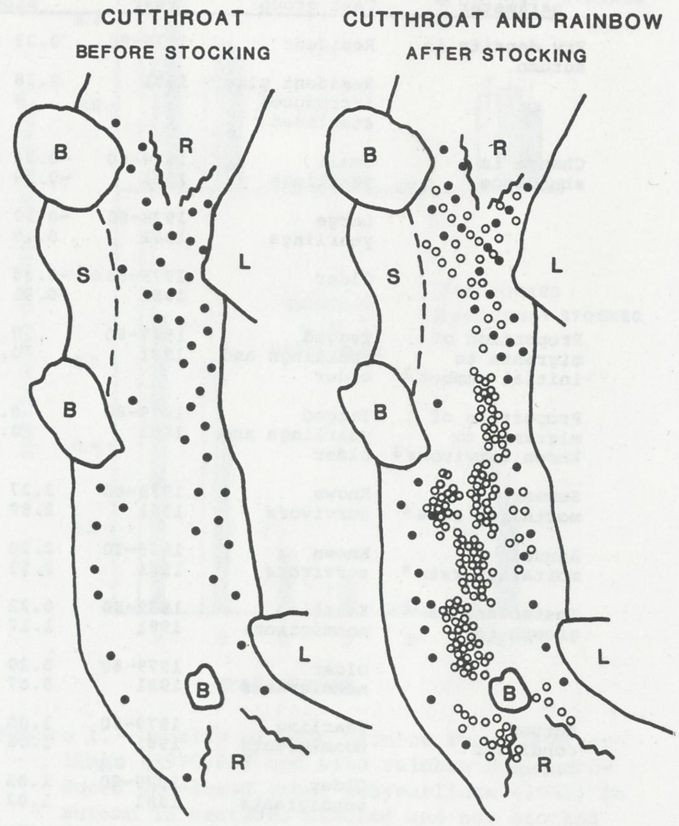

Figure 4.--Approximate distribution of wild cutthroat trout (solid dot) before stocking and of wild cutthroat trout and hatchery rainbow trout (open dot) two weeks after stocking 500 fish in the section, St. Joe River, August 1979. Prominent habitat features are boundary riffles (R), emergent boulders (B), shoal (S), and rock ledges (L). Direction of flow is top to bottom.

Where wild cutthroat trout and hatchery rainbow trout occupied similar habitat, they interacted aggressively. Social dominance was determined primarily by size. Smaller cutthroat trout were displaced to other nearby feeding stations by larger wild and hatchery trout alike.

DISCUSSION

In general, we found relatively minor effects on wild trout from stocking catchable-size hatchery trout, and then only at high stocking densities. We believe the primary reasons for lack of measured effects at lower and intermediate stocking levels are that (1) overlap of habitat use between wild and hatchery trout was incomplete, and (2) older, larger wild trout withstood some degree of direct interaction with hatchery trout because factors controlling their abundance were not density-dependent.

Spatial segregation reduced the potential for wild and hatchery trout to interact socially. As in Pollard and Bjornn's (1973) study, most hatchery trout stocked in the St. Joe River experiment selected deep midstream habitat not used by wild cutthroat trout. A high degree of segregation continued throughout the experiment. In the smaller pools of Big Springs Creek, hatchery rainbow trout lived relatively closer to older, larger wild rainbow trout. But subyearling and many yearling wild rainbow trout inhabited pockets among vegetation in shallow riffles, habitats where we rarely observed the larger hatchery trout.

Direct competition can be defined as the demand, typically at the same time, by more than one organism (or population) for the same environmental resources in excess of the immediate supply (Larkin 1956). Theoretically, stream trout regulate their own densities through competition for the limiting resources of food and space (Chapman 1966). Although biologists seldom know definitely which resources limit a given population, they have measured competition by relating mortality rates and dispersal to changes in density.

Increases in density of juvenile trout and salmon in streams often result in higher mortality rates and/or greater dispersal (Chapman 1962; McFadden et al. 1967; Chapman and Bjornn 1969), processes which tend to stabilize the population. To our knowledge, this density-dependence has not been shown to operate for the sizes and ages of trout which primarily interacted with stocked catchable-size trout in Big Springs Creek and the St. Joe River. These older trout apparently die at a rate independent of their density--within natural ranges of density. Stocking can temporarily increase trout densities well beyond natural ranges. But in our studies, merely doubling or quadrupling the initial trout abundance by stocking resulted in no measurable competitive effects.

Stocking densities currently practiced in Idaho streams and rivers compare more closely with our low and intermediate stocking levels where we found no evidence of competition (fig. 5). Differences between our experiments and actual stocking operations by agencies will, of course, influence a determination of "no-effect" stocking densities. Because some hatchery trout dispersed from our short sections--in similar proportions to wild trout--the measured effects might underestimate true competitive effects. Conversely, the limited harvest during our experiments probably allowed for more competitive interaction than might normally occur when hatchery trout are stocked to supplement wild populations. In practice, hatchery trout may compete directly with wild trout near release sites where densities are extreme. Densities of hatchery trout away from release sites may not be high enough to severely influence wild trout populations through competition. Although the potential for competition cannot be ignored, management decisions to stock or not stock a stream with catchables would be better based on preventing overharvest of wild fish and public preferences.

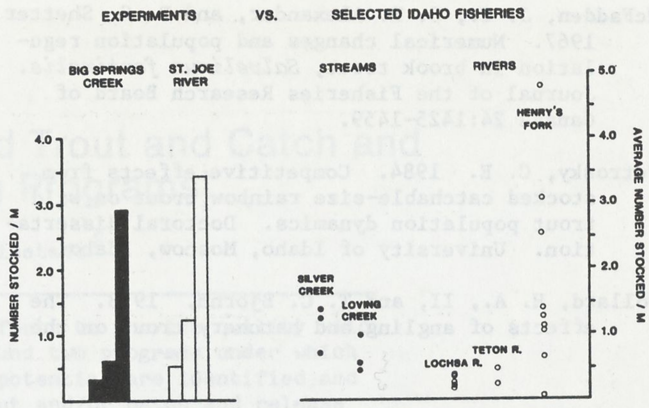

Figure 5.--Experimental stocking densities (linear) compared to average stocking densities in some Idaho streams and rivers.

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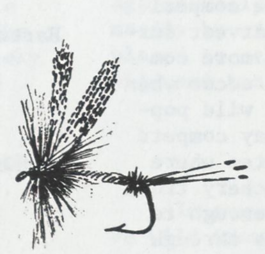

Status of the California Wild Trout and Catch and Release Angling Programs[1]

John M. Deinstadt[2]

Abstract.--California's efforts to provide quality wild trout angling have centered around two programs under which waters with special management potential are identified and designated as official wild trout and/or catch and release waters. The combined programs currently consist of 23 designated streams and four lakes. The earlier California Wild Trout Program emphasized not only improved wild trout angling but environmental protection. The more recent Catch and Release Angling Program is primarily an angling regulation oriented program and, due to its legislatively required annual addition of catch and release waters, has been difficult for the Department of Fish and Game to carry out. Studies conducted under the latter program have shown that some California streams have a greater capacity to carry large, older trout than was originally estimated. Both programs have strong angler support.

INTRODUCTION

In recent decades the need to protect and develop quality angling on the nation's exceptionally productive wild trout streams has led several states to become more involved in wild trout management. In 1968, a group of dedicated California anglers led the way to carrying out a breakthrough project in their state - the Hat Creek Project. The well publicized story of how an excellent trout fishery was developed and maintained under a two-trout limit, after a nongame fish control project was implemented, awakened many anglers to the possibility that California could restore quality fishing in some of its more productive streams (May 1969, Barnhart 1970). California's initial statewide effort to restore quality angling on selected streams, known as the California Wild Trout Program, was a direct outgrowth of the Hat Creek Project. A more recent program, known as the Catch and Release Angling Program, was enacted to improve angling by increasing the number of catch and release waters. This paper describes the management concept or requirements of both programs and the current status of efforts to implement these programs.

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, September 24-25, 1984.

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CALIFORNIA WILD TROUT PROGRAM

Program Concepts and Policies

The California Wild Trout Program, begun in the Early 1970's, is a program under which selected streams are designated and managed with a goal of maximizing wild trout angling opportunities. A priority is placed on maintaining abundant self-sustaining trout populations in which the number of larger, older fish is not significantly reduced by angler harvest. A management program for each water is formulated in a plan intended to emphasis the special qualities inherent in each stream and its trout population. Protection of instream habitat and preservation of the natural character of the streamside environment are general goals under which each plan is written.

To qualify for the program, a stream must be open to the public and "able to support, with appropriate angling regulations, wild trout populations of sufficient magnitude to provide satisfactory trout catches in terms of both number and size of fish" (Calif. Dept. of Fish and Game 1983). Recommendations by the Department of Fish and Game that a stream be designated are heard before the Fish and Game Commission and open to public debate. Streams approved by the Commission are managed under the stipulation that there be no stocking of domestic strains of catchable-sized trout. Suitable strains of hatchery-produced wild or semi-wild trout may be planted, but only if natural trout reproduction is inadequate. Under Commission

TABLE 1.--Description of currently designated wild trout and catch and release waters in California.

Access-Water	Length (km)	Species of trout	Program	Limit Bag	Limit Min. Size
Roadside					
Eel R,MF	45	[1]STHD	[2]CR	0	
Fall R	34	RT,BN	WT,CR	2	18"
Hat Ck	6	RT,BN	WT,CR	2	
Hot Ck	2	BN,RT	WT,CR	0	
Kings R	29	RT,BN	WT	2	
Kings R,SF	18	RT,BN	WT	2	
Klamath R	8	RT	WT	5	
Owens R	26	BN	WT,CR	2	
Sacramento R	23	RT,BN	CR	2	
Truckee R	6	RT,BN	CR	2	15"
Walker R,E	14	BN,RT	CR	2	14"
Yellow Ck[3]	3	BN,RT	CR	2	16"
Trailside					
American R,NF	60	RT,BN	WT	10	
Carson R,EF	37	RT,BN,CT	WT	10	
Clavey R	37	RT,BN	WT	10	
Cottonwood CK	15	GT	WT	5	
Deep Ck	26	RT,BN	WT,CR	2	6"
Feather R,MF	72	RT,BN	WT	10	
McCloud R[4]	6	RT,BN	WT,CR	2	
McCloud R[5]	2	RT,BN	WT,CR	0	
Merced R,SF	24	RT,BN	WT	10	
Nelson Ck	10	RT,BN,BT	WT	10	
Rubicon R	48	RT,BN	WT	10	
Tule R,NF	10	RT,BN	CR	2	
Yellow Ck[6]	13	RT,BN	WT	10	
	Area (ha)				
Roadside					
Heenan L	55	CT	CR	0	
Martis L	28	CT,BN,RT	WT,CR	0	
Trailside					
Kirman L	18	BT	CR	2	
McCloud L	4	CT	CR	0	

[1]STHD=steelhead trout (summer run), RT=rainbow trout, BN=brown trout, GT=golden trout, BT=brook trout, CT=cutthrout trout.

[2]CR=designated catch and release water, WT=designated wild trout water.

[3]Upper section in Humbug Valley

[4]Section below McCloud Reservoir

[5]The Nature Conservancy section

[6]Lower canyon section.

policy, the Department is responsible to take all necessary actions, consistent with State law, to prevent adverse impact by land or water development projects on designated wild trout streams.

Seven roadside (totaling 123 km) and eleven primarily trailside streams (totaling 350 km) are currently managed as designated wild trout streams (table 1 and fig. 1). In 1974, the original stream program was expanded to include one experimental wild trout lake.

Fisheries Management

An active program of field surveys has been pursued to determine if the goals of maintaining abundant trout populations are being met. When creel censuses and/or fish population surveys have shown a decline in expected population levels, changes in angling regulations are sought. More restrictive regulations have been recommended and adopted by the Fish and Game Commission on all seven of the roadside waters since the program began.

Environmental Protection

The State of California owns little of the land adjacent to wild trout streams and is therefore dependent on land owners' cooperation to maintain the desired habitat. Designating streams as Wild Trout Streams has allowed special recognition to be given these waters by land managing agencies. Standard logging practices, road building, trail placement and other operations along several streams on U. S. Forest Service lands have been modified to achieve Wild Trout Program goals. Currently, the Forest Service is coauthoring wild trout plans for streams on their lands.

Special recognition is also beginning to be given designated streams as a group. Recently the State set a policy of opposing small hydroelectric projects on selected waters including designated wild trout streams. Suction dredging of any type has been prohibited on designated streams in some areas.

While the Department is very pleased with the cooperation and support it has received in protecting designated streams, it is recognized that the threat of agency and public opposition to potential developments may create some resistance to designating new waters.

CATCH AND RELEASE PROGRAM

Program Requirements

In 1979, the California Legislature passed the Trout and Steelhead Conservation and Management Planning Act. The bill changed the Department's approach to wild trout management by mandating that three requirements be met as part of the existing wild trout program. The act requires that the Department: (1) Conduct a physical and biological inventory of all

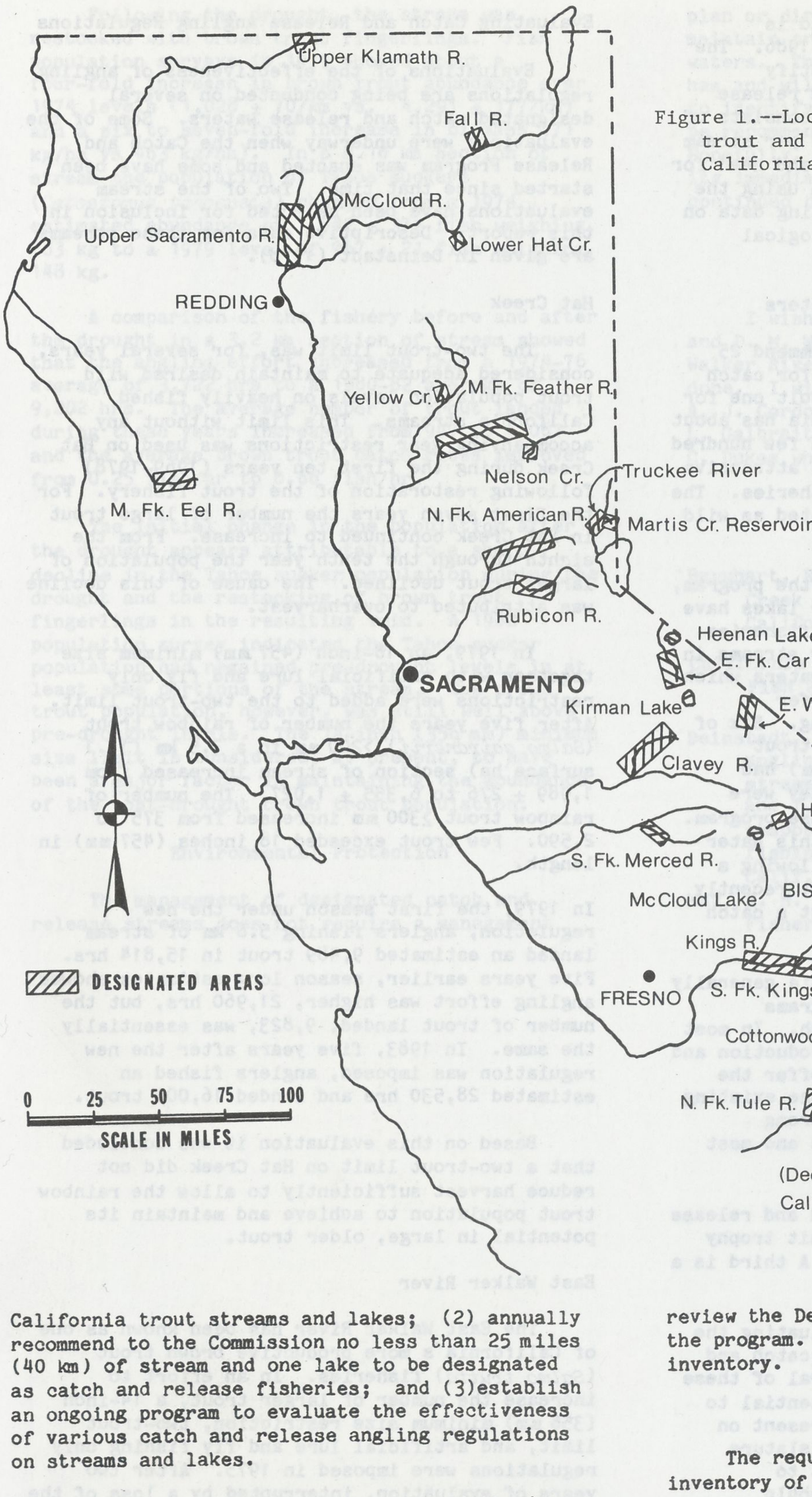

Figure 1.--Location of currently designated wild trout and catch and release waters in California.

California trout streams and lakes; (2) annually recommend to the Commission no less than 25 miles (40 km) of stream and one lake to be designated as catch and release fisheries; and (3)establish an ongoing program to evaluate the effectiveness of various catch and release angling regulations on streams and lakes.

Catch and release fisheries were defined by the act as waters having a zero, one, or two-trout limit. Minimum and maximum size limits may be used in conjunction with one and two-trout limits. Requirements 2 and 3 above were to be met in 1980 and continue thereafter until at least 1986 when the Legislature is scheduled to review the Department's progress in carrying out the program. No schedule was mandated for the inventory.

Statewide Inventory

The requirement to conduct a statewide inventory of trout waters is generally viewed by members of the Department as a positive part of the legislation. Stream fish population and accompanying descriptive data are much needed by biologists in the field and environmental protection specialists in regional offices. A survey of roadside streams was begun by two crews during the summer and fall of 1983 and is scheduled to continue until at least 1986. The primary goal of the survey is to identify potential wild trout and/or catch and release management streams. The method used consists of selecting one or more survey sections per stream (depending upon stream size, access, and need for data), estimating the fish population using the three-pass removal method and collecting data on selected physical, chemical, and biological parameters.

Selecting Catch and Release Waters

The requirement to annually recommend 25 miles (40 km) of stream and one lake for catch and release angling has been a difficult one for the Department to fulfill. California has about 30,000 km of trout stream, but only a few hundred km of stream which readily qualify as attractive and accessible quality wild trout fisheries. The majority of these waters were designated as wild trout streams.

Through the first four years of the program, 12 streams (totaling 203 km) and four lakes have been designated as catch and release fisheries (table 1 and fig.1). Four of the new streams in the program are productive roadside waters which currently offer or are expected to offer opportunities for trophy trout angling. Six of the streams are also designated wild trout waters. Four of these (totaling 50 km) had qualifying regulations at the time they were incorporated into the catch and release program. Another was added when the limit on this water was lowered from ten to two-trout following a decline in the fishery. And, the most recently designated wild trout stream was first a catch and release water.

Roadside trout lakes in California generally have long established management programs centered around stocking hatchery fish. In most instances conversion to wild trout production and catch and release angling could not offer the size or number of fish available in the existing program and would likely encounter strong opposition from commercial operations and most anglers.

Two of the four designated catch and release lakes now in the program are zero limit trophy Lahontan cutthroat trout fisheries. A third is a trophy brook trout fishery.

The Department is currently evaluating the impact of angling on other potential catch and release fisheries. Admittedly, several of these waters do not have the biological potential to provide the quality of angling now present on most designated streams. If the Legislature concludes that the annual requirement to designate catch and release waters should continue beyond 1986, less productive streams with lower population densities and slower growing fish may be expected to become part of the program.

Evaluating Catch and Release Angling Regulations

Evaluations of the effectiveness of angling regulations are being conducted on several designated catch and release waters. Some of the evaluations were underway when the Catch and Release Program was enacted and some have been started since that time. Two of the stream evaluations have been selected for inclusion in this report. Descriptive data for these streams are given in Deinstadt (1978).

Hat Creek

The two-trout limit was, for several years, considered adequate to maintain desired wild trout population levels on heavily fished California streams. This limit without any accompanying gear restrictions was used on Hat Creek during the first ten years (1969-1978) following restoration of the trout fishery. For the first seven years the number of large trout in Hat Creek continued to increase. From the eighth through the tenth year the population of larger trout declined. The cause of this decline was attributed to overharvest.

In 1979, an 18-inch (457 mm) minimum size together with artificial lure and fly only restrictions were added to the two-trout limit. After five years the number of rainbow trout (*Salmo gairdnerii*) ≥200 mm in a 3.5 km (12.1 surface ha) section of stream increased from 1,989 ± 276 to 6,355 ± 1,027. The number of rainbow trout ≥300 mm increased from 375 to 2,590. Few trout exceeded 18 inches (457 mm) in length.

In 1979, the first season under the new regulation, anglers fishing 5.6 km of stream landed an estimated 9,489 trout in 15,814 hrs. Five years earlier, season long estimates showed angling effort was higher, 21,960 hrs, but the number of trout landed, 9,823, was essentially the same. In 1983, five years after the new regulation was imposed, anglers fished an estimated 28,530 hrs and landed 16,000 trout.

Based on this evaluation it was concluded that a two-trout limit on Hat Creek did not reduce harvest sufficiently to allow the rainbow trout population to achieve and maintain its potential in large, older trout.

East Walker River

The East Walker River has been known as one of California's more productive brown trout (*Salmo trutta*) fisheries. In an effort to increase the number of larger trout, a 14-inch (356 mm) minimum size restriction, two-trout limit, and artificial lure and fly fishing only regulations were imposed in 1975. After two years of evaluation, interrupted by a loss of the fishery following the draining of a reservoir at the end of the 1976-77 drought, it was concluded that catch and release angling did not improve the fishery (Deinstadt 1978).

Following the drought, the stream was restocked with brown trout fingerlings. Fish population surveys in 1979 showed about a four-fold increase in brown trout abundance over 1974 levels (1,028 ± 70/km vs. 4,291 ± 177/km) and a six to seven-fold increase in biomass (71 kg/ha vs 463 kg/ha). In a 0.16 km section of stream the population of Tahoe suckers (*Catostomus tahoensis*) changed from a 1974 estimated abundance of 1,642 ± 374 fish weighing 283 kg to a 1979 level of 967 ± 21 fish weighing 148 kg.

A comparison of the fishery before and after the drought in a 3.2 km section of stream showed that the angling effort increased from a 1974-76 average of 3,722 hrs to a 1980-82 average of 9,202 hrs. The average number of trout landed during these years increased from 947 to 6,061 and the average brown trout catch rates improved from 0.25 fish/hr to 0.66 fish/hr.

The initial change in the population after the drought appears attributable to a sharp decline in the Tahoe sucker population during the drought and the restocking of brown trout fingerlings in the resulting void. A 1982 population survey indicated the Tahoe sucker population had regained pre-drought levels in at least some portions of the stream. The brown trout population, however, was still well above pre-drought levels. The 14-inch (356 mm) minimum size limit is considered, at present, to have been a major factor in maintaining the abundance of the post-drought brown trout population.

Environmental Protection

The management of designated catch and release streams does not require a management plan or directly consider an active program to maintain or restore the habitat of designated waters. The Catch and Release Angling Program has and will continue to require the Department to identify productive wild trout waters that can be recommended as designated wild trout streams. Hopefully, the stream inventory program with both its immediate and long-term benefits will be continued beyond 1986.

ACKNOWLEDGMENTS

I wish to recognize and thank T. P. Healey and D. M. Wong with whom the Hat Creek and East Walker River studies, respectively, have been done. I wish also to express my gratitude to A. J. Cordone, who reviewed this paper, L. Galbraith who rendered the figure, and C. Dukes who type the manuscript.

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Effects of a Slotted Size Limit on the Brown Trout Fishery, Au Sable River, Michigan[1]

Richard D. Clark, Jr. [2] and Gaylord R. Alexander [3]

Abstract.--Fishing regulations for brown trout were changed from a 12-inch minimum to a slotted size limit. The slotted limit allowed harvest of trout between 8 and 12 inches and over 16 inches. Abundance of brown trout smaller than 8 inches decreased by 8%, abundance of 8- to 12-inch brown trout decreased by 32%, and abundance of brown trout over 12 inches decreased by 47%. Growth rate did not change significantly. Annual fishing mortality rate between ages 2 and 3 increased from near zero to about 30%, and this reduced the number of fish surviving to older ages and larger sizes. However, unfavorable changes in environmental conditions contributed to decreases in abundance also. Total numerical harvest of brown trout increased nearly five times but consisted of smaller fish. Fishing pressure probably increased somewhat, but the increase in harvest was due primarily to the change in size limits. Voluntary release of legal-sized trout appeared to increase independent of our regulations. We concluded that the greatest effect of the slotted limit was in reshaping man's use of the trout populations. Biological effects were comparatively unimportant, except for their influence on satisfying desires of different factions within the angling community.

INTRODUCTION

The Au Sable River of north central Michigan is considered by many to be one of the best trout streams in America. Wild, self-sustaining populations of brown, brook, and rainbow trout coexist in many areas of the river where their abundance, along with the scent of pines and the flight of the giant mayfly, help give the river a special appeal. In April 1979, experimental fishing regulations were imposed on what is probably the most famous stretch of the river from Burton's Landing to Wakeley Bridge on the Mainstream. The primary element of these regulations was a slotted size limit which allowed harvest of trout between 8 and 12 inches and over 16 inches (fig. 1).

We will describe the effects of the slotted limit and make some general observations concerning its potential as a fishery management tool. We will not give an indepth description of data collection methods or statistical analyses used to evaluate the new regulation but, for those interested, these technical details will be contained in a research report available by early 1985 from Michigan Department of Natural Resources (Clark and Alexander 1985).

THE RIVER

The Au Sable is relatively young for a river, having developed after the last ice age about 12,000 years ago. Its name was given by early French explorers and means "River of Sands". The 1800 square mile Au Sable Basin contains over 100 miles of blue-ribbon trout water. The river consists of three major branches, the North Branch, the Mainstream (or Middle Branch), and the South Branch, and has three major tributaries, the East Branch, and two different Big Creeks. The soils in the basin are light, composed of much sand and gravel, and are very pervious to water infiltration. As a result, a large part of about 30 inches of annual precipitation goes to groundwater recharge, and the influx of this groundwater to the stream throughout the year helps provide cold temperatures and relatively stable flow conditions for trout.

The exceptional quality of the Au Sable River began attracting hundreds of anglers as early as 1873 when the railroad line to the town of Grayling was completed. In those days, they came to catch the Michigan grayling which was the only member of the salmon-trout family native to the river. But the grayling disappeared from the Au Sable by the

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, September 24-25, 1984.

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Figure 1.--Description of slotted size limits posted at entrance of study section at Wakeley Bridge on the Mainstream of the Au Sable River, Michigan.

mid-1880's. Use of the river for log running, overfishing, and competition from the newly introduced trout were all suspected of contributing to its demise. By the 1870's, rainbow trout and probably brook trout were being planted in the Au Sable River by private individuals, and in 1885 the State of Michigan began planting the river with brook trout. Brown trout were the last to be introduced, but today they dominate the river, making up 80% to 90% of the total weight of trout collected in recent biological surveys (Gowing and Alexander 1980).

The first "quality" fishing regulation was established on the Au Sable River in 1901 when the size limit on trout was raised to 8 inches from the 6-inch limit then in effect statewide. The first fly-fishing-only rule was adopted in 1907 on the North Branch. Currently, 44 miles of the river are restricted to flies-only fishing and another 14 miles to fishing with artificial lures only.

There has been a long history of trout research on the Au Sable River and other rivers nearby. The first trout fishery research station in the United States was established by the Michigan Department of Natural Resources, then known as the Department of Conservation, on nearby Hunt Creek in 1939. For about 40 years, the Department has conducted scientifically designed studies to determine effects of various fishing regulations on trout fisheries (see Clark et al. 1981 for a synopsis). As a result of these studies and continuous fisheries management surveys, the Department has accumulated what may be the most extensive and longest series of data on trout streams anywhere in the world. For example, growth, mortality, and birth rates for trout have been estimated for periods of years on different sizes of streams, different trout species combinations, different stocking rates (including no stocking), and different fishing intensities (including no fishing). Furthermore, it is possible to obtain more accurate population data from the streams of this region than from those of most other regions of the country. The relative efficiency of the primary stream sampling device, the dc electroshocker, is extremely high here. This is due to the nature of the streams themselves. They are easy to wade because they have low gradients (about 5.5 feet/mile) and gravel-sand bottoms, and they are high in electrical conductivity because they have hard water (about 190 ppm total alkalinity).

Another point of interest concerning trout research is the fact that some of the first hooking mortality studies were conducted here on the North Branch of the Au Sable River and Hunt Creek (Shetter and Allison 1955, 1958). They showed that death rates of trout caught and released on natural bait were far greater than death rates of trout caught and released on artificial lures or flies. It is largely on these results and those of later supporting studies that today's flies-only and artificial-lures-only regulations can be justified.

THE PROBLEM

Nine miles of river from Burton's Landing to Wakeley Bridge on the Mainstream is one of the best stretches of the Au Sable River. All trout in this stretch are wild fish; trout have not been planted here since 1954. By the early 1970's, anglers of this stretch were complaining that the large brown trout which helped give the area its reputation were gone. At the time, it was thought an increase in fishing pressure might be causing the decline in big browns through overharvest, but this could not be determined with certainty because neither trout population surveys nor creel surveys had been conducted there since 1963. Nonetheless, in response to angler complaints the minimum size limit on brown and rainbow trout was increased from 10 to 12 inches in 1973, and the daily creel limit was reduced from 5 to 3 trout per day. Also, the size limit on brook trout was increased from 7 to 8 inches in 1974. At the same time, annual trout population surveys were resumed so the effects of the 12-inch size limit could be studied in detail.

By 1977, it became apparent that the 12-inch size limit and 3-trout creel limit were not working. Trout population surveys were producing clear evidence that these regulations had failed to bring back the numbers of large trout observed in similar surveys in the 1960's. The most important reason for the failure appeared to be a significant decline in the growth rate of brown trout (Alexander et al. 1979). Mean lengths of brown trout of all ages were considerably less in the 1970's than in the 1960's (fig. 2). For example, the average 3-year-old brown trout was more than 2 inches smaller (11.3 inches versus 13.6 inches). This change in growth had a great impact on the fishery. The estimated number of brown trout larger than 12 inches in the population and the estimated number of these large fish harvested per hour of fishing both decreased by two and one-half times.

The 12-inch size limit did succeed in increasing the number of 10- to 12-inch brown trout in the population by about 40% over the number present under the 10-inch limit in the 1960's. However, it appeared that these fish were only adding to the problem. The size structure of the population seemed to be out of balance; too many mid-sized fish and not enough large fish. One line of thinking suggested that harvesting these "overabundant" mid-sized fish and protecting the rarer, more valuable large fish might solve the problem. It might allow the remaining fish in the population to obtain more food per individual, so they could grow faster. Similar "thinning" operations were

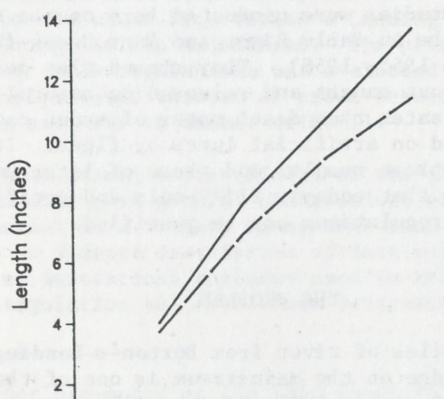

Figure 2.--Brown trout growth in the Mainstream in the period from 1959 to 1963 (solid line) compared to the period from 1974 to 1978 (dashed line).

known to be effective in increasing growth rates of trout, bluegills, and other fishes in lakes. The big question was: Would it work in a trout stream? To find the answer, a slotted size limit was designed to thin the numbers of 8- to 12-inch brown trout by allowing their harvest and to protect 12- to 16-inch brown trout by requiring their release. On April 28, 1979, the slotted size limit went into effect on the Burton-to-Wakeley section.

THE CONTROVERSY

Not everyone was convinced the slotted limits would improve brown trout growth. In fact, not all biologists agreed that the 12-inch size limit was to blame for the decline in brown trout growth. Several alternative hypotheses were advanced to explain the decline. Alexander et al. (1979) described the complexity of the problem in more detail. Briefly, no single factor was identified as the cause for the decline in growth, but there were two leading hypotheses. The first was a considerable decrease in productivity of the river. This came about when two sources of nutrient enrichment at the town of Grayling, about 6 miles upstream of Burton's Landing, were curtailed. The State of Michigan phased out fish production, with its related waste discharge, at the Grayling Hatchery in the mid-1960's and the town stopped putting sewage effluent into the river in 1971. Large amounts of sewage can kill a river, but limited amounts can have the same effect as fertilizer on a garden. It stimulates the growth of aquatic plants, which feed aquatic insects and crustaceans, which feed trout.

The second hypothesis was based on population genetics theory. Favro et al. (1979) suggested fishing under a minimum size limit might reduce the genetic growth potential of brown trout by killing most of the larger trout and leaving behind the smaller trout to reproduce. Cooper (1952) expressed this same concern earlier with regard to Michigan brook trout, and more recently, Ricker (1981) gave convincing evidence that the commercial fishery in the North Pacific had reduced the average size of salmon through genetic selection.

Studies were designed by the Department of Natural Resources to test both sewage enrichment and population genetics hypotheses. Merron (1982) studied the decline in productivity due to sewage diversion. He calculated growth of brown trout from the 1960's through the 1970's on three branches of the Au Sable, the Mainstream, the North Branch, and the South Branch. He used scale samples that were collected during the period from other research and management surveys. Each of the branches had a different history of nutrient enrichment. Sewage effluent was discharged into the Mainstream from the town of Grayling and into the South Branch from the town of Roscommon, but these discharges were stopped in different years, 1971 on the Mainstream and 1974 on the South Branch. The North Branch never received any effluent. Merron found growth rates of brown trout were significantly slower in both the Mainstream and the South Branch after termination of sewage discharges, and that the timing of these decreases in growth corresponded to the timing of sewage diversion. He found no change in growth for the same time intervals on the North Branch. Thus, the results of Merron's study strongly supported the idea that growth of brown trout in the Burton-to-Wakeley section of the Mainstream had decreased in the 1970's because the river was no longer being "fertilized" by municipal sewage and hatchery effluent.

To test the genetics hypothesis, samples of young-of-the-year brown trout were taken from streams in northern Michigan which varied in fishing pressure from light to heavy. The Mainstream of the Au Sable was one of those selected. These fish were marked so their stream origins could be identified, and then they were planted together in the same experimental lakes. The idea was to see if their growth in these common environments was correlated with the degree of exploitation in their home streams. This study has not been completed yet.

Meanwhile, Clark et al. (1980) predicted the slotted size limit would have no effect on the growth of brown trout. They cited a number of examples in which changes in fishing regulations or other management activities had significantly changed trout population densities in streams but had not significantly changed trout growth rates. Numerous scientific references and trout population data in the Department files indicated trout populations in streams adjusted their numbers through density-dependent movement and mortality. That is, trout compete with one another for favorable positions in streams. The relative quality of these positions is related in part to food abundance and to the nearness of cover for protection against predators. When the trout population size exceeds the number of favorable positions, the largest, most agressive individuals take the best positions and force the others to move to other areas where they have less food and protection. Over time, it appears that starvation and/or predation are effective in removing these excess fish. Clark et al. (1980) developed a population dynamics model based in part on these density-dependent mortality relationships and used it to predict that the slotted size limit would actually reduce, and not increase, the number of large brown trout in the Burton-to-Wakeley section. The primary basis for this prediction was the assumption that growth and natural mortality rates of trout would not change enough to compensate for the added fishing mortality on the 8- to 12-inch fish. In other words, anglers would remove enough 8- to 12-inch trout so as to reduce the number surviving to the larger sizes.

EXPERIMENTAL METHODS

The experiment to evaluate the slotted size limit spanned a period of 10 years, 1974 through 1983. Data were collected on the trout populations and angler use of the study section (Burton's Landing to Wakeley Bridge on the Mainstream) from 1979 through 1983 under the slotted size limit and compared to identical data taken from 1974 through 1978 under the 12-inch size limit. Also, identical data were collected on a similar section of the North Branch where no changes in fishing regulations occurred during the period of study. Thus, the North Branch was used as a control. We assumed that any large-scale trout population changes caused by natural phenomenon would be reflected in this control section. Then we would know that similar changes occurring in our study section were not due to the regulations but to environmental effects.

Changes in population and catch statistics observed after the slotted size limit went into effect were tested at the 90% level of significance. The 95% level is often used for statistical testing in scientific experiments, but we thought 95% was too restrictive given the inherent variability in natural fisheries. Henceforth, when we say things have changed significantly or are significantly different, we mean that a statistically significant difference has been detected at the 90% level.

The study section on the Mainstream was discussed earlier. The control section on the North Branch was about 14 miles long, from Sheep Ranch Public Access Site to Kellogg's Bridge near the community of Lovells. At its farthest point, it is only 15 miles from the study section on the Mainstream. Regulations on this section from 1974 through 1983 were artificial flies only, minimum size limits of 8 inches on brook trout and 10 inches on brown trout, creel limit of 5 trout per day from the last Saturday in April to October 31. One of the major differences between this section and the study section was that no rainbow trout were present. However, brown and brook trout populations in the North Branch compared very well with those in the Mainstream.

Limited time and manpower prevented detailed sampling of trout populations in the entire 9-mile study section and 14-mile control section, so two sampling stations, about 1/4 mile long each, were defined within the study section and three within the control section. These stations were considered as index stations in which the trout population dynamics could be studied in detail. We assumed the regulations would affect the trout populations in the study section as a whole similar to how they affected the trout in these smaller sampling areas. Electroshocking gear was used to estimate trout abundance each fall within the boundaries of the sampling stations. Scales were taken from some of the fish at this time also. Later these scales were used to determine the age of trout of various sizes and species. By estimating the age and size of the fish over a period of time, we determined the average growth and survival rates of the population in our index areas.

Creel surveys were conducted on both the study and control sections in 1976, before the slotted size limit, and from 1979 through 1983, after the slotted size limit. These surveys were designed to estimate the total hours of fishing and the total catch of trout, both harvested and released, of each species. Stratified, random sampling methods were used, as described in more detail by Alexander and Shetter (1967) or Malvestuto (1983). Briefly, total hours of fishing were estimated by making progressive instantaneous counts. A clerk floated each section in a canoe, counting the number of anglers on the river at specified times of the day. Catch per hour was obtained by interviewing anglers on the river, usually after their fishing trip was completed. Anglers were asked the length of the fishing trip and also how many trout of each species they had caught and released. Of course, this means that our estimates of trout caught and released were dependent on the honesty of the anglers; their ability to distinguish between brown, brook, and rainbow trout; and their ability to recall the exact number and species and approximate sizes of trout they caught and released that day. To help test the accuracy of these catch-and-release reports from the general public, we recruited a small group of knowledgeable fishermen to keep accurate records of sizes and species of trout they caught. We plan to compare the size and species composition reported by these cooperators to those reported by the general public, but comparisons are not complete at this time. Also during the interviews, trout in the angler's possession (those harvested) were counted, identified to species, and scale sampled for age analysis. Finally, we estimated total catches by multiplying the total hours fished per day times the average catch per hour per day.

RESULTS AND DISCUSSION

The slotted limit was designed primarily for brown trout, and we will concentrate on them in this report. We could not detect any effect from the regulation on brook or rainbow trout (Clark and Alexander 1985).

Earlier research demonstrated that changes in daily possession limits did not affect trout populations while size limits had strong effects (Shetter 1969; Hunt 1970; Latta 1973). The ineffectiveness of possession limits was due primarily to the rarity of anglers catching their limit of trout. Size limits were effective because they applied to every single trout caught. Therefore, even though our daily possession limit increased from 3 to 5 trout, we assumed any effects found were caused by the change in size limits.

We defined the before period as 1974 through 1978 and the after period as 1980 through 1983. This allowed a 2-year transition period (1978 to 1980) for the population to adjust from the 12-inch limit to the slotted limit.

Trout Population Statistics

We compared the size structure of brown trout before and after the slotted limit was applied and found the average abundance of fish of all sizes decreased significantly in both study and control sections (table 1). In the Mainstream, trout smaller than 8 inches decreased 8%, trout between 8 and 12 inches decreased 32%, and trout larger than 12 inches decreased 47%. In the North Branch, the respective decreases were 19%, 24%, and 44%. The average number of trout larger than 16 inches also decreased in both sections, but due to small sample sizes, reliable confidence bounds could not be calculated for these larger trout.

We expected to find reductions in brown trout abundance in the Mainstream because of the increased harvest permitted under the slotted limit, but we did not expect to find similar reductions in the North Branch where regulations remained constant. Despite the relative stability of the Au Sable River as trout habitat, environmental conditions did change in some way, and we were faced with the problem of separating effects of changing fishing regulations from effects of changing environmental conditions.

To accomplish this separation of effects, we examined how the observed size structures were formed through the biological processes of recruitment, survival, and growth. We use the word "recruitment" here to mean the annual number of young fish born and surviving to age 0 (6 months old). Age structure and annual survival of brown trout populations in before and after periods are presented in table 2. We did not include an exceptionally large 1978 year class in these calculations. This year class was twice as large as any other year class in both study and control sections. Including it in the calculations would have inflated

Table 1.--Mean number of brown trout per acre in fall populations by selected size categories. Confidence bounds for the 90% level of significance are in parenthesis.

Stream, time period, (size limit)	Size of trout: Trout smaller than 8 inches	8- to 12-inch trout	12- to 16-inch trout	Trout 16 inches or larger
Mainstream				
1974 - 1978	600	189	18	1
(12-inch minimum)	(±21)	(±6)	(±2)	(-)
1980 - 1983	555	128	10	<1
(Slotted)	(±19)	(±5)	(±1)	(-)
North Branch				
1974 - 1978	525	86	23	2
(10-inch minimum)	(±9)	(±5)	(±1)	(-)
1980 - 1983	425	65	13	1
(10-inch minimum)	(±11)	(±2)	(±1)	(-)

Table 2.--Mean number of brown trout by age and annual survival for fall populations. Confidence bounds for the 90% level of significance are in parenthesis.

Stream, time period, (size limit)	Age of trout 0	1	2	3	4
Mainstream					
1974 - 1978 (12-inch minimum)					
Number	450 (±21)	164 (±8)	114 (±8)	74 (±7)	4 (±1)
Survival rate	0.36 (±0.02)	0.70 (±0.06)	0.65 (±0.07)	0.05 (±0.02)	
1980 - 1983 (Slotted)					
Number	405 (±19)	148 (±9)	80 (±11)	35 (±6)	1 (±1)
Survival rate	0.37 (±0.03)	0.54 (±0.08)	0.44 (±0.09)	0.02 (±0.01)	
North Branch					
1974 - 1978 (10-inch minimum)					
Number	478 (±9)	92 (±3)	43 (±4)	21 (±2)	1 (±1)
Survival rate	0.19 (±0.01)	0.47 (±0.04)	0.49 (±0.06)	0.05 (±0.01)	
1980 - 1983 (10-inch minimum)					
Number	366 (±9)	78 (±3)	33 (±3)	12 (±2)	2 (±1)
Survival rate	0.21 (±0.01)	0.42 (±0.05)	0.35 (±0.07)	0.15 (±0.07)	

mean numbers at age and misrepresented the effects of the regulation.

We found a significant decrease in annual recruitment in both study and control sections but no change in annual survival rates, except at older ages where survival was influenced by changes in fishing mortality (table 2). Environmental factors most often affect fish populations through fluctuations in annual recruitment of young fish (Cushing 1977; Backiel and Le Cren 1978), and our data showed that environmental conditions must have been less favorable for recruitment of brown trout in the after period. Average recruitment of age-0 fish decreased 10% in the Mainstream and 23% in the North Branch.

Even without changes in regulations, reduced recruitment alone would have led to reductions in abundance of older, larger trout in both streams. However, regulations did change in the Mainstream causing additional mortality of 8- to 12-inch trout through harvest. This harvest mortality added to the environmental effect to reduce the number of larger, older trout even further. More specifically, the survival rate from age 0 to 1 in the Mainstream did not change. Trout at this age were smaller than 8 inches and not affected by harvest. (This is illustrated by growth data given later.) Survival from age 1 to 2 decreased significantly from 0.70 under the 12-inch limit to 0.54 under the slotted limit. Some trout at this age reached 8 inches and were harvested under the slotted limit. Thus, fishing mortality added to the existing natural mortality from age 1 to 2 and reduced the survival rate.

Survival from age 2 to 3 decreased significantly in the Mainstream from 0.65 to 0.44 (table 2). Almost all trout at this age were between 8 and 12 inches. They received the full effect of harvest under the slotted limit but were still protected under the 12-inch limit. This means the difference between instantaneous total mortality rates at this age, measured before and after the regulation change, can be used as an estimate of the instantaneous fishing mortality on the Mainstream brown trout (assuming natural mortality remained constant--see Ricker 1975). In this manner, we estimated the instantaneous fishing mortality rate to be 0.39, and this estimate is only slightly higher than estimates made earlier using other methods (Clark et al. 1980 used a conditional fishing rate of 0.30 which corresponds to an instantaneous fishing rate of 0.36).

Survival from age 3 to 4 did not change significantly in the Mainstream (table 2). About half the trout at this age were smaller and half larger than 12 inches, so about the same proportion of fish in the age group were vulnerable to harvest under each regulation; the smaller half under the slotted limit and the larger half under the 12-inch limit.

In the North Branch, survival of brown trout did not change significantly in the after period until age 2, the age they began to exceed the minimum size limit of 10 inches. Here survival decreased from 0.49 to 0.35 (table 2). This decrease was not due to any change in regulations but was probably due to a slight increase in fishing pressure to be discussed later in this report. One result which seemed unrealistic was an apparent increase in survival rate from age 3 to 4 (0.05 to 0.15). We expected a decrease in survival at this age for the same reason it decreased at age 2--increased fishing pressure. It is our opinion that these survival rates estimated for age 3 to 4 were unreliable due to small sample sizes of trout at age 4. The number of age-4 brown trout averaged only 1 per acre before and 2 per acre after. Therefore, we based our interpretation of results solely on abundance and survival rates of fish age 3 or younger.

While fishing and environmental factors combined to reduce abundance of brown trout in both study and control streams, this did not lead to an increase in growth rates. Growth of brown trout did not change significantly in the Mainstream (fig. 3), and in the North Branch a slight, but statistically significant decrease in growth was detected (fig. 4). Thus, the classical inverse relationship between growth and abundance which has been observed in pond and lake fisheries was not observed in our trout streams. However, decreased growth in the North Branch suggested environmental conditions might have acted to reduce growth, along with recruitment, in the after period. If so, the additional reduction in abundance caused by the slotted limit in the Mainstream could have increased growth there; just enough to balance the negative environmental effect and to result in no net change in growth. But even if the regulation did cause this slight improvement in growth, the relatively larger increase in mortality it caused between ages 1 and 3 was clearly the more important effect in determining the abundance of trout larger than 12 inches.

In summary, the growth rate of brown trout did not change significantly as a result of the slotted size limit. Abundance of brown trout of all sizes in the Mainstream decreased 10% in the after period due to lower recruitment of young fish, but this was caused by some unknown change in environmental conditions. Abundance of 8- to 12-inch fish was reduced an additional 22% (32% in total) from angler harvest under the slotted limit. Abundance of fish larger than 12 inches was reduced an additional 15% (47% in total) by further angler harvest. Notice that it took about 2 years (from age 1 to 3 on the average) for brown trout to grow through the harvest slot from 8 to 12 inches, so they were subjected to 2 years of angler harvest before they reached 12 inches. Once fish reached 12 inches, they were protected under the slotted limit but fewer trout reached this size because they were harvested at 8 to 12 inches.

Creel Survey Statistics

No confidence bounds were calculated in the 1976 creel survey and bounds for the 1980 through 1983 surveys were not nearly as narrow as the bounds for the trout population surveys. Nonetheless, it was obvious that total harvest of brown trout from the Mainstream study section changed significantly (table 3). It increased from an estimated 440 brown trout per year under the 12-inch minimum limit to an average of 2,090 brown trout per year under the slotted limit. In terms of harvest per hour of fishing, this was 0.014

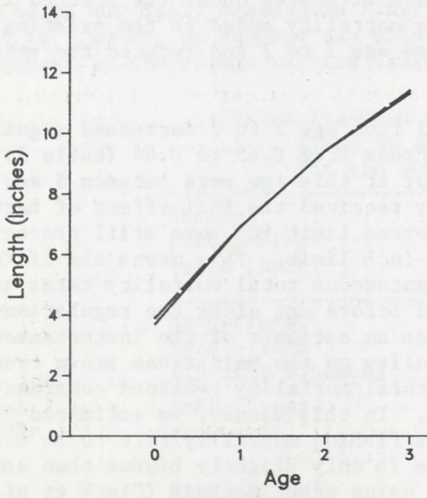

Figure 3.--Brown trout growth in the Mainstream in the period from 1974 to 1978 (solid line) compared to the period from 1980 to 1983 (dashed line).

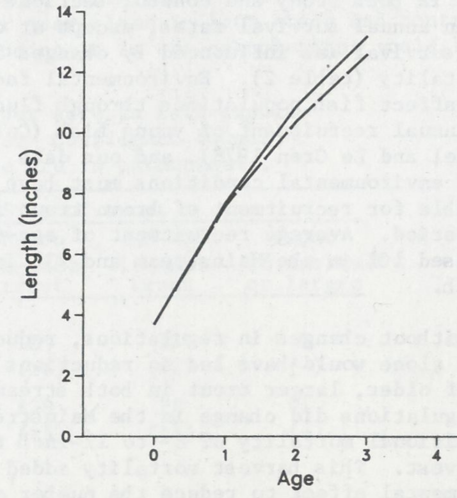

Figure 4.--Brown trout growth in the North Branch in the period from 1974 to 1978 (solid line) compared to the period from 1980 to 1983 (dashed line).

Table 3.--Mean numbers per year of brown trout harvested and caught and released in selected size categories. Confidence bounds for the 95% level of significance are in parenthesis. No confidence bounds were calculated for the 1976 survey.

Stream, time period, (size limit)	Size categories								Total fishing pressure (hours)
	8 to 12 inches[1]		12 to 16 inches		Over 16 inches		Total[1]		
	Harvested	Released	Harvested	Released	Harvested	Released	Harvested	Released	
Mainstream									
1976 (12-inch minimum)	-- (--)	-- (--)	410 (--)	520 (--)	30 (--)	40 (--)	440 (--)	-- (--)	30,500 (--)
1980-1983 (Slotted)	2060 (±900)	5440 (±2230)	-- (--)	1050 (±710)	30 (±60)	70 (±160)	2090 (±910)	5510 (±2250)	34,500 (±6,400)
North Branch									
1976 (10-inch minimum)	1110 (--)	770 (--)	430 (--)	300 (--)	60 (--)	40 (--)	1600 (--)	1110 (--)	24,300 (--)
1980-1983 (10-inch minimum)	1030 (±440)	1360 (±720)	360 (±210)	470 (±310)	50 (±70)	60 (±90)	1440 (±577)	1890 (±965)	26,800 (±4,900)

[1] For North Branch this includes only trout larger than 10 inches because a 10-inch minimum size limit was in effect.

brown trout per hour versus 0.061 brown trout per hour. Total fishing pressure did not change significantly, but a slight increase is suggested by the estimated means. Of course, numbers of fish were not the only difference in the total harvest. The size of fish harvested under the slotted size limit was much smaller than under the 12-inch minimum limit. Almost all the former were between 8 and 12 inches, while the latter were all over 12 inches.

For the same time periods, no significant change was observed in the total harvest of brown trout in the North Branch control section (table 3), although a slight decrease was suggested by the means, 1,600 brown trout before versus 1,440 brown trout after. In terms of harvest per hour, this was 0.066 brown trout per hour versus 0.054 brown trout per hour. Total fishing pressure did not change significantly in the North Branch, but again, a slight increase was suggested by the means.

There were only two other creel survey statistics we can confidently say changed significantly, and those were the changes mandated by law. The number of 8- to 12-inch brown trout harvested increased from near zero under the 12-inch limit to 2,060 under the slotted limit, and the number of 12- to 16-inch brown trout harvested decreased from 410 under the 12-inch limit to near zero under the slotted limit (table 3). We made no deliberate effort to estimate the illegal harvest, but our creel census clerks did observe a small harvest of illegal-sized fish during the study. We can only hope this illegal harvest was negligible or that it was no more severe under the slotted limit than the 12-inch limit.

Even though effects of the slotted limit on other creel survey statistics could not be verified statistically, some effects suggested by the data were interesting to think about. For example, the estimated catch of 12- to 16-inch brown trout, that is, the sum of harvest and catch and release, was nearly the same in the after period as the before period in both study and control sections --930 before versus 1,050 after. Yet, we know the number of brown trout of this size in the population decreased by over 40% (table 1). Thus, it appears anglers caught the same number of fish, even though fewer fish were available. Either they improved their fishing skills over the years, or they caught, released, and recaptured the average brown trout from one and one-half to two times. The former explanation is flattering, but difficult to accept by those of us who have observed the behavior of anglers over the years. The latter explanation makes the most sense, because an increase in the release rate of brown trout in this size category was mandated by the slotted limit on the Mainstream. In the North Branch, it appears in general that the release rate of trout has increased over the years, even though the fish may be legal to harvest. Anglers reported releasing about 41% of the legal-sized brown trout on the North Branch in 1976 and about 57% in the 1980's. This increase in release rate was probably responsible for maintaining a relatively constant catch of 12- to 16-inch trout in the North Branch (730 before versus 830 after), while abundance declined.

FISHERIES MANAGEMENT IMPLICATIONS

The greatest effect of the slotted size limit was not in the trout population itself, but in the change in man's use of the trout population. In the Mainstream, anglers traded the harvest of 12- to 16-inch brown trout for about a five-fold increase in the total number of brown trout harvested, although the new harvest consisted of smaller fish (8 to 12 inches). At the same time, they still caught at least as many 12- to 16-inch brown trout, but had to release them.

Is harvesting five trout between 8 and 12 inches worth as much as harvesting one trout larger than 12 inches? Fenske (1984) surveyed the opinions of Michigan trout anglers and found a nearly even split on a question very similar to this one. Of those questioned, 45% thought it was better to catch five 8-inch trout, while 39% thought it was better to catch one 12-inch trout. Is catching and releasing a 12-inch trout worth as much as catching and harvesting a 12-inch trout? We suspect most anglers would answer no to this question, yet there is no doubt catching and releasing a trout has considerable value. The main point of these questions was to suggest that beyond protecting trout populations from extermination, the primary function of fishing regulations is to satisfy different, and often competing, angler preferences. From this standpoint, slotted size limits have the desirable feature of being able to compromise between those who prefer to harvest many small trout and those who prefer to catch fewer larger trout. However, it should also be recognized that this same compromise could be achieved more simply by dividing a stream into two smaller sections; one section having an 8-inch minimum limit for the first group of anglers and one having a 12-inch minimum limit for the second group of anglers. Likewise, a similar compromise could be achieved with a 10-inch minimum limit applied to the whole area (see Clark 1981).

With regard to the fishery in the Burton-to-Wakeley study section, it appears that no change in fishing regulations is capable of returning the number of large brown trout observed there in the past. Brown trout growth has declined, and short of fertilizing the river with sewage again, we doubt if growth can be returned to former levels. However, this part of the river continues to produce large numbers of medium-sized trout and still produces a few trophy-sized trout for fly fishermen.

Slotted limits were not as good as a 12-inch minimum size limit in producing larger trout in the Au Sable River, and this is probably true in general for trout stream fisheries. The reason was that harvest mortality had a more significant effect in reducing survival of trout to older ages and larger sizes than it had on increasing growth rate to larger sizes. If harvest of mid-sized trout had any effect on growth rate of brown trout in our study, the effect was minor, and results of other studies indicated growth rates of trout in streams were independent of relatively large changes in population density and fishing intensities (Cooper 1949; McFadden et al. 1967; McFadden 1969; Bachman 1984). Thus, it appears that the following "rules of thumb" for trout streams regulated under simple minimum size limits will also apply for slotted limits (Clark 1981):

1. If the minimum limit is set at a small size, for example 6 to 8 inches, a large number of trout can be harvested, but the average trout caught will be smaller and the number of trophy-sized trout both in the population and the harvest will be fewer than for higher size limits. In the case of slotted limits, the catch of trophy-sized trout will be inversely related to the width of the harvest slot.
2. If the minimum limit is set at a large size, for example 12 to 15 inches, the total number of trout harvested will be small, but the average trout caught will be larger and the number of trophy-sized trout in the populations will be greater than for lower size limits. Catch-and-release regulations, or a closure of the fishery, will produce the maximum number of trophy-sized trout in the population.
3. The higher the existing fishing mortality is, the more noticeable any change in size limits will be.

This also means the effects of slotted limits can be predicted about as well as those of simple minimum size limits, at least on a per-recruit basis. Our predictions for the Mainstream brown trout in 1979 (Clark et al. 1980) were fairly accurate on a per-recruit basis, but we could not have predicted the change in environmental conditions and its effect on recruitment of young fish.

Finally, results of this study demonstrated the importance of an experimental control. Without a control it is impossible to determine to what degree observed changes were caused by management actions versus environmental effects. Although the Au Sable River is known for its stability in environmental conditions for trout, changes in conditions had a relatively large effect on annual recruitment of juvenile trout during our study. Annual brown trout recruitment decreased about 23% and brook trout recruitment increased by about 40% in the North Branch where fishing regulations remained constant. Such population changes might also be interpreted as natural cycles in the competitive struggles of two ecologically similar species (Hutchinson 1978), and we think competition between brook and brown trout must be playing at least some part in observed population changes. However, relative sizes of year classes produced in both branches of the river were in phase, and this is more indicative of environmental influences. We think subtle changes in average temperatures during the growing seasons for young trout might have been the cause. Colder temperatures correlated with poor brown trout year classes and good brook trout year classes in our data set, and the average temperature in our after period was colder.

What is the future of the slotted size limit in the Au Sable River? We think this should depend on the popularity of the regulation among anglers. The slotted limit is just one of many regulations that could be used to protect Au Sable brown trout from extinction due to overfishing. Other biological effects of regulations are comparatively unimportant, except for their influence on satisfying the desires of different factions within the angling community.

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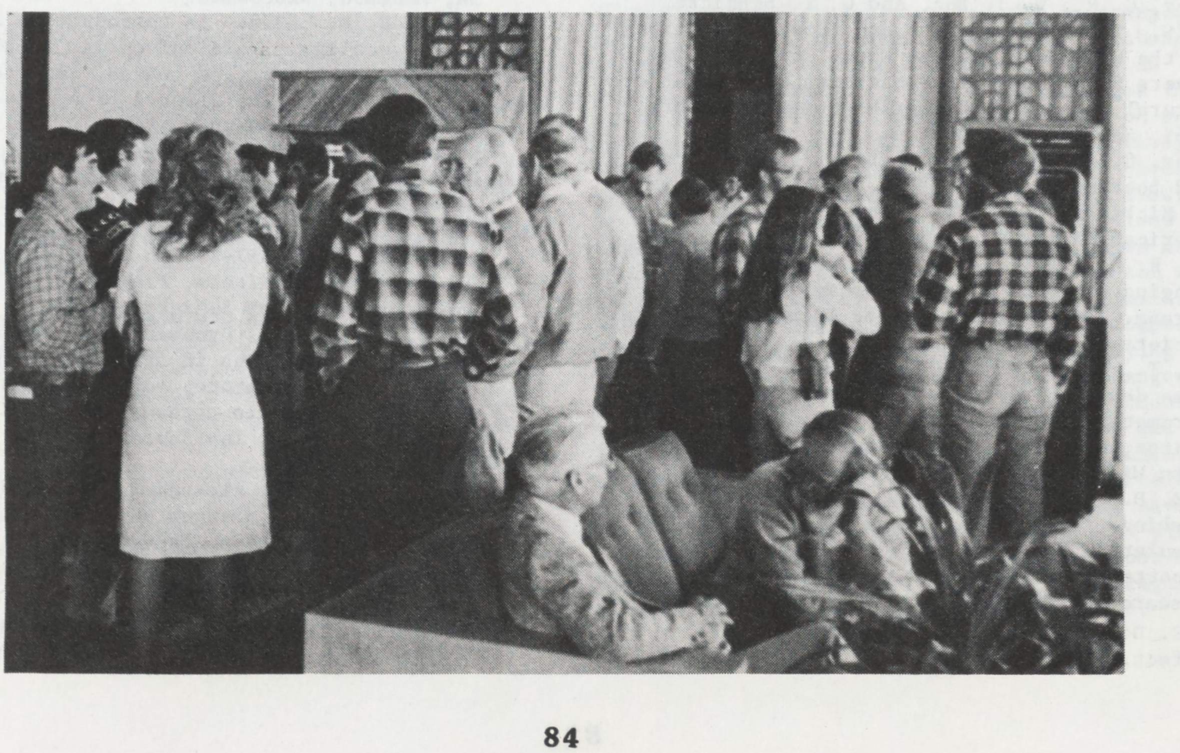

Missouri Trout: Wise Use of a Limited Resource[1]

Spencer E. Turner[2]

Abstract.--Missouri is geographically outside the natural distribution of salmonids yet has developed a popular and progressive trout management program on 177 miles of cold-water streams and one 1,730 acre cold-water reservoir. The resource even though limited is used by more than 120,000 trout fishermen annually who fish more than 2,400,000 hours. Missouri's trout management program provides trout fishermen with a diversity of opportunity including four trout parks, seven trout management areas, three trophy trout management streams, four wild trout management streams that support self-sustaining rainbow trout populations andone tailwater trout fishery. The program has been extremely successful and provides a balance between put-and-take stocking of hatchery trout and special catch and release fisheries; it meets the needs of most trout fishermen.

INTRODUCTION

Missouri is geographically outside the natural distribution of salmonids, yet it has a popular and progressive trout management program. The program offers trout fishermen diverse opportunities including put-and-take fishing, a trophy trout fishery using stocked brown trout, a wild rainbow trout fishery, and a tailwater trout fishery that has the elements of both a put-and-take trout fishery and put-grow-and-take trout fishery.

HISTORY OF MISSOURI'S TROUT PROGRAM

Missouri's trout program evolved during the past 104 years from an emphasis on stocking to a balanced program reflecting the limited nature of the resource and the needs of the trout fishermen. Salmonids were first stocked in 1878 when California salmon were released in tributaries of the Missouri and Mississippi rivers to create a migratory run of salmon from the Gulf of Mexico to Missouri (Turner 1979). Brook trout from Wisconsin were released in 1879 and rainbow trout from the McCloud River in California in 1880. This early period was characterized by indiscriminate releases of rainbow trout, steelhead, brown trout, Atlantic salmon, grayling, lake trout and brook trout in streams, rivers and ponds that were too warm to support salmonids. Most were stocked from the Neosho National Fish Hatchery in Neosho, Missouri. In 1911, state trout hatcheries began stocking large numbers of rainbow trout. It was a very political period of time, and patronage rather than biology frequently prevailed.

This all changed in 1937, following establishment of the Missouri Department of Conservation as a constitutional state agency. Trout stocking was restricted to cold water streams in three trout parks and five trout management areas which were open to public fishing. The program was expanded over the years and now includes four trout parks, 11 trout management areas, four wild trout fishing areas, and Lake Taneycomo, the largest tailwater trout fishery in the midwest (Turner 1979). The operation and maintenance costs of the trout program are supported by trout fishermen through the purchase of daily trout tags, trout stamps and special winter fishing permits.

MISSOURI'S TROUT RESOURCE

Most of the state's waters are too warm to support trout throughout the year. Trout live in the headwaters of a few streams in the Ozarks where cold water flows from springs at a constant 57 degrees F. Missouri has approximately 177 miles of streams cold enough to support trout (less than 1.0 percent of the stream-miles in the state) and one 1,730 acre cold-water reservoir, Lake Taneycomo (Turner 1979). Approximately 45 percent of the resource, 77 miles, is open to the public for fishing; the remainder is privately owned and trespass is strictly controlled. Today, Missouri's trout resource is utilized by more than 120,000

[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-24, 1984.

[2] Fisheries Research Biologist, Missouri Department of Conservation, Columbia, Missouri.

Figure 1. Missouri's trout parks receive more than 435,000 fishing trips annually or approximately 54,000 trips per mile of stream. Most trout park fishermen do not fish in the trout management areas or the wild trout streams.

trout fishermen who spend an estimated 2,400,000 hours fishing for trout.[2]

MANAGEMENT PROGRAMS

Trout Parks

Missouri's four trout parks: Bennett Spring, Montauk, Roaring River (State Parks) and Maramec Trout Park, are located downstream from major springs and have either a hatchery or rearing facility. Management in the three state parks is by cooperative agreement. The division of Parks and Historic Preservation of the Department of Natural Resources administers the park and the Department of Conservation manages the trout rearing and stocking program. Maramec Trout Park is privately owned by the James Foundation. The Missouri Department of Conservation, by lease agreement, manages the trout fishery.

At all parks, 10-inch rainbow trout are stocked daily at a rate of 2.25 trout per estimated fisherman from March 1 through October 31. In 1983, the parks received more than 435,000 fishing trips, or approximately 54,000 fishing trips per mile of stream (fig. 1). A daily tag costs $1.50.

Each winter, from the second weekend of November, until the second weekend of February, the parks are open for catch and release trout fishing. Each park is stocked before the opening with catchable size trout and excess broodstock, some weighing 8 pounds or more. A $5.00 permit is required. In 1983, the trout parks received 2,962 winter fishing trips. Anglers fished 16,325 hours and caught 24,465 trout.[3]

Trout Management Areas

Missouri's trout management areas are not as intensively managed as the trout parks and provide trout fishermen with more traditional trout fishing in a natural setting (fig. 2). Seven streams are stocked with catchable rainbow trout 8 to 10 times annually for put-and-take trout fishing. Fishermen must have a fishing license and a $5.00 trout stamp and may harvest five trout daily.

Three streams, Meramec River, Current River and North Fork of White River are managed for trophy trout fishing. Both rainbow and brown trout

[2] Dr. Weithman, A. S. 1984, Personal communication, Supervisor, Water Quality Unit, Missouri Department of Conservation, Columbia, Missouri.

[3] Unpublished information, in the Fisheries Division files, Missouri Department of Conservation, Jefferson City, Missouri.

Figure 2.-- Missouri's trout management areas and wild trout managment streams provide more traditional trout fishing in a natural setting.

are present in these streams. Brown trout are stocked annually because water temperatures are too warm during the incubation period for them to reproduce successfully.[4] Two of the three trophy areas receive rainbow trout that escape from trout parks located upstream from the areas. The other trophy area has a wild rainbow trout population. The daily limit is three, 15-inch trout per day. Fishermen on the Meramec River are also restricted to the use of artificial lures and flies to reduce mortality of released trout.

The Meramec and North Fork of White River trophy areas receive more than 11,000 fishing trips annually (Turner 1983). The reason for the popularity is fishing success. In the Meramec River trophy area, the most popular, fishermen caught and released more than 14,000 brown and rainbow trout and harvested an average of 1,000 trout annually from 1978 to 1980. Fishing success, defined as catching at least one trout per trip, ranged from 32 percent to 82 percent per year. Fishing was rated excellent by 18 percent, good by 40 percent, fair by 32 percent, and poor by 10 percent of the fishermen.

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[4] Turner, Spencer E. 1981, unpublished information in Fisheries Research files, Columbia, Missouri.

WILD TROUT MANAGEMENT

Rainbow trout spawning and the presence of wild rainbow trout in Missouri streams was first reported by Maynard (1887). Later observations by Bridges (1966) and Turner (1975 and 1979) indicated that there were approximately 12 self-sustaining wild rainbow trout populations in Missouri. The existence of these populations was largely the result of protection by private landowners. In the 1970s, sections of these streams containing wild trout were opened to public fishing under state-wide trout regulations and the populations declined. To protect these small, unique populations, the Missouri Department of Conservation implemented wild trout management regulations on four streams; Crane Creek, Mill Creek, Spring Creek and Blue Spring Creek, beginning in 1982.

The wild rainbow trout in Crane Creek are unique; they are descendents of trout stocked from the McCloud River in California in the 1880s. Electrophoretic protein studies of the genus _Salmo_ indicate that the rainbow trout population in Crane Creek is one of the few remaining pure, McCloud strain rainbow trout populations in the United States (Gall et al. 1981). To protect this unique population, harvest was prohibited on two miles of Crane Creek owned by the Missouri Department of Conservation and fishermen are restricted to artificial lures and flies.

At Blue Spring Creek, Spring Creek, and Mill Creek, management is slightly different. Fishermen must release all trout less than 18 inches and must use artificial lures and flies. The regulation allows the wild trout to spawn at least once before harvest, yet still gives fishermen the opportunity to keep a trophy-sized trout. These wild trout streams all support trout larger than five pounds.

TAILWATER TROUT MANAGEMENT

Missouri has one tailwater trout fishery, Lake Taneycomo. When Table Rock Dam upstream from the reservoir was closed in 1958, Lake Taneycomo was changed to a cold-water reservoir because of hypolimnetic water releases. The environment is ideal for trout and Lake Taneycomo has gained national recognition as one of the best trout fisheries in the United States. This fame brought with it a price. Fishing pressure increased from approximately 7,500 trips in 1959 to more than 350,000 fishing trips in 1983 (Turner 1984). Catch rates decreased in the mid-1970s to less than 0.5 trout per hour and the numbers of large trout--larger than five pounds--caught decreased significantly.

In 1979, the Missouri Department of Conservation designated a management committee to develop and implement a management plan to improve the structure of the trout population and improve fishing. The committee was comprised of three fisheries biologists, a trout pathologist, a hatchery manager, and a local conservation agent.

The trout management plan developed by the committee recommended increasing the number of catchable rainbow trout stocked, adding 50,000 brown trout to the stocking program, and requested that fishermen voluntarily release 12- to 16-inch trout they catch. This was the first time fishermen had been asked to participate in a management program without being forced to by regulation.

Before the management plan was implemented, fishermen released approximately 13 percent of the trout they caught and less than 4 percent of the trout population was 16 inches or larger.[5] More than 90 percent of the trout stocked were harvested in 60 days or less.

The management plan was implemented in 1980, and within 3 years, the numbers of trout between 12 to 16 inches voluntarily released by fishermen increased to 29 percent; trout larger than 16 inches increased to more than 8 percent of the population, and catch rates improved to 0.62 trout per hour.

DISCUSSION

Trout management in Missouri and elsewhere has changed drastically from a single faceted program relying only on stocking to a multifaceted program involving both wild and stocked trout, and put-and-take and catch-and-release fishing during the past 20 years. The change is the result of changing economic and social conditions, better informed trout fishermen and a better understanding of the resource. We can no longer rely on simply stocking more trout to meet increasing demands. Hatchery trout have become increasingly more expensive to produce and facilities are taxed to near capacity. We know enough about trout management, wild or stocked, to taylor management programs to provide fishermen with a diversity of opportunities commensurate with the habitat or the resource.

Missouri's trout management program is a good example of providing a diversity of opportunities with a limited resource. Regardless of whether an angler is a fly fishing purist or once-a-year bait dunker, or whether he wants to fish with the multitudes for trout stocked daily or fish in relative solitude for large trout, anglers have these choices in Missouri.

Trout fishermen who visit our trout parks know trout will be available. To them, it doesn't matter that these trout are fresh out of the hatchery; they can see the fish in the stream and catch them relatively easily. They pay for this privilege by buying a daily tag. It would be impossible to maintain a trout fishery of this magnitude without stocking trout and this program fills a definite need. Most of the fishermen at the parks do not fish the trout management areas or the wild trout streams.

[5] Unpublished information in Fisheries Research files, Missouri Department of Conservation, Columbia Missouri.

The trout management areas provide a different type of trout fishing experience. They are less crowded and fishermen can experience more traditional trout fishing in a more natural setting.

Our trophy trout fishery is popular because fishing is consistently good throughout the year and anglers have a realistic opportunity to catch a large trout. We have found that fishermen are satisfied catching and releasing numerous small sublegal trout as long as the stream produces that occasional trophy. It does not matter whether the trout they catch are wild or stocked. Hatchery trout can be used to support trophy trout fisheries in areas where wild trout populations can not be maintained naturally; catch rates may even be higher. Harvest of trout in a trophy fishery will be low, but fishing quality is measured in the number of satisfied trout fishermen and high catch rates, not numbers of trout harvested. Our experience is that fishermen like the option of fishing for large trout and will accept special restrictions limiting harvest.

Wild trout fisheries, in Missouri or elsewhere, are aesthetically pleasing to trout fishermen and are a valued resource to be cherished and protected. Wild trout populations in the midwest are unique and a very limited resource that can provide high quality fishing but support only a limited harvest. Most importantly, wild trout fisheries add important diversity to a trout program. In Missouri, our wild trout populations are small, usually less than 40 pounds of trout per acre. Under state-wide regulations of 5 trout, fishing pressure could (and did) quickly reduce the number of trout to a level below that needed to maintain a viable natural population. These populations require special fishing regulations to prevent overharvest and reduce catch-and-release mortality.

The management of Lake Taneycomo is unique because the anglers have been given a choice in helping to make fishing better by voluntarily releasing trout. The key to this approach was publicity. We used newspaper articles, permanent signs at all of the accesses, smaller signs distributed to all of the resort owners along with stick-down rulers for their boats, and public meetings to accomplish our objectives. If a management approach such as this will work at Lake Taneycomo, I believe it will work at some less intensively used areas.

In summary, Missouri's trout program provides a balance between put-and-take stocking of hatchery trout and special catch-and-release trout fisheries. Although Missouri's trout resource is very limited, a multifaceted and intensive management program has been extremely successful and meets the needs of most of our trout fishermen.

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PANEL: Catch and Release — Panacea, Myth, or Tool?[1]

Gardner Grant[2]

The Catch and Release Panel benefited from the well-prepared papers published here.

Perhaps even more stimulating was the open question-and-answer session which followed the formal presentations.

A spirited discussion of law enforcement and its relation to Catch and Release and other special regulation situations developed some thought-provoking comments. We heard that "90% of all anglers" are honest and obey the regulations, but we also heard of illegal canning operations by some of the minority who flaunt the law. We pondered the allocation of limited resources to law enforcement in special regulation situations as opposed to other areas of responsibility. There is concern over effectiveness and levels of law enforcement. Clearly, time should be devoted to this subject at Wild Trout IV.

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[1]Panel discussion leader's summary remarks of the panel at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24, 1984.

[2]Gardner Grant is an active conservationist from Scarsdale, New York, He is a National Director of Trout Unlimited, Chairman of the Board of the American Museum of Fly Fishing, and Past President of the Federation of Fly Fishers.

Perhaps even more important, we learned that the presently limited amount of Catch and Release waters have proven immensely popular, creating unanticipated people problems. One official commented that the demand obviously exceeds the supply, that a poll of anglers in his state indicated that over 50% wanted the opportunity to fish Catch and Release waters, yet much less than 1% of that state's trout waters are so designated. A permit system was mentioned as a possible solution to over-crowding, but several speakers felt this should only be considered as a last resort. One posed the question - "When are you making the best use of the resource? - when you are getting the maximum number of people out there enjoying it and doing a lot to protect it, or when you are keeping people away from it?" Clearly, there is need for the expansion of Catch and Release angling opportunities and Wild Trout IV should focus on the response to this.

The question of barbed versus barbless hooks provoked interest. While most speakers agreed that the literature indicates that there is little difference in mortality using either, some questioned the validity of the "literature." There seems to be need for more research here, hopefully to be reported on at Wild Trout IV.

In summary, Catch and Release has moved beyond the experimental arena. Where properly applied, it is a successful and cost-effective means of providing great angler satisfaction. Its very success has generated questions that we must now address.

A Synopsis of Some New York Experiences with Catch and Release Management of Wild Salmonids[1]

Gerald A. Barnhart and Robert Engstrom-Heg[2]

Abstract. Catch and release regulations are an effective tool for accomplishing a variety of wild salmonid management objectives in New York. Absolute or partial harvest restrictions have been successfully employed to: 1) increase angler catch rates of wild brown, rainbow and lake trout; 2) reduce need for stocking to maintain acceptable stream brown trout and lake trout fisheries; 3) restore or enhance wild brown, rainbow and lake trout populations; and 4) in limited instances, increase the maximum size, abundance and catch rate of large stream trout. Attainment of these objectives has typically been at a cost in take-home yield, but size limit protection has frequently produced increased yields. Implementation of catch and release regulations has typically caused short-term depression in angler use followed by partial or complete recovery within several years. Neither lack of angler compliance nor hooking mortality have precluded attainment of catch and release objectives. Short and long-term impacts of harvest restrictions have frequently been different and distinct. Evaluation schemes for catch and release management programs should include several years of post-implementation monitoring.

INTRODUCTION

The New York State Bureau of Fisheries has applied the catch and release concept to salmonid management for several decades. New York is blessed with an abundant coldwater resource comprised of 15,000 miles of streams and more than three million acres of lakes and ponds suitable for salmonid management. This extensive resource is diverse, as are its uses and users. The response of the resource, and its users, to catch and release management has also been diverse, ranging from disappointing to highly satisfactory. The purpose of this paper is to describe New York's experience with catch and release and to draw some broad conclusions about the conditions necessary for successful catch and release management of New York wild salmonids.

Let us begin by defining catch and release as the immediate return of angler-caught fish to the water from which they were taken. Catch and release management may be partial, i.e., focused on release of a subset of fish caught, or absolute, all fish caught are released. It may be mandated through a management agency's statutory authority to regulate fisheries or implemented through public education and voluntary participation. Catch and release management may be employed to attain a variety of fishery objectives. In New York, those objectives have included: 1) increase fishing quality, either size of fish caught, or number, or both; 2) rehabilitation or enhancement of wild salmonid stocks; and 3) combinations of the above. The following case histories provide examples of how fish and fishermen have responded to catch and release management in a variety of New York waters.

CASE HISTORIES

Amawalk Outlet

Amawalk Outlet is located in northern Westchester County, New York (fig. 1). It begins as a bottom draw release from Amawalk Reservoir and flows southerly about 2.9 miles before entering Muscoot Reservoir. Average width is about 30 feet and mean summer discharge is about 40 cfs. Summer water temperatures rarely exceed 70°F. Although the stream is located in one of the most densely populated areas of New York its banks are undeveloped and it is well shaded. The lower 1.9 miles of the stream contain abundant spawning, rearing and holding habitat.

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[1]Paper presented at the Third Wild Trout Symposium, Mammoth, Wyoming, September 24-25, 1984.

[2]Gerald A. Barnhart is Supervising Aquatic Biologist, New York State Department of Environmental Conservation, Albany, N.Y.

Robert Engstrom-Heg is Research Scientist II, New York State Department of Environmental Conservation, Stamford, N.Y.

...orts of subjects...

Scientists may have PCB solution

By Martin Armstrong
Special Correspondent

Scientists at General Electric and Michigan State University may have finally discovered a solution to the PCB dilemma.

It seems that a naturally occuring bacteria is slowly eating away at the PCBs in the Hudson River and is changing the highly toxic and cancer causing chemical into a less toxic form.

The less toxic form of PCB at this time is not considered a potential hazard to either humans or to marine life.

GE scientists discovered the existence of the non-oxygen using bacteria last year when studies and tests showed a change in PCB concentrations in the Hudson River. These results were confirmed by researchers at Michigan State.

PCBs, known to cause cancer in laboratory animals, were dumped legally into the Hudson River by General Electric before scientists realized the potental danger. In 1977 Congress banned the manufacturing of PCBs, but the chemical is still in use today.

Scientists are now studing ways to better utilize, control and grow the bacteria.

Similar changes, although not as dramatic, have occurred at New Bedford, Mass. and at Waukegan, Ill.

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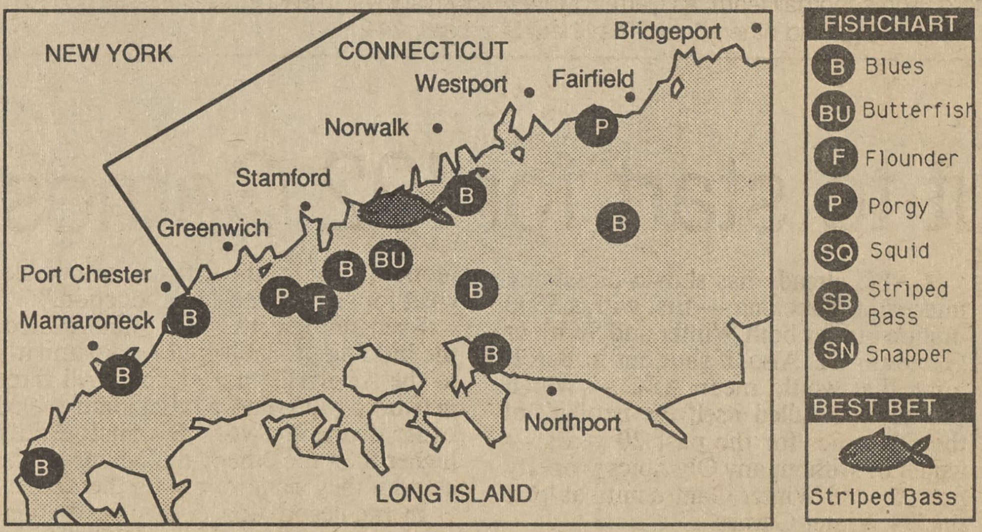


The cold and windy weather has forced many anglers to hang up their gear for the winter. It's a shame because the fishing is hot.

Saltwater anglers can choose from striped bass, bluefish, blackfish and winter flounder. And freshwater anglers are catching trout and freshwater bass.

The best bet of the week was striped bass. There were thousands of stripers in our area last week as the migratory fish passes through on its way to the Hudson River for the winter. The only problem, however, is that most of the stripers taken are too small to keep.

Fred Salvatore took some time off from his bait and tackle shop to do some fishing with his pal John Horynak. Fishing at the "cows," the two anglers caught, and released, 50 stripers. Buoyed by their success the two anglers returned the next day and caught 85 more bass. The largest of their catch measured a less-than-legal 30 inches. All of the stripers were caught on diamond jigs.

Also doing well at the "cows" last week was Jan Darula, who caught 60 striped bass and 40 bluefish. The bass were all too small to keep and the largest bluefish weighed in at 16 pounds. All of the fish were caught while drifting a bucktail lure.

Salvatore's wasn't the only tackle shop owner who took some time off last week to catch some fish. John Pipicelli, coowner of Sportsman's Den, went flounder fishing with Billy Coolidge last Monday despite the high winds. Fishing in water only two to three feet deep at Greenwich Cove, the two anglers caught 25 flatties in less than two hours. All of their fish were large enough to keep and many of the fish weighed between one and two pounds. All were caught on sandworms.

Also catching some flatties last week were Ronnie Bova, who boated 25 flounder while fishing at Scott's Cove and George Russo, who reeled in a pail full while fishing at the "gut" in Darien.

Blackfishing is still good though not many fishermen are willing to brave the cold winds and rough water to catch them. Those anglers who are willing to battle the elements are catching some nice fish, however.

The largest blackfish of the week was caught by Joe "The Lobsterman" Criazzina, who caught a 14-pound blackfish while working the waters at buoy 32A last Sunday. He caught the big black with a green crab.

Gene Barry did well last weekend while fishing at Smith's Reef. Barry boated 15 blacks, each weighing about six pounds, also with green crabs.

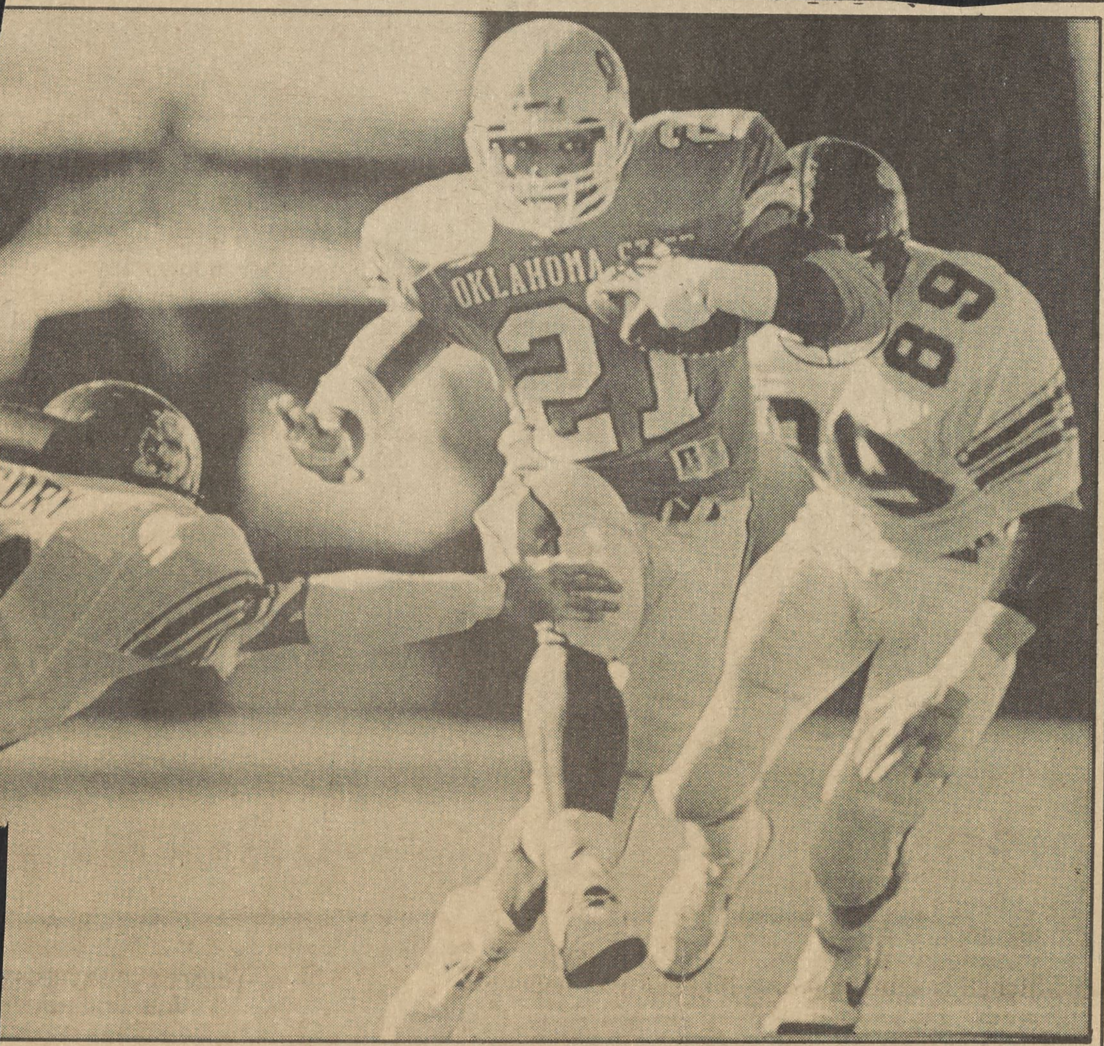
Tony Macy reeled in eight blackfish while fishing at Smith's Reef. All of his fish weighed between eight and 10½-pounds and were caught on green crabs.

Vu Tan of Greenwich has discovered a way to beat the high price of lobsters. Tan has been catching lobsters in the waters off Steamboat Road by throwing out a ball of fishing line with some sandworms attached. It seems that when the lobsters, some of which weigh more than three pounds, try to grab the worms they get tangled in the ball of line. Once tangled, Tan simply pulls his valuable catch to shore.

Trout fishing in the Saugatuck River is improving as the water temperature in the reservoir drops. Several local residents have been catching lots of rainbow trout in the upper reaches of the river. Some of the fish caught measure more than 20 inches.

In the lower Saugatuck, at the Trout Management Area off Ford Road, Dan Howard and Frank Lederer caught, and released, six brown and rainbow trout last Tuesday morning. They were using a variety of flies and streamers.

Martin Armstrong is a Stamford resident who writes on fishing topics when he isn't too busy fishing.



AP PHOTO

...te tailback Barry Sanders (21) cuts past Kansas defenders Jason Tyrer (right) and Troy Gregory
...ay's game.

...hold key to bowl pairings

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ence unbeaten since Texas in 1983. Arkansas, 10-0 and 7-0 in the conference, finishes the season against Miami on Nov. 26. Their opponent in Dallas on the day after New Year's figures to be UCLA or Florida State.

Reggie Slack threw two touchdown passes on bootleg rollouts as ninth-ranked Auburn knocked No. 17 Georgia out of the SEC race and kept its title and Sugar Bowl hopes alive with a 20-10 victory.

The Tigers, 9-1 overall and 5-1 in the SEC, can gain a share of the conference championship with No. 12 Louisiana State by beating Alabama in Birmingham on Nov. 25.

LSU clinched at least a share of the title earlier in the day with a ...

ed for the Hall of Fame Bowl against either LSU or Auburn.

Iowa appears a good bet to play in the Peach Bowl, regardless of how the Hawkeyes finish the season, a Peach Bowl representative said Saturday.

D.J. Mackovets, the only bowl scout in the press box for Saturday's Ohio State-Iowa game, said prior to the game that Peach Bowl officials would like to see Iowa win its last two games, which would give it a 7-3-2 overall record.

Iowa played to a 24-24 tie with Ohio State, and now stands 5-3-3 for the season.

Freshman Antonio Walker scored on a blocked punt and Collin Mackie hit four field goals as ...

Pittsburg... defeats Penn St.

Freshman back powers Panthers to 14-7 win

Associated Press

STATE COLLEGE, Pa. — Freshman Curvin Richards ran for 159 yards and a touchdown yesterday and became the sixth runner in Pittsburgh history to gain more than 1,000 yards in a season as the Panthers beat arch-rival Penn State, 14-7.

Richards, who now has 1,091 yards, helped Pitt, 6-3, win its fourth straight game and keep alive its hopes for a Sun Bowl bid.

COLLEGE ROUNDUP

Penn State dropped to 5-5, and unless the Nittany Lions can beat or tie No. 1 Notre Dame next week, they will suffer their first losing season in 50 years.

The victory enabled Pitt to close the gap in this 88-year-old series to 43-41-4. Scouts from the Sun, Aloha and All-American Bowls, all looking for a strong eastern independent, attended the game.

Ohio State 24, Iowa 24

IOWA CITY, Iowa — Jeff Skillett, who missed two earlier field goals, booted a 40-yarder with 16 seconds to play to give Iowa a 24-24 Big Ten tie with Ohio State.

Iowa stands at 5-3-3 overall and 3-1-3 in the conference, while Ohio State is 4-5-1 and 2-4-1.

Ohio State tied the game at 21 on its first possession of the second half when Scotty Graham scored on a 7-yard run to cap a 78-yard, 7-play drive.

Pat O'Morrow then gave the Buckeyes their first lead of the day, 24-21, with a 39-yard field goal with 8:22 to play.

Iowa quarterback Chuck Hartlieb, who threw for two touchdowns, then marched the Hawkeyes from their own 33 to the OSU 10 before the drive bogged down. A 32-yard kick by Skillett, who also missed a 46-yarder before halftime, was wide to the right and the Buckeyes simply had to run out ...

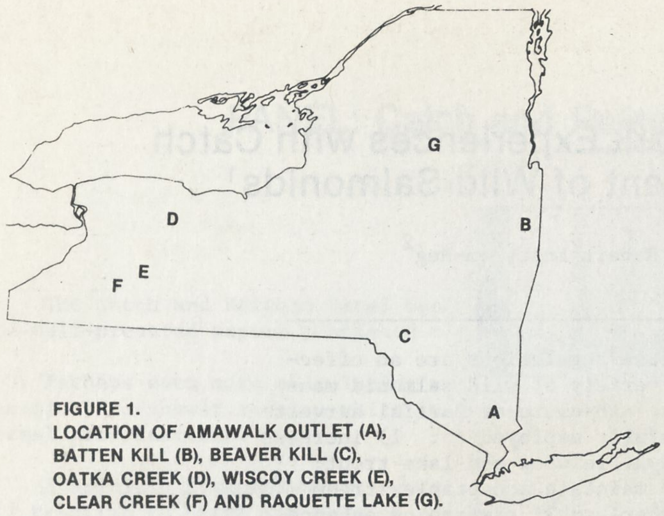

FIGURE 1.
LOCATION OF AMAWALK OUTLET (A), BATTEN KILL (B), BEAVER KILL (C), OATKA CREEK (D), WISCOY CREEK (E), CLEAR CREEK (F) AND RAQUETTE LAKE (G).

Prior to 1963, Amawalk Outlet was managed as a put and take trout stream and received annual stockings of brook (Salvelinus fontinalis) and brown trout (Salmo trutta) yearlings. Field surveys in 1961 and 1962 documented significant numbers of naturally spawned brown trout and suggested the lower 1.9 miles could be successfully managed for wild brown trout. Stocking was discontinued in that section and restrictive regulations were implemented for the entire 2.9-mile reach. The regulations included no allowable harvest, hereafter referred to as no-kill, and a terminal tackle restriction limiting anglers to artificial lures with a single hook point.

Ten standardized electrofishing stations were established and sampled annually from 1963 through 1972 to evaluate the impact of the restrictive regulations (Bonavist 1973). Six of these stations were the same as those sampled in 1962. No direct estimates of trout numbers or biomass were made. Sampling effort was consistent among years; each annual collection was considered one unit of effort and the number of trout collected was assumed to be a valid indicator of abundance. Scale samples were taken for age and growth analysis.

Electrofishing results showed a dramatic increase in numbers of brown trout greater than eight inches immediately after implementation of the restrictive regulations (table 1). However, less than one percent of the trout captured were greater than 14 inches and virtually none were larger than 16 inches.

Beginning with the 1966 angling season, harvest restrictions were eased to allow fishermen to creel one trout, 14 inches or larger. Electrofishing collections made from 1966 through 1968 indicated this change had no impact on the abundance or size distribution of brown trout (table 2). The 1966 and 1968 collections did indicate that two and three-year old brown trout were growing substantially slower and were in poorer condition than in previous years (fig. 2). Additionally, collections of 0+ brown trout were much lower in 1968 than in prior years (table 2). In response to a marked decrease in growth, condition and recruitment, harvest restrictions were further relaxed in 1969 to allow anglers to creel two fish, 10 inches or greater in length. Later collections indicated this change resulted in a slight decrease in relative abundance of brown trout over 10 inches but increased growth of two and three-year old fish (fig. 2) and increased recruitment (table 2). A cursory survey in 1979 indicated continued strong natural recruitment and an abundance of adult brown trout from 6.7 to 15.6 inches (Gann 1979)[3].

Batten Kill

The Batten Kill enters New York from Vermont and flows westerly for 30 miles through Washington County to the Hudson River (fig. 1). The upstream 3.9 miles have been managed under restrictive harvest regulations since 1971. Average width of that section is about 70 feet and mean summer discharge is approximately 65 cfs. Summer water temperature rarely exceeds 70°F. Substrate is predominantly rubble and gravel; abundant spawning, rearing and holding habitat is present.

[3]Gann, M. C. 1979. Data on file NYSDEC, Region 3 Fisheries Management Unit, New Paltz, N.Y.

Table 1. Size distribution of brown trout collected from six stations on Amawalk Outlet before (1962) and after (1963-65) implementation of restrictive harvest regulations.

Total Length (inches)	1962 No.	1962 %	1962 Cum. %	1963 No.	1963 %	1963 Cum. %	1964 No.	1964 %	1964 Cum. %	1965 No.	1965 %	1965 Cum. %
2.0-3.9	119	68.8	68.8	82	40.0	40.0	2	0.9	0.9	56	16.8	16.8
4.0-5.9	8	4.6	73.4	5	2.4	42.4	5	2.3	3.2	16	4.8	21.6
6.0-7.9	23	13.3	86.7	40	19.5	61.9	40	18.2	21.4	125	37.4	59.0
8.0-9.9	16	9.2	95.9	52	25.4	87.3	79	35.9	57.3	72	21.6	80.6
10.0-11.9	3	1.7	97.6	21	10.2	97.5	77	35.0	92.3	51	15.3	95.9
12.0-13.9	4	2.3	100	3	1.5	99.0	15	6.8	99.1	14	4.2	100
14.0-15.9				2	1.0	100	2	0.9	100			
16.0+							1	0.4				
Total	173			205			220			334		

Table 2. Size distribution of brown trout collected from ten stations on Amawalk Outlet under three restrictive harvest regulation regimes.

Total Length (inches)	No-Kill 1963 No.	%	1964 No.	%	1965 No.	%	14-in. Size Limit 1-Fish Bag Limit 1966 No.	%	1968 No.	%	10-in. Size Limit 2-Fish Bag Limit 1969 No.	%	1970 No.	%	1971 No.	%	1972 No.	%
2.0-3.9	122	40.5	330	35.6	71	15.1	422	38.6	6	0.9	0		442	65.7	223	56.7	25	3.4
4.0-5.9	8	2.7	5	0.5	19	4.1	20	1.8	10	1.4	0		18	2.7	15	3.8	22	3.0
6.0-7.9	54	17.9	292	31.5	156	33.3	308	28.2	205	29.1	19	11.2	6	0.9	215	54.7	348	47.0
8.0-9.9	75	24.9	186	20.1	96	20.5	198	18.1	332	47.1	101	59.4	63	9.4	87	22.1	231	31.2
10.0-11.9	30	10.0	96	10.4	89	19.0	124	11.3	116	16.5	47	27.5	128	19.0	46	11.7	101	13.6
12.0-13.9	6	2.0	15	1.6	35	7.5	19	1.7	30	4.3	3	1.8	15	2.2	7	1.8	10	1.4
14.0-15.9	5	1.7	2	0.2	3	0.6	3	0.3	5	0.7			1	0.1			2	0.3
16.0+	1	0.3							1	0.1							1	0.1
Total	301		926		469		1094		705		170		673		393		740	

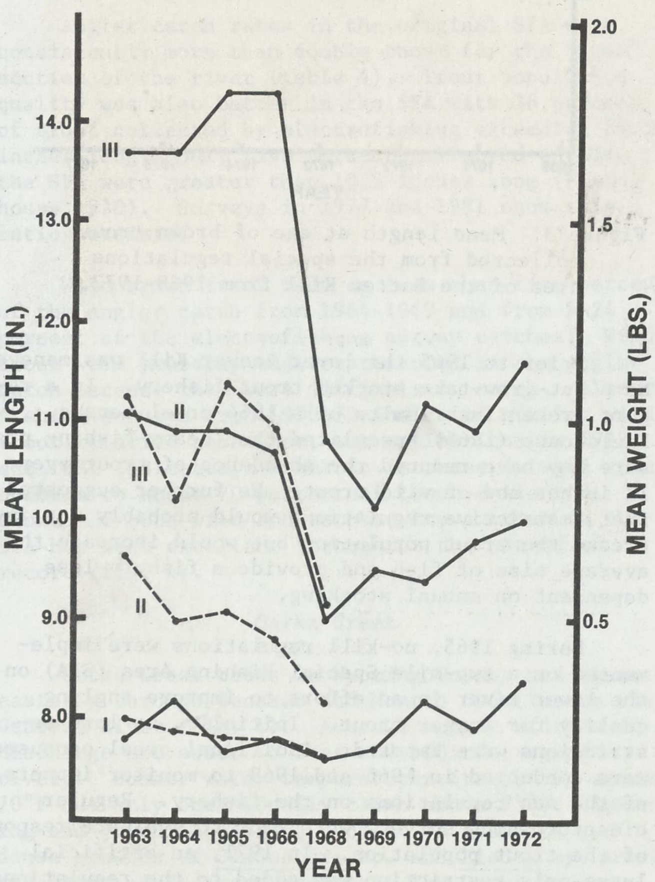

Figure 2. Mean length (——) and weight (----) at age of brown trout collected from Amawalk Outlet from 1963-1972.

Prior to 1968 the upstream 3.9 mile reach of the Batten Kill was managed as a put-grow-take trout stream and stocked annually with brook and brown trout yearlings. Electrofishing surveys and creel census in 1967 showed significant numbers of wild brook and brown trout and indicated that this section could be successfully managed for wild trout. Stocking was discontinued and the surveys and census repeated in 1968 to monitor impacts on the fishery.

Comparison of the creel census data show angler use and harvest declined dramatically following cessation of stocking. Total catch rates declined, but the average size of angler-caught brown trout increased (table 3). Lantiegne (1969) concluded intense fishing pressure prior to 1968 was stimulated by yearling stocking and resulted in over-harvest of wild trout. The decreased fishing pressure in 1968 resulted in reduced harvest of small wild trout and an increased abundance of two-year old trout.

Restrictive harvest regulations were implemented on this reach of river in 1971 in an attempt to take advantage of more abundant, older wild trout and maximize production of trophy trout. The regulations included a 12-inch size limit, 3-fish creel limit and restriction of terminal tackle to artificial lures only. Standardized electrofishing surveys were conducted from 1971-75, and 1977 and a creel census was made in 1973 to evaluate impacts of the new regulations on the fishery.

The 1973 creel census showed catch rates of wild fish were equal to those achieved when the Batten Kill had been stocked (table 3). Creel rates were dramatically reduced by the 12-inch limit but average size of brown trout creeled increased to 13.2 inches. Brook trout made up only two percent of all fish creeled indicating the 12-inch limit was functioning essentially as no-kill protection for that species. The census also revealed that anglers were releasing 48 percent of all legal-sized trout they caught.

Electrofishing surveys indicated abundance of wild trout was greater in 1973 than 1971 when the restrictive regulations were implemented. Brown trout exhibited a slight slowdown in growth of one, two and three-year old fish and a decrease in condition of larger individuals indicating stockpiling was resulting in intraspecific competition (Lantiegne 1974). This led to a recommendation to extend the open trout season to all year to promote additional harvest of larger brown trout and decrease competition. In 1975, the season was extended from April 1 - September 30 to all year.

Electrofishing collections in 1974 indicated no further decline in growth or condition of brown trout. But, collections made in 1975 and 1977 indicated growth and condition had further declined (Miller 1978). Mean length of age three brown trout collected in both years was less than the 12-inch size limit (fig. 3). Brook trout abundance declined in 1974, fell further in 1975 and in 1977 was about one-third of the 1971-73 values. The size limit was reduced to ten inches in 1981.

Beaver Kill

The Beaver Kill rises in the heart of the Catskill High Peaks and flows 44 miles westerly through Ulster, Sullivan and Delaware Counties before joining the East Branch of the Delaware River (fig. 1). Downstream of Roscoe, New York, the Beaver Kill is a large river with mean width and summer discharge of 100 feet and 125 cfs, respectively. Summer water temperatures frequently exceed 70°F and occasionally are above 75°F. There is little trout spawning or juvenile rearing habitat in this section, but holding habitat for yearling and older trout is abundant and of exceptional quality.

Probably no other river is as storied in the literature and traditions of American trout angling. The Beaver Kill below Roscoe is classic dry fly water with long flat pools separated by runs and riffles. It has long held a reputation of providing quality fishing for moderate size brown trout and regular catches of fish over three pounds. Much of the Beaver Kill's past reputation and present popularity is based on a fishery for stocked trout. But, wild trout historically and presently contribute to the overall quality of this system.

Table 3. Comparison of angler use and catch data for the Batten Kill in 1967, 1968 and 1973.

	Year		
	1967	1968	1973
Angling Pressure (hr/acre)	471	214	325
Trout Caught	12,488	4,387	11,489
brown trout	10,333	3,773	6,893
brook trout	3,166	614	4,596
Catch Rate (no/hr)	0.62	0.48	0.66
brown trout	0.51	0.41	0.40
brook trout	0.11	0.07	0.26
Trout Creeled	7,742	2,910	745
brown trout	6,426	2,503	730
brook trout	1,316	407	15
Creel Rate (no/hr)	0.39	0.32	0.04
brown trout	0.32	0.27	0.04
brook trout	0.07	0.05	-
Mean Total Length (inches)			
brown trout	9.4	9.9	9.5
brook trout	8.5	8.2	8.6

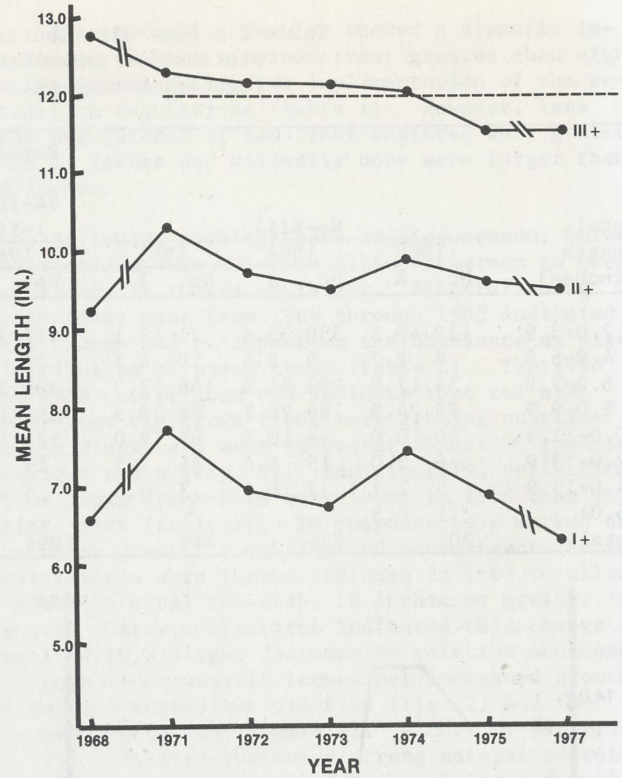

Figure 3. Mean length at age of brown trout collected from the special regulations area of the Batten Kill from 1968-1977.

Prior to 1965 the lower Beaver Kill was managed as a put-grow-take stocked trout fishery. In a report presenting results of a 1964 creel census, Fieldhouse (1965) speculated that heavy fishing pressure may have reduced the abundance of trout over 12 inches and of wild trout. He further suggested that restrictive regulations would probably not increase the trout population but would increase the average size of fish and provide a fishery less dependent on annual stocking.

During 1965, no-kill regulations were implemented on a two-mile Special Fishing Area (SFA) on the lower river in an effort to improve angling quality for larger trout. Initially, no lure restrictions were imposed. Additional creel censuses were conducted in 1965 and 1969 to monitor impacts of the new regulations on the fishery. Regular electrofishing surveys were made to evaluate response of the trout population. In 1971, an artificial lures only restriction was added to the regulations for the Beaver Kill SFA and in 1972 it was expanded to cover an additional 0.5 miles of stream. A second, no-kill SFA, 1.6 miles long, was created at Horton, downstream of the original, in 1975.

Angling pressure on the SFA was lower in 1965 than for the Beaver Kill in general in 1964 or 1965, but rebounded to higher levels by 1969 (table 4). Aerial angler counts indicate the original SFA continue to receive intensive pressure and supports nearly half of the angling between Roscoe and Horton. Similarly, the new SFA at Horton enjoys great popularity, supporting nearly 75 percent of the fishing between Horton and the river's mouth.

Table 4. Comparison of angler use and catch data for the Beaver Kill in 1964, 1965 and 1969.

	Year (Section)[1]				
	1964 (Total)	1965 (Open)	(SFA)	1966 (Open)	(SFA)
Angling Pressure (hr/acre)	200	166	108	179	215
Trout Caught	13044	12534	4886	12879	6629
Catch Rate (no/hr)	0.37	0.42	1.68	0.40	1.14
Trout Creeled	13044	12534	0	12879	0
Creel Rate	0.37	0.42	0	0.40	0

[1]Open = statewide angling regulations
SFA = special fishing area

Angler catch rates in the original SFA were consistently more than double those for the "open" section of the river (table 4). Trout population quality was also better in the SFA with 36 percent of trout collected by electrofishing exceeding 10.5 inches long. Only five percent collected outside the SFA were greater than 10.5 inches long (Fieldhouse 1970). Surveys in 1977 and 1981 show this ratio persists.

Wild brown trout made up less than five percent of the angler catch from 1964-1969 and from 9-24 percent of the electrofishing survey catches. Wild trout were probably underrepresented in the angler catch because they were difficult to catch. Electrofishing surveys from 1970-72 indicated similar wild trout relative abundance, but collections in 1977 and 1981 indicated a dramatic increase in wild trout numbers to about 70 percent of trout collected. Growth of both wild and stocked brown trout in the SFA has been excellent throughout the period of record (fig. 4).

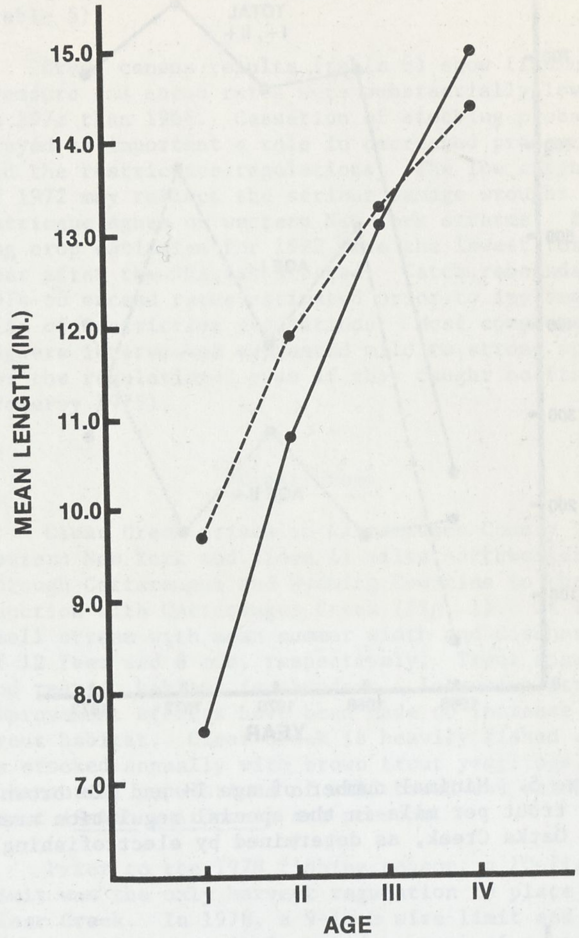

Figure 4. Mean length of stocked (----) and wild (——) brown trout collected from the Beaver Kill special fishing area from 1968-1981.

Oatka Creek

Oatka Creek rises in Wyoming County and flows easterly through Genesee and Monroe Counties to the Genesee River (fig. 1). Average summer width and discharge are about 75 feet and 100 cfs, respectively. Summer water temperatures frequently exceed 70°F but only occasionally climb above 75°F. Spawning and juvenile rearing habitat is abundant and dense growths of *Cladophora* sp. and *Elodea* sp. provide excellent adult trout shelter. The Oatka is naturally fertile and further enriched by treated sewage.

Prior to 1968 a one-mile section of Oatka Creek was privately owned and fishermen access was restricted. The County of Monroe purchased this section of the stream in 1968 for development of a County Park. A stream survey was conducted to determine the status of the Oatka's wild brown trout population and to ascertain what management would be required to perpetuate this resource under public ownerhsip. The 1968 survey revealed an excellent population of wild brown trout (Abraham 1976).

Because of Oatka Creek's proximity to the major metropolitan area of Rochester, New York, significant fishing pressure was expected after the stream was opened to the public. Regulations in place for the initial public season consisted of only a 10-fish bag limit. Restrictive harvest regulations, consisting of a 12-inch size limit, three-fish bag limit and artificial lures only tackle limitation were implemented on a 1.7-mile Special Regulations Area (SRA) in 1969 to protect this high quality resource. Electrofishing surveys were conducted in fall from 1968-1973 to evaluate impact of the regulations on the trout population. Response of the fishery was monitored by creel census in 1970.

The density of combined age one and two brown trout increased dramatically after implementation of special regulations (fig. 5). Combined density of the two age groups has remained relatively constant, but distribution between age groups has shifted dynamically as a result of strong year classes and intraspecific competition (Abraham 1976). Age three and older fish remained at a relatively stable level of abundance. Growth of one and two-year old brown trout declined over the period of study (fig. 6) but age three fish were still recruited to legal size. Electrofishing surveys in 1976 revealed numerous brown trout over 15 inches up to a maximum of

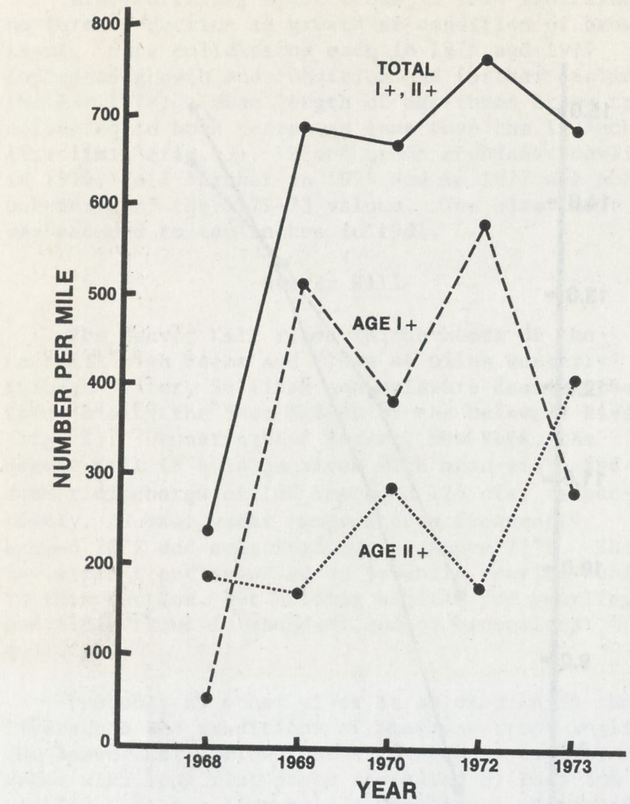

Figure 5. Minimal number of age I+ and II+ brown trout per mile in the special regulation area, Oatka Creek, as determined by electrofishing.

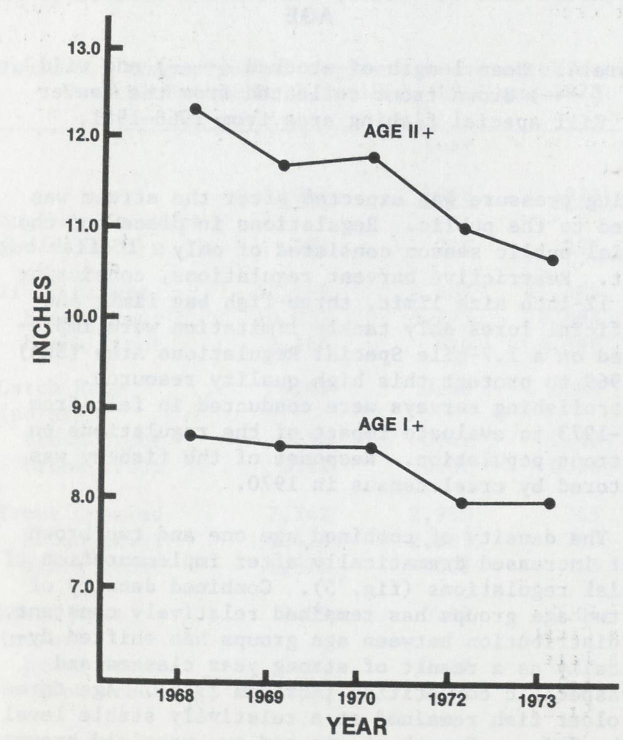

Figure 6. Mean length at age of brown trout collected from the special regulations area of Oatka Creek from 1968-1973.

22 inches (Abraham et al 1976)[4].

Oatka Creek supported tremendous angling use in 1970 and although angling pressure was more than 1500 hours per acre, catch rates remained at an acceptable 0.41 fish per hour (Abraham 1976). Creel rate was only 0.08 fish per hour but the intensive use of the area indicated a high degree of angler acceptance of the fishery produced under special regulations.

Wiscoy Creek

Wiscoy Creek arises in southern Wyoming County and flows 21 miles to the Genesee River (fig. 1). The watershed lies within a dairy and potato farming region approximately 50 miles southeast of Buffalo and 60 miles southwest of Rochester. Summer stream flows average 10 cfs in the 15 miles of trout water. Summer water temperatures only occasionally exceed 75°F. Mean width is about 30 feet.

Up through 1966, a 10.5-mile section of the Wiscoy was stocked with 1,480 brown trout yearlings per mile and in 1966 all were marked. Several stations were surveyed by electrofishing in 1966 and wild young-of-year brown trout were collected at each location. Samples from five stations on private, posted land yielded few stocked trout but indicated a mean standing crop of 66 pounds per acre of wild brown trout. Public sections of the stream supported standing crops less than 30 pounds per acre (Holmes 1966)[5]. Holmes proposed an acceptable level of fishing could be maintained on public sections of the Wiscoy through natural reproduction if special regulations were imposed. In 1968, restrictive harvest regulations including a 12-inch size limit, three-fish creel limit and artificial only tackle limitation were implemented on a one-mile Special Regulations Area (SRA). No fish were stocked in the SRA but the remainder of the unposted portion of the stream continued to be stocked with yearling brown trout.

Standing crop of trout was estimated in September of 1967-74, 1976, 1978, 1979 and 1980 (Pomeroy 1975, 1977, 1979, 1980a, 1980b) for four stations in the SRA and four stations downstream of the SRA. Creel censuses were conducted over the unposted portions of the Wiscoy in 1966, 1972 and 1974 (Pomeroy 1975). Spot censuses were conducted in the SRA in 1968 and 1969.

Mean standing crop of brown trout in the SRA nearly doubled after the first year of restrictive harvest regulation while remaining constant in waters outside the SRA (table 5). Spot censuses in 1968 and 1969 showed a creel rate of only 0.01 trout per hour and catch rates of 0.27 and 0.17 trout per hour, respectively. The 12-inch limit was essentially functioning as a no-kill regulation. To provide for some harvest and yet, still maintain a strong wild trout population, the harvest regulations were modified to a 10-inch size limit and 5-fish creel limit

[4]Abraham, W. J., R. King and J. Robbins 1976. Data on file NYSDEC, Region 8 Fisheries Management Unit, Avon, N. Y.
[5]Holmes, E. D. 1966. Data on file NYSDEC, Region 9 Fisheries Management Unit, Olean, N. Y.

Table 5. Estimated number of brown trout per acre in each age class, and total pounds of trout per acre in Wiscoy Creek in September, 1967 - 1980.

Section	Year	Age 1+	2+	3+	4+	Lbs./ Acre	Mean
SRA	1967[1]	63	15	1	2	28.0	
	1968[2]	67	56	19	4	50.3	
	1969	115	44	7	4	53.4	
	1970	93	78	7	4	61.6	57.7
	1971	98	85	19	5	74.7	
	1972	67	59	11	1	48.5	
	1973[3]	112	79	7	2	63.0	
	1974	174	85	19	1	78.0	
	1976	68	54	32	7	64.0	
	1978	126	39	12	5	59.3	65.5
	1979	64	48	17	3	59.0	
	1980	90	78	18	2	69.8	
Lower	1967[1]	23	17	4	4	21.9	
	1968	17	23	11	4	20.8	
	1969	53	20	8	1	22.9	19.1
	1970	14	29	3	1	16.0	
	1971	22	12	9		13.8	
	1972[4]	17	25	8		19.6	
	1973	36	52	8	1	35.2	
	1974	70	56	14	3	41.7	29.3
	1976	17	17	14	3	20.8	
	1978	46	23	3	3	25.9	
	1979[5]	26	35	4	1	29.0	
	1980	84	70	18	1	59.3	53.1
	1981	41	36	27	7	70.9	

[1]five-fish bag limit.
[2]12-inch size limit, three-fish bag limit and artificial lures only.
[3]10-inch size limit, five-fish bag limit and artificial lures only.
[4]10-inch size limit and five fish bag limit.
[5]10-inch size limit, five-fish bag limit and supplemental stocking.

in 1973. These regulations were also implemented on the remainder of the Wiscoy in Wyoming County in 1972 and all stocking ceased. Anglers continued to be limited to artificials only in the SRA but bait is permitted in the rest of the stream.

Implementing the less restrictive size and creel limits had no negative impact on brown trout in the SRA. Mean standing crop under the 10-inch limit has been slightly higher than under the 12-inch limit (table 5). The 10-inch limit on the lower sections of the Wiscoy did produce an increased biomass of brown trout. Mean standing crop increased about 50 percent after size limit implementation, but was still only about half that of the SRA. Pomeroy (1975) speculated wild trout recruitment in the lower sections was not adequate to bring the biomass up to carrying capacity. A fall fingerling brown trout stocking policy was begun in 1978 for the lower Wiscoy. Standing crop of brown trout subsequently increased a further 80 percent to nearly equal that estimated for the SRA (table 5).

Creel census results (table 6) show fishing pressure and catch rates were substantially lower in 1972 than 1966. Cessation of stocking probably played as important a role in decreased pressure as did the restrictive regulations. The low catch rates of 1972 may reflect the serious damage wrought by Hurricane Agnes on western New York streams. Standing crop estimates for 1972 were the lowest for any year after the SRA was created. Catch rebounded by 1974 to exceed rates estimated prior to implementation of restrictive regulations. Most completed anglers interviewed expressed mild to strong approval for the regulations, even if they caught no fish (Pomeroy 1975).

Clear Creek

Clear Creek arises in Cattaraugus County in western New York and flows 11 miles northwesterly through Cattaraugus and Wyoming Counties to the junction with Cattaraugus Creek (fig. 1). It is a small stream with mean summer width and discharge of 12 feet and 6 cfs, respectively. Trout spawning and rearing habitat is abundant. Intensive stream improvement efforts have been made to increase adult trout habitat. Clear Creek is heavily fished and is stocked annually with brown trout yearlings. Substantial populations of wild brown and rainbow trout (*Salmo gairdneri*) are present.

Prior to the 1978 fishing season, a 10-fish bag limit was the only harvest regulation in place on Clear Creek. In 1978, a 9-inch size limit and five-fish bag limit was implemented as part of a statewide trout regulations change. Population estimates were conducted in October 1977, May and September 1978, May and September 1979 and September 1980 and creel censuses were run in 1978 and 1979 to evaluate the effects of the regulation change.

The new regulations had little impact on wild brown trout biomass or the fishery for wild brown trout (Engstrom-Heg and Hulbert 1983), but did have an important effect on wild rainbow trout. Fall estimates of two-year old rainbows increased from 3 per acre in 1977 to 22 per acre in 1978 (table 7).

Table 6. Comparison of angler use and catch data for Wiscoy Creek in 1966, 1972 and 1974.

	Year 1966	1972	1974
Angling Pressure (hr/acre)	966	461	479
Trout Caught	13247	2391	7930
Catch Rate (no/hr)	0.32	0.14	0.43
Trout Creeled	13247	1265	1247
Creel Rate (no/hr)	0.32	0.07	0.07

Table 7. Estimated number and biomass of wild rainbow trout per acre in Clear Creek from 1977 - 1980.

	Year					
	1977	1978		1979		1980
Age	Fall	Spring	Fall	Spring	Fall	Fall
0	7		20		545	283
1	45	5	9	10	10	267
2	3	29	22	12	13	17
3		1		8	4	1
Total Biomass (lbs/acre)	5.3	4.3	5.4	6.2	8.3	22.9

Spawning of these fish in Spring 1979 produced a fall population of age 0+ fish about 75 times greater than that observed in 1977. This strong production carried through to Spring 1980 when yearling rainbows were six times more abundant than in 1977.

Creel census results showed anglers expended nearly 1,000 hours per acre of effort on Clear Creek in 1978 and caught an average of 0.12 wild rainbow trout per hour. A simulation of a Clear Creek fishery at that level of effort and no size limit indicated only 3.2 two-year old rainbows would have survived to Fall 1978 as opposed to 22 per acre observed under the nine-inch limit (Engstrom-Heg and Hulbert 1983).

Raquette Lake

Raquette Lake is a 5400-acre lake located in Hamilton County in New York's Adirondack Mountain region (fig. 1). It has a maximum depth of 96 feet but nearly half of the lake is less than 30 feet deep. Total alkalinity is about two ppm. The lake thermally stratifies in summer but the hypolimnion remains well oxygenated. Raquette has been considered good lake trout (Salvelinus namaycush) water since the 1800s. Other common fish species include smallmouth bass (Micropterus dolomieui), whitefish (Coregonus clupeaformis), brook trout, smelt (Osmerus mordax), white sucker (Catostomus commersoni), finescale sucker (Catostomus catostomus), yellow perch (Perca flavescens and brown bullhead (Ictalurus nebulosus).

Raquette Lake has been used by DEC as a source of lake trout eggs since 1933. It has been stocked with lake trout since 1918. Population estimates made in 1941-43 indicated the spawning population of lake trout ranged from 7-10,000 individuals. In the mid-1960s, anglers began to complain of declining fishing success. Coincidentally, DEC field crews reported increased effort was required to obtain the annual egg take quota. In 1968, an intensive survey effort of the Raquette Lake lake trout population was begun. The program included summer juvenile gill netting, fall trap netting and marking of spawning adults and monitoring of the fishery, either via creel census or a volunteer angler diary program. Angling regulations in effect at that time included a 15-inch size limit, three-fish bag limit and April 1 - September 30 season.

Population estimates from 1968-1972, based on fall netting and marking data, indicated the mature lake trout population averaged only about 1,100 individuals as compared to more than 7,000 historically (Shupp 1973). Age and growth analysis showed female lake trout did not mature until 6-8 years of age at 20-21 inches long. Gill netting surveys demonstrated a strong population of juvenile lake trout was present and that it was made up almost entirely of fish of hatchery origin. Angler creel rates were low, 0.03 trout per hour and comprised largely of fish less than 20 inches. Based on these results, Shupp (1973) recommended a 21-inch size limit for Raquette Lake lake trout.

In 1973, an experimental 21-inch size limit was implemented and has remained in effect to the present. The response of the lake trout population to this management measure has been dramatic. By the Fall of 1974 the population of mature lake trout increased threefold to about 3800. Estimates made in 1975-1978 indicate the spawning population stabilized at about 3500 individuals. Angler catch and creel rates averaged 0.29 and 0.08 lake trout per hour from 1973-1978, well above levels observed in 1968. In 1977, juvenile lake trout of wild origin were collected during summer gill netting (Smith and Pfeiffer 1979). The contribution of wild lake trout has increased to about 74 percent since that time (Smith, personal communication)[6].

DISCUSSION

The preceding case histories are representative of New York's experience with catch and release management. Our degree of success, or lack thereof, has been largely determined by the nature of the resource involved and the realism of our fishery objectives.

Fishing Quality

Fishing quality has nearly as many definitions as the Yellowstone River has cutthroats. There is no single measure of trout fishing quality that is acceptable to all New York anglers. Quality is comprised of several elements, variously weighted, depending on the values and desires of the individual fisherman. In New York it may include some mix of at least: 1) numbers or rate at which fish are caught; 2) number of fish creeled; 3) average size of fish caught; 4) maximum size of fish caught; 5) origin, wild or stocked, of fish caught and 6) aesthetic quality of the angling environment.

The use of catch and release regulations in New York has nearly always had a positive impact on angler catch rates. Analysis of data from Amawalk Outlet, Batten Kill, Beaver Kill, Oatka Creek and Wiscoy Creek shows that protective regulations produced an immediate increase in the abundance of two and three-year old brown trout. Creel census results

[6]Smith, D. B. 1984. Personal conversation. NYSDEC, Region 5 Fisheries Management Unit, Ray Brook, New York.

from the Batten Kill, Beaver Kill and Wiscoy reflect that increase and show that angler catch rates also increased. Recycling of fish (i.e., an individual fish caught more than once) contributed significantly to increased catch rates. The combined impact of increased abundance and recycling was sufficient to offset lower vulnerability to angling of wild brown trout as compared to stocked trout. The lake trout fishery of Raquette Lake responded in a like manner, exhibiting increased abundance of lake trout and elevated catch rates.

In all cases, it is likely that an increase (unmeasured and unknown) in hooking mortality was associated with recycling of fish. In no instance was this of sufficient magnitude to offset the benefits of the protective regulations. Use of "artificial lures only" tackle restrictions probably helped minimize hooking mortality on stream fisheries examined (Hulbert and Engstrom-Heg 1980). But even Raquette Lake lake trout, which were frequently caught on bait and also subjected to rapid increase in temperature and decrease in pressure as they were hauled from deep water to the surface and landed, survived the catch and release process frequently enough to produce a net increase in abundance.

By definition, catch and release regulations produce a net decrease in number of fish creeled. The initial decline in fishing pressure following implementation of catch and release management on the Batten Kill, Beaver Kill and Wiscoy Creek is probably partially a result of loss of opportunity to keep trout to eat. Elimination of stocking undoubtedly had a similar effect on the Batten Kill and Wiscoy fisheries. Initial decline in use was generally followed by long-term increased use of Special Regulation Areas. In at least one case, the Beaver Kill, use of the Special Regulation Area is currently much greater than adjoining sections of the river managed with less restrictive regulations. Use of streams examined ranged from 200 to 1,000 hr/acre prior to catch and release management. The most recent use estimates for the same streams, under catch and release regulations, range from 200 to 500 hr/acre. Oatka Creek supports more than 1500 hr/acre under restrictive harvest regulations.

The stockpiling effects of no-kill or high size limit regulations produced an initial increase in the mean length of fish caught in all of the stream fisheries examined. With the notable exception of the Beaver Kill, stockpiling also resulted in long-term declines in growth and condition of wild brown trout due to increased intraspecific competition. Stockpiling and loss of condition of Amawalk Outlet brown trout was severe and may have negatively impacted reproductive success. We believe the virtual failure of the 1968 and 1969 year-classes resulted from the combined impacts of cannibalism and the extremely poor condition of spawning adults and corresponding low egg quality and survival. Batten Kill brown trout growth declined to the point that three-year old trout did not recruit to legal size under a 12-inch size limit. Few of these fish survived to age four or were available for legal harvest. The Wiscoy Creek situation was similar and in both cases the 12-inch size limit functioned essentially as a no-kill regulation.

Impacts of restrictive regulations on maximum size attained by wild brown trout was generally disappointing. The production of trout greater than 14 inches was low in most streams regardless of the harvest regulations employed. The combined impact of growth reductions and hooking mortality may partially explain this observation, but we feel it is more likely a representation of the productivity and habitat of many small to moderate-sized New York trout streams. Data from lightly fished New York wild brown trout populations support this contention (Engstrom-Heg and Hulbert 1983). These populations tend to produce high standing stocks of one and two-year old fish, lesser numbers of three-year olds and almost no fish older than four. Preall (1984) estimated the population of wild brown trout in Furnace Brook, (a small, lightly fished stream in central New York) at 381.4 kg/ha. Seven percent of trout collected were three-year olds and only one percent were four. Exceptions to this generalization usually occur in our larger, productive rivers with limited spawning and juvenile rearing habitat, but good holding habitat in the mainstem. The Beaver Kill is a good example. Recruitment to this system is limited but relatively stable with production occurring in the upper river and small tributaries. This limited production is not sufficient to overload the carrying capacity of the main river. Intraspecific competition does not negatively impact reproductive success or growth and large, old, wild trout are comparatively abundant.

Rehabilitation/Enhancement of Wild Stocks

Restrictive harvest regulations produced an increased abundance of two and, to a lesser extent, three-year old wild brown trout in the streams examined. On the Batten Kill, Wiscoy Creek and Oatka Creek, the increase was sufficient to produce a satisfactory catch rate in the absence of supplemental stocking and at high levels of angler use. In all streams examined, except the Beaver Kill, the increase in wild trout abundance was immediate, indicating that the regulations operated by protecting yearling and two-year old trout. Even at use levels approaching 1,000 hr/acre and under liberal harvest regulations, wild brown trout maintained sufficient spawning stocks to perpetuate and even increase in abundance once juveniles were afforded protection. Restrictive harvest regulations are rarely needed to ensure successful reproduction or stock maintenance of New York wild brown trout. Such regulations can increase abundance of older trout and decrease or eliminate the need for supplemental stocking to maintain a satisfactory fishery. Harvest protection for wild brown trout is probably unnecessary at angling pressures less than 150 hr/acre, may produce modest increases at 150 to 400 hr/acre and can cause quite dramatic increases under intensive fishing pressure of 400 to 1500 hr/acre.

Protection of wild brown trout may have had adverse impacts on the Batten Kill's wild brook trout population. Abundance of brook trout mirrored brown trout growth, showing a continuous decline from 1971 through 1977 to one-third of initial levels.

Wild rainbow trout are more vulnerable to overfishing than wild brown trout in New York. Data from Clear Creek show that overharvest had depressed the spawning stock to the point that recruitment was threatened. Implementation of size limit protection produced an increased abundance of three-year old rainbows and, subsequently, a phenomenal increase in young-of-year and yearling wild rainbows. Fishing pressure on Clear Creek was intense, nearly 1,000 hr/acre, atypical of most wild rainbow streams in New York. Applicability of catch and release regulations to wild rainbow trout depends on fishing pressure and growth rates. Heavily fished, fertile, rainbow streams can definitely benefit from regulations which protect spawning stocks.

Wild lake trout stocks also suffer negative impacts from overharvest. The data from Raquette Lake clearly show that spawning stocks and recruitment can be reduced by overfishing and that these negative impacts can be reversed through judicious use of size limits. Size limit protection of stocked lake trout increased the Raquette Lake spawning stock threefold within two years. Within four years, wild lake trout juveniles were found and wild fish now make up three quarters of the juvenile lake trout population, the balance originate from annual yearling stocking.

CONCLUSIONS

Catch and release regulations can be used in a variety of New York wild trout waters to accomplish specific objectives. Stream fisheries with wild trout enhancement objectives can be successfully managed with a partial catch and release approach (i.e., size limits). But, size limits will rarely produce significant benefits at use levels less than 150 hr/acre. Selection of an appropriate size limit depends on stream fertility, size, habitat quality, recruitment, use and yield targets. A nine-inch size limit is adequate for fisheries used at 150-400 hr/acre and with dual objectives of optimizing contribution of wild stocks and take-home yield. Higher size limits may be necessary when maximizing catch rate is the primary objective or at use levels greater than 400 hr/acre. A 12-inch limit is the option of choice for larger, fertile New York waters with good trout growth, while 10-inch limit is better for smaller, less fertile streams. Terminal tackle restrictions limiting anglers to artificial lures only are appropriate to minimize hooking mortality due to recycling of trout caught from waters managed under a 10 or 12-inch size limit. Currently, 44 New York streams are managed with this approach and 11 of these have a 10-inch or higher size limit.

No-kill regulations directed at producing more big fish have limited application to New York's wild trout stream fisheries. Currently, five stream sections are managed as absolute catch and release waters, but wild fish dominate in only two, both on the Beaver Kill. Our experience with stockpiling, reduced growth and condition and fluctuating recruitment, indicate no-kill is not an appropriate approach for most New York streams. Future use of no-kill in streams will likely be confined to large, fertile waters where recruitment is limited and stable, or to stocked streams where recruitment is controlled. There are several large stream systems in New York where absolute catch and release may eventually be the management approach of choice, but current fishing pressure does not justify no-kill at this time. Waters in the Delaware River and Saranac River systems are good examples.

Catch and release regulations have wide application to restoration of wild lake trout fisheries in New York. We currently use a 21-inch size limit as the statewide regulation for lake trout and employ a 23-inch limit in two lakes with ongoing restoration programs. In an alternate restrictive approach, we use a one-fish bag limit for lake trout in Lake Erie and may soon follow suit in Lake Ontario. Regulations implemented as part of a current landlocked Atlantic salmon (*Salmo salar*) restoration effort in Lake Ontario include a 25-inch size limit and one-fish creel limit.

Catch and release works, and works well, in New York. It is a tool we would be loath to lose, but not the only tool available to tackle wild trout management. The diversity of both New York's wild trout resource and its users demands that catch and release be an important tool, but not the only strategy used to attain our wild salmonid management objectives.

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Catch-and-Release May Be the Answer — Now, What Was the Question?[1]

John Baughman[2]

Abstract.--Wyoming's experiences with "special regulations" have followed typical patterns seen in other parts of the country. Many fisheries managers traditionally opposed restrictive angling regulations in favor of management for maximum sustained yield. Earliest programs utilizing special regulations were politically motivated, often limited only to terminal tackle restrictions, and generally unsuccessful in improving fishing. Recent programs involve establishing specific fishery objectives, utilization of size limits in conjunction with terminal tackle restrictions, and thorough pre and post-regulation evaluation. Fishery management in the future will follow two important trends: 1) more programs will be directed towards specific management objectives, 2) there will be greater public involvement in designing management plans.

BACKGROUND

The evolution of catch-and-release fishing regulations in Wyoming has followed a typical pattern seen in many parts of the country.[3] Until recently, management of nearly all waters was directed towards maximum sustained yield (MSY). This never caused many problems since we have had the luxury of a lot of water and few people. Also, it is not surprising that MSY would be standard procedure since most American anglers were raised with the ideal of catching and keeping a limit of fish, and several generations of fishery biologists were taught straight MSY at our universities. Up until about 10 years ago, biologists were still learning that old fish were a drain on production because of predation and slow growth, any fish that succumbed to natural mortality rather than a frying pan was wasted, and that our goal was to maximize poundage in the fisherman's creel. Naturally, we resisted restrictive angling regulations because they conflicted with our traditional definition of fish management.

Eventually, certain user groups began asking for "special regulations" as means to improve fishing. The early demands were usually to have some waters set aside for fishing with flies or flies and lures only. Most of these requests were ignored because we felt such programs discriminated against bait fishermen and would do little towards improving fishing. After all, if someone wanted to fly-fish and throw back everything he caught he could do that anywhere. Much of the literature on terminal tackle restrictions from the 1950's, 1960's and early 1970's supported these contentions. (Hunt, et al. 1962; Shetter and Alexander 1962; Latta 1973; Klein 1974).

Disagreements between biologists and some user groups continued over the role of terminal tackle restrictions in management programs. Finally, enough political pressure was brought to bear on fish managers, and terminal tackle restrictions were implemented on a few waters.

Unfortunately, most of these programs failed to produce a positive response in the fishery (i.e., more and/or larger fish). The reasons they usually failed were because of little baseline data, lack of objectives, and poor design. What

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[1]Paper presented at the Wild Trout III Symposium; September 24 and 25, 1984; Yellowstone National Park, Wyoming.

[2]Fisheries Management Coordinator, Wyoming Game and Fish Department, Cheyenne, Wyoming, 82002.

[3]"Catch-and-release" refers here to regulations which require part or all of the fisherman's catch to be returned to the water unharmed.

we had were "regulation" programs rather than "management" programs. Users were asking for regulations - and they got them - when what they really wanted was better fishing.

In the mid to late 1970's things began to change. The concept of optimum sustained yield (OSY) began to replace MSY (i.e., management to optimize public benefits through consideration of a wide array of factors rather than simply maximizing pounds of fish harvested). Long-range planning and management by objective crept into conservation agencies' operations. Public participation became more important in formulation of governmental plans and programs. Equally important, a number of good studies were done on the use of catch-and-release regulations in conjunction with terminal tackle restrictions to produce more and/or larger fish (Chapman, et al. 1973; Johnson and Bjorn 1975; Marcoux 1980; Varley 1980).

The stage was finally set for catch-and-release regulations to become an important and effective management tool.

PRESENT STATUS

We are all aware that fishery management programs utilizing catch-and-release regulations to improve the size structure and/or population numbers of fish are becoming more common and more successful. In Wyoming, the Game and Fish Department adopted a policy governing use of restrictive angling regulations (e.g., catch-and-release) in 1980. Basically, the policy recognizes catch-and-release regulations as a valid and effective management tool when properly used. However, these regulations are to be used as a means to an end and not an end in themselves. Management programs utilizing catch-and-release regulations require baseline data, specific objectives, and evaluation. Terminal tackle restrictions won't be used simply to discriminate against certain segments of the angling public, and terminal tackle restriction to artificial lures (including flies) is favored over fly only restrictions since significant differences between hooking mortality rates of fish caught on flies versus lures have not been consistently demonstrated (Wydoski 1977). Size limits are also favored over no-kill regulations since the expectation and/or opportunity to keep some fish is an important part of the angling experience for many fishermen (Phillips and Ferguson 1977).

Since this policy was adopted, catch-and-release regulations have been implemented on 61 miles of major rivers and several hundred miles of smaller streams. Even though these programs did not go into effect until 1982, the fish populations in most waters are already showing a significant response. The management program on 6 miles of the upper Green River (Kurtz 1980) is a good example of where baseline data, specific objectives, public involvement, catch-and-release regulations, and evaluation have all been integrated in a program that works.

The upper Green River is classified as a "Blue Ribbon" or nationally important trout stream. It is managed as a basic yield fishery, i.e. stocking is necessary due to very limited natural recruitment. Habitat on the stretch in question is relatively intact, but the river is subject to extreme, natural low flows in winter months. Consequently, over-winter habitat imposes severe limits on the standing crop of trout. Low natural recruitment and heavy fishing pressure coupled with limited over-winter habitat resulted in post-season trout populations as low as 475 trout (over 6 inches) per mile. The average size trout in the post-season population ranged from 7.8-8.1 inches between 1975 and 1979, with only 3.3-6.1% of the trout population exceeding 10 inches. Historical data, occasional large fish, and growth analysis indicated the river was capable of growing and sustaining much larger fish. An angler attitude survey was also run during this 5 year study to determine how fishermen perceived the quality of their angling experience and to get their impressions on needs for improvement.

Following informal public meetings and a formal public hearing, a new regulation was implemented on a 6 mile stretch of the Green River in 1982. The regulation reduced the creel limit from six to two trout, only one of which could exceed 20 inches. All trout between 10 and 20 inches have to be released, and fishing is permitted with artificial flies and lures only.

Objectives for this section had been established as follows:

1. Maintain a post-season trout population of at least 850 trout/mile and 14.3 lbs./acre.
2. Maintain a post-season trout population with a size structure of 20-25% over 10 inches (based on trout over 6 inches).
3. Maintain a total catch rate of at least 1.0 trout/hour.
4. Maintain an average trout size of 9 inches in the creel.
5. Encourage the harvest of whitefish.

Evaluation through 1983 indicates a rapid response in the fishery. Numbers of 6+ inch trout already exceed the highest levels seen between 1975 and 1981. Catch rates are already exceeding 1.0 trout per hour also. We have not yet reached our objective for the percentage of trout exceeding 10 inches, however, percentage of larger trout should increase quickly as soon as the expanding population stabilizes. Admittedly, the good water flows during the past three winters have hastened the fishery's improvement.

The management program on the upper Green River is working. The reason it is working is because it was well designed and directed towards specific objectives. Use of catch-and-release regulations can be one of the most cost-effective management tools for improving numbers and sizes of fish when used in this manner.

The Green River program and similar programs in Montana, Yellowstone, Idaho, and other states involved years of study before some of the better catch-and-release regulations were implemented. With this background of good data now available, the amount of time and information necessary to design effective management programs utilizing catch-and-release can be greatly reduced. However, at the very minimum it is still essential that data be available on fish numbers, size structure, mortality, and growth potential if we are to continue implementing, evaluating, and modifying good programs.

Specific objectives rather than management procedures should form the basis for management programs. The objectives we are using in Wyoming include standing crop, fish size, and catch rates. Other parameters such as yield and mortality rates have also been used when applicable.

FUTURE TRENDS

The number of waters managed under some form of catch-and-release regulation will increase because fishing pressure is increasing, public attitudes are changing, catch-and-release is a cost/effective management tool, and we have a lot better data on how to use these regulations than we did 10 years ago.

Two other trends in fish management will be even more important:

1. More management programs will be directed towards specific objectives.
2. There will be more public involvement in designing these programs and setting objectives.

The sooner biologists and fishermen recognize and accept these trends and get on with business, the sooner we will become better fisheries managers with a more supportive and satisfied clientele.

Catch-and-release regulations might be the answer to some management problems; sometimes they won't; sometimes they will be part of the answer. Before we can find the right answer we have to ask the right question, and the first question is, "What are the objectives?"

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Ten Years of Catch-and-Release in Yellowstone Park[1]

Ronald D. Jones[2]

Abstract.--The results of ten years of the catch and release regulation on three waters vary from increases in use of 70% on one water to slight decreases on another. Landing rates range from modest decreases to a 100% increase while average size of fish landed has demonstrated increases of up to 15.9%. A maximum size limit on Yellowstone Lake has also shown favorable results while allowing some harvest. The economic benefits of the catch-and-release regulation can also be substantial. Cutthroat trout appear to respond better to the catch-and-release regulation than brook or brown trout.

Yellowstone National Park is classified as a natural area in the National Park system and as such must be managed to preserve pristine conditions. The fisheries are supported mainly by fragile subalpine environments where replacement of a catchable size fish can take years.

Fishing has been a popular and accepted activity in the Park since its establishment in 1872. Increasing visitation and angler use since the 1930's has necessitated radical changes in the fishery management objectives. Regulations have gone from very liberal consumptive oriented, to more restrictive non-consumptive oriented of today. The specific objectives of the present sport fishing program are:

1. To manage the fishery as an integral part of the Park's ecosystem.

2. To preserve and restore native species and aquatic habitats.

3. To provide anglers with a high quality angling experience with wild trout in a natural setting.

The attainment of these objectives requires that naturally reproducing fish populations be maintained before any resource allocations are made to angling.

Regulations have included manipulating season dates, bait and terminal gear restrictions, and the use of creel and size limits (including catch-and-release-only). Some waters have been closed to angling in order to protect spawning fish, nesting birds, or to provide scenic vistas with undisturbed wildlife (including fish). Catch-and release-only has been one of the most successful regulations at attaining the Park's fishery objectives. Catch-and-release was implemented in 1973 on several of the popular roadside waters. These waters were selected because heavy fishing pressure was having a detrimental affect on the fish stocks. This regulation has provided maximum protection of fish stocks as determined by numbers, biomass, and size and age structure. It has enhanced angling quality in most situations. In Park waters with highly gullible native cutthroat trout, the response to no kill regulations has been positive and almost instantaneous, while the response from brown and brook trout has not been as positive.

Slough Creek has shown a very positive response to the catch-and-release regulation and has gained a reputation among many anglers for being one of the finest cutthroat trout streams in North America. The stream originates in the Beartooth Mountains of Montana and meanders through the northeast corner of the Park.

Prior to the 1970's, Slough Creek had a variety of regulations with a 3 fish creel and a 14 inch minimum size limit in effect during 1971-1972. Under this regulation the fishery sustained 6,900 days of angling with a catch rate of 1.52 fish per hour and an average size of 11.9 inches for fish creeled. When this fishery initially went under catch-and-release, angler use declined by 25% during the first four years, but then rose to a record high in 1981. The fishery sustained 11,726 angler days of use in 1981 with a landing rate of 1.48 and an average size of fish landed of 13.5 inches. In 1983 the fishery sustained 7,479 angler days with a catch rate of 1.03 fish per hour and an average fish size of

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[1]Paper presented at Wild Trout III Symposium, Yellowstone National Park, Wyoming, September 24-25, 1984

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13.8 inches. The Slough Creek fishery during 10 years of catch-and-release regulations has provided up to a high of 70% more angler days of use, maintained a landing rate of over 1.0 fish per hour and has had an increase in average size of fish landed of 15.9% (fig. 1).

The catch and release section of the Yellowstone River below Yellowstone Lake has been our greatest success story. Prior to 1973, this section of the river sustained 45,000 angler days of use with a landing rate of 0.74 trout per hour and an average size of fish landed of 14.7 inches. Angler use on the river took a precipitous decline the first year after catch-and-release regulations were implemented but has increased steadily since that time to a record high in 1981. By 1981, the fishery had regained its losses and had 48,800 angler days of use with a landing rate of 1.0 fish per hour and an average fish size of 15.4 inches. In terms of fishable water, these figures equate to 5,600 angler days per mile or 122 angler days per acre. The upper section, above Sulfur Caldron receives 95% of the angling use (7,200 angler days per mile). In 1983 the fishery supported 39,300 angler days with a catch rate of 1.06 fish per hour. The average size of fish landed was 15.6 inches and continues to increase (fig. 2).

The success of catch-and-release in the Park is in part related to the fish species. The cutthroat trout respond especially well to restrictive regulations for a variety of reasons. The variables which are most important are low hooking mortality, catchability, and longevity.

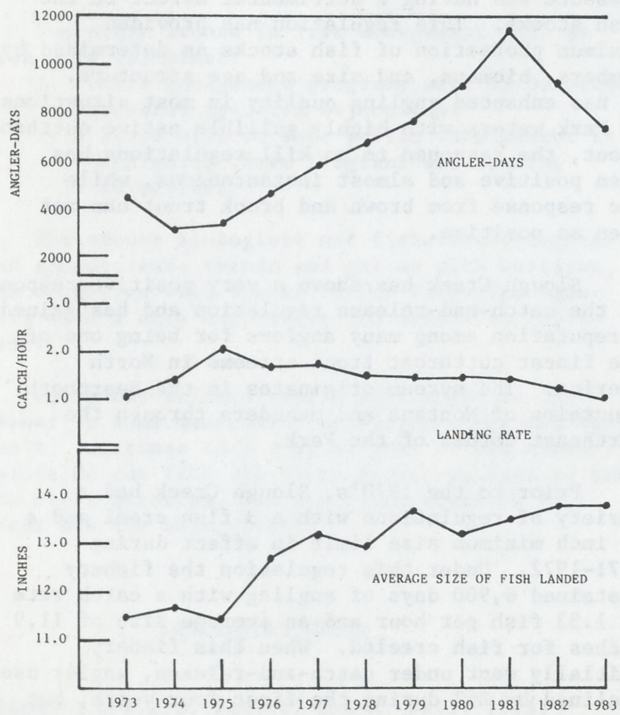

Figure 1.--Angler-days, landing rates, and average size of fish landed for the trout fishery, Slough Creek, 1973-1983.

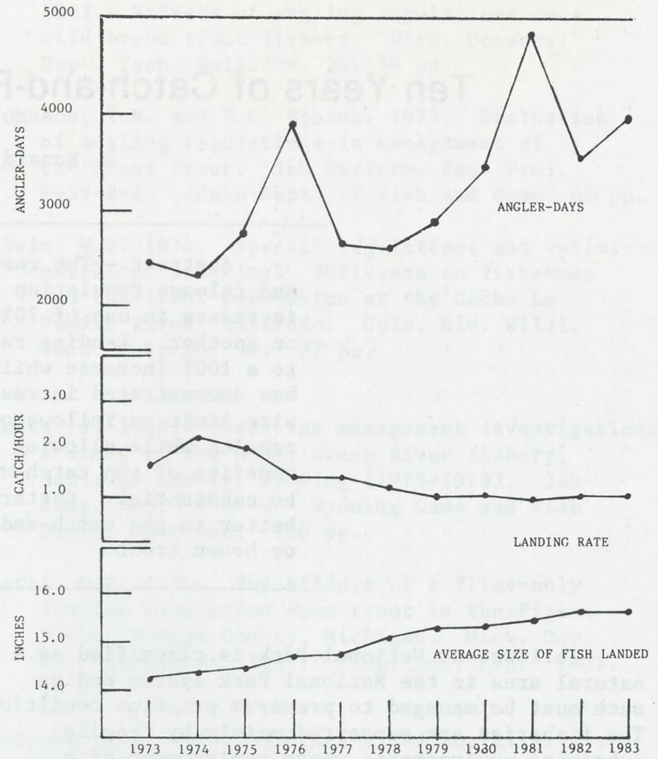

Figure 2.--Angler-days, landing rates, and average size of fish landed for the trout fishery, Yellowstone River C&R section, 1973-1983.

A hooking mortality study was conducted on the upper section of the Yellowstone in 1980 and 1981 (Schill, Griffith and Gresswell 1983)[3]. The study was conducted by counting actual fish mortality by snorkeling the river throughout the fishing season and counting mortality. The study reports a hooking mortality on a per capture basis of 0.3%, and a population mortality of about 3%. Mortality rates were higher during the first part of the season when angling pressure was highest and the fish population was lowest, and lower near the end of the season when pressure was low and fish population high. A comparison of total fish landed for the study area (123,800 cutthroat) and population estimates for the section (1,750 trout per km) suggest that trout may be captured an average of 9.7 times during the 108 day season. The Yellowstone cutthroat also live a long time, with fish ranging up to 11 years (Gresswell 1980).

One of our less successful experiements has been the catch-and-release section of the Lewis River. There is no information on this section of stream prior to 1973 except that it contained mainly brook and brown trout and was under a 5 fish any size regulation.

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[3] Schill, D.J., Griffith, J.S. and R.E. Gresswell. 1983. Hooking mortality of cutthroat trout in a catch-and-release segment of the Yellowstone River. Unpublished report, in review. Yellowstone National Park, Wyoming.

Angler use data on the catch-and-release section of the Lewis indicates a drop in use in 1973, however due to a lack of data we are not sure if this statistic is reliable. Since 1973 use has remained rather constant with an average of 1,427 angler days per year. If there was a decline of angler use on the Lewis similar to the type seen on other catch-and-release areas, it has not recovered. The landing rate has shown a steady increase from 0.8 fish per hour in 1973 to 1.85 in 1983. The average size of fish landed has remained virtually unchanged, with an average size of 10.1 inches since 1973. The only significant change in this fishery has been the increase in catch rate (fig. 3).

Another regulation has been very successful on Yellowstone Lake. Yellowstone Lake has had a variety of regulations over the years with a maximum sustained yield philosophy in effect during the 1950's and 1960's. A 14 inch minimum size limit was imposed during the early 1970's, but neither of these regulations proved successful against increasing effort and harvest.

In 1975, a 13 inch maximum size restriction was adopted and allowed a daily creel of two fish under 13 inches total length. This regulation takes advantage of compensatory survival in younger age groups and has improved the population age structure. The lake fishery experienced a 2.9% increase in angler use from 1974-1981 and a sharp decline in 1983. The landing rate remains over .9 fish per hour and the average size of fish landed increased from 13.8 to 14.7 inches.

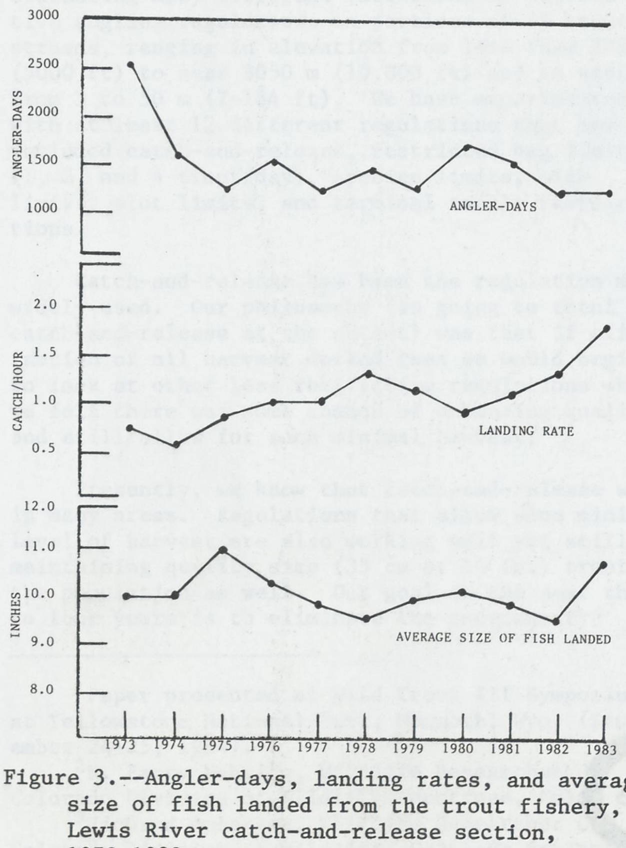

Figure 3.--Angler-days, landing rates, and average size of fish landed from the trout fishery, Lewis River catch-and-release section, 1973-1983.

One of the most encouraging improvements is the survival of proportionately more fish to older and larger size groups. The number of fish landed in the 20 inch size range is substantially higher than before the regulation change. These changes have occurred while use remains approximately 150,000 angler days annually and harvest averages about 100,000 trout per year (fig. 4).

The catch and release portion of the Yellowstone River sustains the highest level of use in the Park and is probably one of the most intensively fished wild trout fisheries in the country.

The economic benefits of restrictive regulations on naturally reproducing fish populations can also be substantial. To obtain a trout as large as the average fish landed in the Yellowstone River (15.4 inches) from a fish hatchery would cost approximately \$1.55 per fish (Varley 1984). In the catch-and-release section of the Yellowstone River, each fish is caught an average of 9.7 times in one year and is worth \$15.00 the first year. These fish remain in the fishery for approximately 3 years and are worth \$45.00 per cutthroat trout. From this example it is easy to see that the catch-and-release regulation

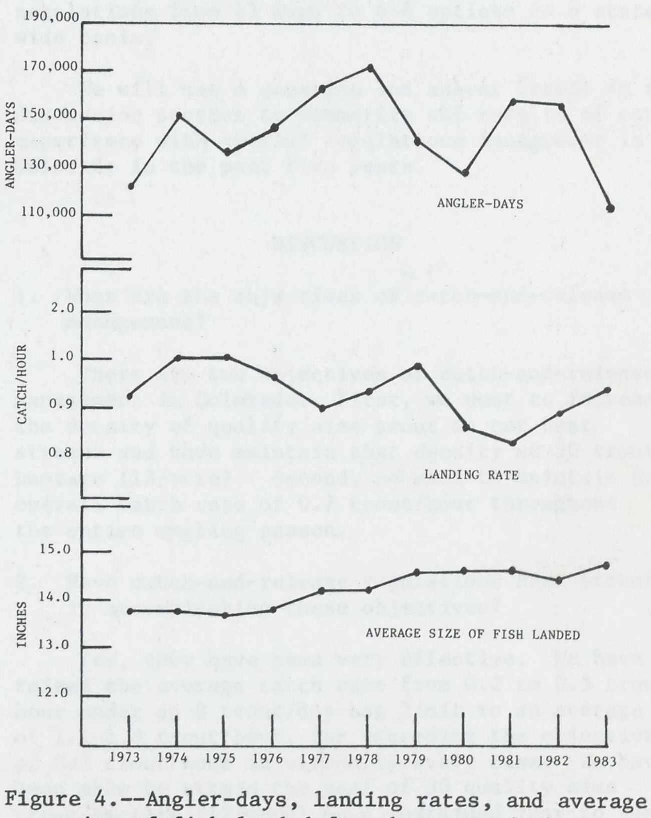

Figure 4.--Angler-days, landing rates, and average size of fish landed for the trout fishery, Yellowstone Lake, 1973-1983.

[4] Varley, J.D. 1983. The use of restrictive regulation in managing wild salmonids in Yellowstone National Park, with particular reference to cutthroat trout, Salmo clarki. Unpublished report, in press. Yellowstone National Park, Wyoming.

could provide a workable alternative. Of course we must also realize that hatcheries, as good as they are, do not produce wild fish at any price.

Restrictive regulations have proven to be a valuable fishery management tool in Yellowstone Park. If they are used properly in combination with the right species and environmental factors, they can serve a variety of fishery management objectives. In most situations, the catch-and-release-only regulation can provide sport fishing in natural systems without significant departures from pristine conditions.

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Catch and Release Management in Colorado — What Works? How, When, Where, Why?[1]

R. Barry Nehring[2] and Richard Anderson[3]

Abstract.--Catch-and-release management began in Colorado in the 1960s. Intensive experimentation began on 17 streams in 1979. Twelve regulations including catch-and-release, species limits, size limits, slot limits, and terminal tackle restrictions have been used. Management objectives of maintaining a density of 30 quality size (35 cm) trout/hectare and a sustained catch rate of 0.7 trout/hour have been met. Angler acceptance has been high and law enforcement problems have been minimal. Angling pressure of 250 hours/hectare deplete rainbow and brown trout stocks 30 cm and larger, requiring restrictive regulations to maintain angling quality.

INTRODUCTION

Colorado began exploring catch-and-release management and limited-kill regulations in the early 1960s. However, real evaluation of these management alternatives on an intensive basis did not begin until 1979. Since then we have been evaluating many different variations of restrictive angling regulations on portions of 17 trout streams, ranging in elevation from less than 1525 m (5000 ft) to near 3050 m (10,000 ft) and in width from 3 to 50 m (7-164 ft). We have experimented with at least 12 different regulations that have included catch-and-release, restricted bag limits (1, 2, and 4 trout/day), species limits, size limits, slot limits, and terminal tackle restrictions.

Catch-and-release has been the regulation most widely used. Our philosophy (in going to total catch-and-release at the outset) was that if elimination of all harvest worked then we would begin to look at other less restrictive regulations where we felt there was some chance of enhancing quality and still allow for some minimal harvest.

Presently, we know that catch-and-release works in many areas. Regulations that allow some minimal level of harvest are also working well yet still maintaining quality size (35 cm or 14 in.) trout in the population as well. Our goal in the next three to four years is to eliminate the unnecessary regulation options and try to reduce the number of regulations from 12 down to 4-6 options on a statewide basis.

We will use a question and answer format in the discussion section to summarize the results of our experience with special regulations management in Colorado in the past five years.

DISCUSSION

1. What are the objectives of catch-and-release management?

There are two objectives of catch-and-release management in Colorado. First, we want to increase the density of quality size trout in our best streams and then maintain that density at 30 trout/hectare (12/acre). Second, we want to maintain an overall catch rate of 0.7 trout/hour throughout the entire angling season.

2. Have catch-and-release regulations been effective in accomplishing these objectives?

Yes, they have been very effective. We have raised the average catch rate from 0.2 to 0.5 trout/hour under an 8 trout/day bag limit to an average of 1.1-1.8 trout/hour, far exceeding the objective of 0.7 trout/hour in virtually every case. We have been able to attain the goal of 30 quality size trout/hectare (12/acre) on a sustained year to year basis in most instances.

3. Where and why have catch-and-release programs failed?

Catch-and-release programs have failed in very few areas in Colorado. When we went into this sort of management in a big way in 1979 we purposely chose a few areas where we were expecting the

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[1]Paper presented at Wild Trout III Symposium at Yellowstone National Park, Mammoth, Wyo. (September 24-25, 1984).
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regulations to fail in order to document the fact that catch-and-release is not a cure-all panacea for all trout fishing situations. In several areas the failure was expected due to the high elevation and short growing season. Most of these areas were near 3050 m (10,000 ft) elevation. In one instance the species was an allopatric brown population; in another an allopatric Rio Grande cutthroat trout (*Salmo clarki virginalis*) population; in a third an allopatric brook trout population; and in a fourth a sympatric brown, brook, rainbow trout population. In all instances it was possible to maintain a catch rate of at least 0.7 trout/hour, but the environment did not have the degree-days per growing season to meet the objective of 30 quality size trout/hectare on a sustained yearly basis.

In the only area where failure was not anticipated (the Arkansas River) chronic low level heavy metal pollution, siltation, and lack of food have apparently combined to inhibit any positive response from the brown trout population.

4. Is voluntary catch-and-release an important component of fishery management programs?

Yes, it has been in some areas in Colorado. Fishermen voluntarily released 92% of the entire season catch on the Fryingpan River in 1983, despite the fact that the regulation allowed anglers to keep one rainbow and one brown trout/day. Had they not done so the take-home harvest would have been much greater than 8% of the season catch. However, we are not relying upon this sort of cooperation in hopes that the "good-will" on the part of the angling public will produce the desired response. Our regulations are designed to produce the desired response given adequate enforcement and angler compliance.

5. Is there enough data to predict where and why catch-and-release regulations will succeed or fail?

Yes, I think there is on a state-by-state basis in many areas of the country, particularly in the western U.S. However, I seriously doubt the experiences with these programs in Colorado can necessarily be applied with a "broad brush" across all areas of the U.S., especially in states east of the Mississippi River. The responses may not be the same because of vast differences between states in angler acceptance, fishing pressure, climatological differences, environmental variables, and the like.

6. Are there alternatives to catch-and-release programs that will produce similar fisheries?

Yes, in Colorado we are beginning to experiment with size limits, slot limits, species limits, and severely reduced bag limits (one or two trout) in various combinations as an alternative to total catch-and-release. In essence, we are trying to maintain trout populations with a high density of quality size trout that provide a catch rate of at least 0.7 trout/hour and yet allow some minimal amount of harvest with the opportunity to keep a real trophy if the angler so desires. We are already seeing some very positive responses in several different streams with these restricted harvest regulations. In two of these areas the response has been statistically significant in just one year after the regulation was implemented.

7. What does the user think of catch-and-release?

In Colorado, public acceptance of catch-and-release and limited-kill areas is very high. In 1980, 4460 anglers were surveyed in eight different areas on three different streams, 1192 by mailback postcard questionnaire and 3268 by personal interview. An astonishing 88% favored catch-and-release areas already in existence, 6.2% were opposed to them, and 5.8% had no opinion. Of the 4460 anglers surveyed, 2854 (64%) were fishing in an 8 trout/day angling area with no terminal tackle restrictions. Thus, despite the fact that the majority of anglers were fishing in a standard regulations area when contacted, they overwhelmingly supported the concept of catch-and-release. Similarly, in 1981, of 2403 anglers surveyed, 1769 (73.6%) favored catch-and-release angling areas, 397 (16.5%) were opposed, and 237 (9.9%) had no opinion.

8. What do law enforcement officers think of catch-and-release?

In Colorado, most law enforcement officers (especially at the supervisory level) support the concept of catch-and-release because of the positive support and response on the part of the angling public, and tremendous improvement in angling quality and success, and the minimal amount of enforcement problems we have experienced in most areas.

9. Under what habitat conditions are catch-and-release regulations most suitable?

These regulations work best where (1) natural reproduction is capable of sustaining a wild trout population, (2) food resources are not limiting, and (3) where the stream has enough temperature units to produce a 25-30 cm trout (10-12 in.) in three summers of growth. In Colorado, this is in streams between 1830-2449 m (6000-8000 ft) elevation. In a few tail-race situations we have had success below this range due to the ameliorating effects of hypolimnial releases on the thermal regime of the stream. However, we have found that unless the thermal regime is capable of raising trout to an average size of 25-30 cm in three summers, catch-and-release regulations will be ineffective at increasing the number of quality size trout in the population.

10. At what level of use does catch-and-release become a logical alternative?

In Colorado, the majority of our catch-and-release areas are on streams where brown trout are the dominant species or brown and rainbow trout (occasionally brook and cutthroat) exist in sympatry. Fishing pressure in excess of 247 hours/hectare (100 hours/acre) per season has a detrimental impact on the number of quality size trout remaining in the population. When pressure levels reach 988 hours/hectare (400 hours/acre) per season rainbow stocks are totally decimated and brown stocks are severely impacted as well with both numbers and quality decreasing dramatically over a four-year period under an 8 trout/day angling limit. Avery and Hunt (1981) have documented similar impacts on brown trout populations in Wisconsin. Where fishing pressure ranged from 376-398 hours/acre/season exploitation rates were as high as 68-78% for the age II and III+ components of the population.

In Colorado, even when spring biomass levels exceed 100-150 kg/hectare (89-134 lb/acre) for rainbow and brown trout stocks combined, angling pressure of 741-988 hours/hectare (300-400 hours/acre) has reduced the number of trout 30 cm and larger to less than 3% of the population. All trout over 35 cm have been eliminated from the population in some areas. In our highest use area (on the South Platte River within 40 km of the Denver metropolitan area) angling pressure is so high (near 5000 hours/hectare or 2000 hours/acre per year) catch-and-release is the only alternative. Here angling pressure and high catch rates are capable of removing the entire trout population three times over in one angling season, even if the bag limit were only one trout per day! Skeptics argue that at some point angling quality would decline to the point where it was not interesting enough to keep the pressure so high and the trout population would survive. However, we have already witnessed the reduction of trout standing crop on the Eagle River from 60 kg/hectare to 2 kg/hectare in two angling seasons. Furthermore, in the catch-and-release area on the South Platte more than 90% of the trout in the population range from 30-40 cm in size (approximately 12-16 in.) and it is quite likely that virtually every trout in the population would be caught that is over 20 cm (8 in.) in size. We have found that 20 cm is about the minimum acceptable size to anglers. Anglers usually voluntarily release trout under 20 cm total length.

11. What should be the role of special interest groups (TU, FFF, Izaac Walton League, etc.) in the decision-making regulations-setting process?

I believe special interest groups can be most effective by providing morale support and gentle patient persuasion to the staff of fisheries professionals within the state and federal management agencies, especially when bureaucratic foot-dragging becomes a problem. Special interest groups can be most effective by providing general direction in the decision-making and regulation-setting process, leaving the specific regulation design and stream site selection for regulation implementation to the professionals in most cases. Above all, I believe it is of paramount importance that both special interest groups and fisheries professionals always remember that "we're in this together" and "we share common goals." Each group must avoid alienating our best supporters and allies. Doug Stange (1981) in an article entitled "An Open Letter to Anglers and Fisheries Professionals" published in the first issue of the North American Journal of Fisheries Management, provided some very lucid advice along these lines that should be required reading for every angler and fisheries professional in this country.

12. How important are long-term studies in the evaluation of catch-and-release and other special regulations management techniques?

The importance of long-term studies cannot be overemphasized. The impact of climatological and environmental variables within and between years on an individual stream and its trout population can induce large natural fluctuations in trout population size, reproduction, density, biomass, age, growth, and species composition over time. Due to this problem we feel three- to five-year studies are an absolute minimum length to clearly document and separate the natural environmental impacts and the regulation impacts on the trout population. Many study areas in Colorado are in the sixth year of investigation and will be evaluated for at least another 3 or 4 years.

13. Can catch-and-release be considered a management tool for wild trout only or can it be used on stocked trout as well?

We are not presently using catch-and-release on any stream sections in Colorado that receive catchable-size rainbow trout plants. We are beginning to use limited-kill regulations on one or two streams and lakes that receive fingerling trout plants. We have no plans to use limited-kill or catch-and-release on any waters receiving catchable trout plants. Our management objectives on these waters is to maximize return to the creel, with a 60-95% or better return rate as the management objective.

14. How have different species responded to catch-and-release management?

Colorado's best response to catch-and-release management has been with rainbow, brown, brook, and cutthroat trout in descending order of success. Best success has been with rainbow, then brown trout, and very little response from either brook or cutthroat trout. The lack of response by the latter two species is due to environmental constraints in the streams that support these species. Our best cutthroat and brook trout populations occur at elevations of 2750 m (9000 ft) and higher where the growing season is too short and the thermal regime too cold to produce very many trout in excess of 20 m (8 in.), much less quality size 35 cm and larger trout.

15. How much angling mortality is associated with catch-and-release management?

Angling mortality associated with catch-and-release management in Colorado is very small, certainly less than 5% of the spring standing stock. Our total catch in the highest use areas is 1.5 to 3 times the total population density for all trout 15 cm (6 in.) total length. Fifty to 75% of all trout that size in these areas have visible hooking scars or inflamed areas on the mandible or maxillary bones when handled during fall electroshocking surveys. With angler use as high as 5000 hours/hectare (2000 hours/acre) per season, we would definitely receive reports of many dead trout were angling mortality running at more than 1-2% of the

Limit Your Kill, Don't Kill
Your Limit. – ~~auxillary~~ supplementary
Game fish too valuable to be caught once

— Early history – to – 1959-60 – stor –

harvest – – recycling – My 1989 article.

– re what works, why – – – – ~~emphasized~~,

– dif. factor dif results – works where

– old fish – 5-6-7 – very inefficient – but P/B

– typically cause decline – laundry list
* over harvest / habitat – degraded – – Yes but harvest easily less – cut – Kelly Crk St. Joe – 13+ Yellowstone

– – – more – more acceptance – –

– so mentioned – last – nonkill fly fisher – – –

polarize – politicians – voter bl. – phrase

common man (upon resident) vs. elitist (nonresident and) – "taking" of fish

1960 influence be – 1959-60 sport fish 30-yrs ago – Max. sustained yield – "harvestable" – "sustainable" –

surplus – a valuable and profit wasted lost by not taken all

but uncertainties unpr – models and fail to ont

b overharvest – – Sport fishing – not sustain fish/mean

but sustained catch rate – (recycling) – wild fish – Henry Fk / Madison – wild spp / >50% nonres

– offer hatch fish – ponds – parks – no experience with + res

* Missouri Mile Way – Native to sp. dis –

– if can overcome angler opposition

strictly management tool rear – constant supply – catch increased rate

Thus: Two factors – sport – blood sport / "kill" – others degrade into playing games

European tradition ① – (Izaak Walton) not comp

– U.S.

② cruelty to and pain –

C&R – assume pain, suffering for human enjoy another basis –

– Only can ask fish, they learn – but – circumst – (no known recorded) – melectro, wounded – resting e.g. zip –

conferences Summer 1961 - First National Convention
of T U March ~~61~~ - Chicago -

headline item T U Quarterly

Wis: Size ~~&~~ bag limits has
little effect on harvest

1 Wis:
Lawrence Crk. - B/B 0-1-2
10g - 100g.
1/3 oz 3 oz
500

- dif size, bag limits,
complete closure (fence to stay) 1000 -

1970 - St. Joe / Kelly C. / Yc 2 1A - green
Spec Regs single barbless
only
recycler
no good
- "fake" food
lure

2 ~~March~~ Summer 61 Gerald Cooper
chief
Fish. Res. Inst.

Not what wild ~~T~~
~~wanted~~ to hear

overwinter mortality
+ Fall 1960
- Policy Statement

brown

danger
in diverse resc
"all sp"
"all streams"

I. The causes of the high annual winter mortality of all Trout in streams are a primary concern of T.U. and we encourage investigations.

trout population. We do receive a few reports each fall of trout with fungal infestions, demonstrating that anglers do report dead and dying fish even when they make up only a very small percentage of the trout population.

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Restrictive Regulations — The Montana Experience[1]

Jerry Wells[2]

Montana entered the world of restrictive fishing regulations rather late. Only seven years ago, the state-wide limit for trout was ten fish or ten pounds, which ever came first. The year, 1977, marked an abrupt turn in fisheries management in Montana. The dust had finally settled following our controversial decision in 1975 to manage strictly for wild trout in all of our rivers and streams capable of supporting them. The Natural Streambed and Land Preservation Act was two years old and for the first time we had means of controlling the habitat destruction that was occurring on our rivers and streams. While things had never looked better for the future of wild trout, fishermen on the upper Madison River began complaining in force about the size of the trout they were catching. They were catching plenty of fish but not many larger than 10 inches. At about this same time some of our fisheries biologists, such as Dick Vincent, Ron Marcoux and Denny Workman, began to express concern about the effects of increasing fishing pressure on our larger trout. In response to this concern, we closed a section of the Madison River to fishing in 1977 in an attempt to quantify the impact of fishermen on the trout population.

In 1978, we dropped the trout limit in streams to 5 fish and in an effort to alert the public to the fact that large trout were not infinite in number, allowed only one of the five to be over 18 inches long. After looking at the response of the trout population to one year of closure in the study section of the Madison, it became apparent that fishermen were impacting the larger trout. In response to this information, we proposed a catch-and-release (artificial flies and lures only) regulation for 20 miles of the Madison River with a management objective of increasing the opportunity of catching wild trout larger than 13 inches. After extensive public meetings and discussion before our Fish and Game Commission, the proposal was adopted by the Commission in January, 1978. The results, as most of you are aware, have been spectacular. After five years of catch-and-release regulations, numbers of wild brown trout over 13 inches have tripled and numbers of larger rainbow have increased even more.

In 1981, in response to overharvest concern by fishermen and our biologists, we proposed and the Commission adopted, slot limits for 15 mile reaches of the Big Hole and Gallatin Rivers that protected trout between 13 and 22 inches. Since this regulation involved considerable catch-and-release, we limited gear to artificial flies and lures only. Once again, our management objective was to increase numbers of trout over 13 inches. After three years of this slot regulation on the Big Hole River, we have seen the numbers of brown trout larger than 18 inches increase from 40 per mile to 140 per mile. Numbers of rainbow larger than 13 inches have doubled in the same time period. During the same period of time, larger brown and rainbow trout numbers remained static or increased very slightly in our control section.

While the slot-limit has been an unqualified success on the Big Hole, the same regulation on the Gallatin River has been a failure. The trout population (almost entirely rainbow) over 13 inches did not increase at all over the three year period which suggested that factors such as growth rates and winter conditions rather than fishermen were controlling the population. In response to this information, we removed the slot-limit and bait restrictions on the Gallatin River in 1984.

We are finding that each of our rivers is different in potential and in degree of need for restrictive regulations. We are also finding that different species require different degrees of protection. Cutthroat trout are clearly the species most susceptible to angling. Catch-and-release regulations on a section of Rock Creek near Missoula have dramatically increased numbers of west slope cutthroat trout and it appears that the cutthroat is now out competing rainbow trout. We have also recently initiated catch-and-release regulations for Yellowstone cutthroat trout on a 50 mile reach of the Yellowstone River.

Rainbow trout in general are more vulnerable than brown trout to angling and we are in the second year of species regulations on reaches of the Big Horn and Middle Madison Rivers that encourage harvest of up to 5 brown trout but allow only one rainbow. Species regulations appear to clearly be the wave of the future in Montana.

We have rivers in Montana with brown trout populations that are so prolific that they currently require no restrictive regulations. Perhaps our two finest trophy brown trout rivers, the Beaverhead and Big Horn, are in this category. Recruitment rates, unlike in the Big Hole River,

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[1] Paper presented at the Wild Trout III Symposium, September 24-25, 1984, Yellowstone National Park, Wyoming.

[2] Region Three Fisheries Manager, Montana Department of Fish, Wildlife, & Parks, Bozeman.

are so great in these two rivers in most years that increased densities have resulted in decreased growth rates and poorer condition of the larger brown trout.

There have been several important components to our successes in special regulations. We have chosen fairly long reaches of river (usually 15-20 miles) for restrictive regulations recognizing that these areas would attract large numbers of fishermen. We have carefully chosen realistic management objectives to measure the success or failure of the regulations and have not been reluctant to change them if they have failed. We have also made the commitment to intensively monitor study sections both within the restrictive regulation areas and study sections outside these areas to evaluate the success or failure of the regulations.

Trout Unlimited has played a major role in the evolution of restrictive regulations in Montana by supporting good data, recognizing the fact that catch-and-release is not the answer for every stream and funding fisheries research. The Montana Fish and Game Commission has played an even greater role by supporting regulation changes that have been based on strong biological information and public support. The Commission, under the leadership of Chairman Spence Hegstad, has demonstrated a commitment to sound and progressive wild trout management. The fishery resource we all cherish today reflects the foresight of these gentlemen.

In Montana, we believe that the key to successful fisheries management is diversity. We offer a wide array of fishing opportunities and restrictive regulation waters are a part of this diversity. We are presently entering into a wild trout management approach to several lakes and reservoirs that will add to this diversity. As a result of the hard work of our fisheries people and the support of fishermen and our Commission, we believe that we offer some of the finest wild trout fishing in the country today. The last ten years have been an exciting and dynamic time in fisheries management in Montana and we look forward to the new challenges of the future.

Special Fishing Regulations — Southeastern Style[1]

Monte E. Seehorn[2]

Paper presented by Randy Geddings,
Clemson, South Carolina

Abstract.--This paper provides a general summary of current trout regulations in ten southeastern states including West Virginia, Virginia, Maryland, North Carolina, South Carolina, Tennessee, Georgia, Kentucky, Arkansas, and Missouri. Data includes information concerning extent of trout resources (primarily stream), and the degree to which special regulations are utilized. General management philosophies are presented.

INTRODUCTION

Wild or self sustaining trout fisheries in the Southeast, for the most part, are limited to mountainous freestone streams of 1000'-1200' or more elevation. Freestone, for the purpose of this paper refers to softwater streams originating primarily from metamorphic and igneous rock formations in N.C., S.C., Tenn., and Ga., and a combination of metamorphic, igneous, and sedimentary formations in other States. These streams, although aesthetically appealing with their overall steep gradient, waterfalls, and rock formations, provide a relatively harsh environment when compared with the low gradient streams common to north central and northeastern states. With gradients in some of the high elevation streams exceeding 400 feet per mile, annual floods literally scour the streambed, sometimes displacing boulders as large as automobiles. At elevations exceeding 3500', anchor ice becomes a serious problem. In southernmost states, high water temperature begins to limit trout distribution at elevations below 1600'-1800' Once critical temperature levels are reached, downstream areas become uninhabitable, since there are few or no spring flows to buffer rising temperature. On stream systems without natural barriers such as waterfalls, trout populations are limited even further by competition from warm or coolwater fish species. These conditions are most prevalent in Georgia, North Carolina, South Carolina, and Tennessee streams below 2400' elevation. Even in the better freestone streams, biomass or standing crop of trout is relatively low (in most cases ranging from 20 to 60 pounds of trout per acre) with the majority of the biomass in Age I & II fish that are less than 9" in length.

Brook and rainbow trout become sexually mature at Age I+ & II and begin to experience accelerated mortality at age II+ even without fishing pressure. The bulk of the fisherman harvest is age II+ fish, with few reaching age III and practically none exceeding age IV. The sterile nutrient poor waters of the southern Appalachians simply do not provide a food base adequate to support populations equivalent to those found in "hardwater" streams, even where cover is adequate. Conductivity in southern waters generally ranges from 17-30 micromhos per cubic centimeter, while total hardness and alkalinities seldom exceed 10 and 15 milligrams per liter respectively. Attesting to the limiting nature of such parameters, and concurrent paucity of food organisms, is the fact that in a few "typical" streams owned by private individuals or clubs, supplemental feeding has produced standing crops many times greater than normal. One such program on a Chattahoochee National Forest stream in Georgia (the only program on public waters in this Region) sustains trout at better than ten times normal standing crop (15 to 20 pounds per acre vs 200+ pounds per acre). Under natural conditions, brook and rainbow seldom exceed 12" in these streams, however feeding programs can produce brook in the 2-3 pound range and rainbow exceeding 6-7 pounds. Where supplemental feeding is not feasible, brown trout normally provide the only potential for trophy fisheries. Most streams containing brown trout occasionally produce fish exceeding 20" in length, although without feeding it may take 5-7 years to reach this size.

Excluding lake fisheries and Piedmont streams in Maryland, there are two other distinct type trout fisheries of significance in the Southeast. One is the tailwater fisheries created by large impoundments, and the other is the comparatively recent development of limestone spring fisheries in Virginia and Missouri that, in most cases, originally held no trout.

The tailwater fisheries are of special significance because of their comparatively

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1 Paper presented at the Wild Trout III Symposium, September 24-25, 1984, Yellowstone National Park, Wyoming.

2 Fisheries Habitat Management, Southern Region, USDA Forest Service, Atlanta, Georgia.

large size and generally greater productivity than natural streams. Although limited in mileage, their potential for supporting extremely heavy fishing use, and potential for producing trophy fish make them especially important.

The "spring run" fisheries currently developed or being developed are even more productive than the tailwaters, and in some cases are providing natural recruitment to the system. These fisheries along with the tailwaters provide potential for trophy fishing equal to any in the country.

REGULATIONS

Special regulations, in the past have been established through political pressure to a greater degree than through biological need. Trophy regulations have been established in waters where few if any fish reach the established minimum size limit. Low (6"-7") minimum size limits have been established where reproduction and population levels were adequate before the limits were set. Lure restrictions have been established with little or no biological justification. Overly restrictive seasons have been set with little input from professional fishery managers. Although some regulations are currently generated by politics (and likely will continue to be), the trend in recent years has been to place greater emphasis on biological justification. Given such emphasis, special regulations certainly deserve consideration in any overall fishery program.

Emphasis on special regulations varies significantly by State (see table). Arkansas has no special harvest regulation other than a unique restriction on "herding" large tailwater trout. This evolved through the large brown trout's reluctance to swim under fishermen's boats, making them susceptible to herding and subsequent snagging. North Carolina in contrast has 440 miles of stream under special regulations.

Criteria for establishment of special regulations are as divergent as is the emphasis upon establishing them. Some states select marginal streams (from a wild trout standpoint) for their catch and release or other highly restrictive fishery, relying primarily upon hatchery stock to support the program. Other states select their best wild trout streams for such restrictions.

Seasons vary from selected days during a four month period to year round, with some States allowing and some excluding night fishing.

The Following is a summary, by States, of current special harvest regulations. A few of the regulations were combined or "lumped" for practicality in preparing the data presented in the table.

Maryland

-Catch & return (fly fishing)	-all fish returned -singlehook flies only (maximum of two per line) -restricted to conventional fly fishing tackle (fly cannot be cast directly from a reel) -year round season
-Catch & return (other)	-all fish returned -artificial single hook lures only -year round season
-Restricted to under 16, over 65, and blind individuals	-year round season

On four streams without wild populations, special regulations were enacted to reduce harvest, and make fish available throughout the year. Two self sustaining populations (one brook-brown, the other brown) were put under special regulations to protect them from over-exploitation. Criteria for selection were ability to support trout, water quality, aesthetic qualities, and public access.

Brook and brown trout are the dominant salmonid in Maryland streams.

West Virginia.

-Catch & return (fly fishing)	-all fish returned -single hook, barbless flies only -restricted to conventional fly fishing tackle -year round season
-Catch & return	-all fish returned -barbless hooked artificial lure only -year round season

Special regulations are limited to streams without self sustaining fisheries, although two of the six special regulation streams have significant carryover. Three of the six were selected because adjacent landowners were not willing to allow access unless special regulations were enforced. In general, only waters with similar problems are considered for special regulations at present. Demand for special regulation streams in West Virginia is negligible.

Brook trout are the dominant fish in the majority of wild trout streams.

State	Total Stream Mileage: Freestone or other	Tailwater	Spring Creek	General Rules: Season	Creel	Min. Size	Lure Restriction	Special Regulations - Number and mileage of areas: No."No Kill"	Mi."No. Kill"	No. trophy (14")	Mi. trophy (14")	No. "other"	Mi. "other"	no. flies only	no. barb-less hooks only
Maryland	450	5	25	year round	5	none	none	6	25	0	0	0	0	2	0
West Virginia	1200	9	25	year round	6	none	none	6	13	0	0	0	0	3	3
Virginia	2600	25	450	10 1/2 months	6	7"	none	0	0	2	6	10	41	1	0
Shenandoah, Nat. PK. (VA)	132	0	0	6 1/2 months	5	8"	single hook art.	1	13	0	0	0	0	0	1
North Carolina	4000	88	0	11 months	7	none	none	0	0	3	30	54	410	3	0
Tennessee	1115	126	115	year round	7	R6-none Br. none Brook-6"	none	0	0	0	0	12	40	0	0
Great Smokies Nat. Pk. (N.C.-Tenn)	733	0	0	year round	5	7"	single hook art.	0	0	0	0	1	16	0	0
Georgia	4000	60	5	7 months	8	none	none	0	0	2	20	7	41	0	0
South Carolina	200	11	0	year round	10	none	none	0	0	0	0	4	12	0	0
Kentucky	424	64	10	year round	8	0	none	0	0	0	0	0	0	0	0
Cumberland National Park (KY)	18	0	0	-	-	-	-	0	0	0	0	2	18	0	0
Arkansas		200	10	year round	6	none	none	0	0	0	0	0	0	0	0
Missouri	0	19	177	year round	5	none	none	2		6		1 (voluntary)	19	2	0
Cherokee Indian Res. (N.C.)	139	0	0	7 months	10	none	none	0	0	0	0		13	0	0

Virginia

Trophy (fly Fishing)	-16" minimum size -2 fish per day -artificial fly only -year round season
Trophy (other)	-16" minimum size -2 fish per day -artificial single hook lures -year round season
Special (stocked)	-12" minimum size -6 fish per day -artificial single hook lure -10-1/2 mo. season
Special (wild)	-9" minimum size -6 fish per day -artificial single hook -10-1/2 month season

Shenandoah N.P. (Virginia.)

Fish-for-fun	-all fish returned -artificial single barbless hook lure -year round season

Virginia's "trophy" regulations are placed upon highly productive limestone spring runs or tailwaters capable of routinely producing trout exceeding 16" in length. Emphasis is to provide a fishery where fishermen can catch substantial numbers of 12"-16" fish year round, with the possibility of catching an occasional "lunker". Brown trout are the featured species, although rainbow are present in most trophy areas.

"Special regulation stocked streams" are productive fisheries capable of good growth rate and carryover but do not produce wild fish. These are primarily tailwaters containing brown and lesser numbers of brook and rainbow.

The "special regulation wild streams" are freestone streams with limited growth potential but excellent characteristics otherwise, that are under unusually heavy fishing pressure. The objective here is to provide fishermen with the opportunity to catch maximum numbers of 7"-9" fish, with occasional fish exceeding 9"-10". Primary species are brook and rainbow.

The "fish-for-fun stream" in Shenandoah National Park is a historical regulation, established twenty years ago, on an extremely heavily fished brook trout stream. Due to the no kill regulation, the stream supports an excellent population of larger than average brook trout. Although no new fish-for-fun streams are being considered at present, no change is considered for this stream.

North Carolina

"Experimental"	-slot limit, one trout greater than 16" and three trout between 7" and 10", or four trout between 7" and 10" -artificial flies only -year round season
"Experimental"	-slot limit - one trout greater than 14" and three trout between 7" and 10", or four trout between 7" and 10" -artificial flies only -year round season
Native	-slot limit - one trout greater than 10" and three trout between 7" and 10", or four trout between 7" and 10" -artificial single hook lures -11 mo. season

Cherokee Indian Reservation (North Carolina)

Winter Trophy Program	- 12" minimum -4 fish per day -artificial lure only -Nov. 1 - Feb. 28 season

N.C. changed their special regulations significantly in 1983. Previously they had a "trophy" designation on several streams, consisting of a 16" minimum size, one fish creel limit, with lures restricted to artificial flies. "Native" regulations applying to the majority of the special designation mileage consisted of a 10" minimum size on rainbow and brown trout, and a 7" minimum size on brook trout. Creel limit was four fish, with lures restricted to artificial single hook.

Neither regulation accomplished the original purpose of increasing number of 16"+ and 10"+ fish in the standing crop, although both designations increased numbers of small and intermediate size fish below the minimum lengths. Some biologists feel that the minimum size regulations actually reduced the number of fish larger than the minimum size in effect.

The recommended change in regulations at the time was to place all "trophy" and "native" streams under one modified slot restriction, allowing three fish from 7" to 10" and one over 10" (or four fish less than 10") to be creeled. Lures would be restricted to artificial single hook only. This was implemented as recommended, except for three "experimental" streams (see above) that were requested by fishermen. The assumption was that the new regulations would allow harvest of smaller fish, most of which are lost to natural mortality, and at the same time reduce fishing pressure on larger fish.

With the exception of a few pure brook and brown trout streams, the dominant species, by numbers in most North Carolina trout streams are rainbow. The majority of these streams also contain small to significant numbers of brown trout.

Georgia

Trophy (supplemental feeding)	-22" minimum on rainbow and brown - 18" minimum on brook -one fish per day -artificial single barbless lure, size 6 or smaller hook. -landing net must not exceed 2' in length -open Sat. and Sun. only April - Oct.
Trophy	-16" minimum size -artificial lure only -7 mo. season
Special	-artificial lure only -7 mo. season

The original intent of the "trophy" regulations on both streams was to produce substantial numbers of fish in excess of the minimums established. This was generally accomplished on the stream receiving supplemental feeding. All species, including brook, brown and rainbow, have responded to the feeding program as demonstrated by the 60+ fish creeled in 1983.

The other trophy stream contains an excellent population of rainbows up to 10" or 12" (none exceeding 16"), and occasional brown trout exceeding 16". The majority of fish caught by fishermen are Age I and II rainbow less than 10" in length. The estimated number of fish creeled (all brown) over 16" is four to six per season.

Most special regulations have been established primarily due to requests from the public and were not based upon particular biological needs at the time.

Tennessee

"Wild stream"	-9" minimum on rainbow and brown - 6" minimum on brook -3 fish per day -artificial single hook lure -7 month season. Closed on Monday, Tuesday, Wednesday
"Wild stream"	-10" minimum on rainbow and brown - 7" minimum on brook -4 fish per day -artificial single hook lure -year round season
"Wild stream"	-9" minimum on rainbow and brown - 6" minimum on brook -7 fish per day -artificial single hook lure -year round season. Closed on Thursday and Friday

Tennessee's special regulations are established with the intent of providing the maximum number of fish in the 8"-9" size class (or 9"-10" depending upon established minimum) to the angler. The 10" minimum regulation applying to one stream was established as a cooperative gesture on a stream serving as the boundary between North Carolina and Tennessee. The few large fish taken are invariably brown trout, although rainbow are dominant by numbers in most streams.

Great Smoky Mountains National Park
(Tennessee-North Carolina)

Special	-12" minimum all species -4 fish per day -artificial single hook lure -6 mo. season

Closed	-110 miles of brook trout streams are closed to fishing.

General regulations were changed from 9" to 7" in 1983. Although the need for a minimum size limit was questioned, input from area biologists suggested the implementation of a 7" minimum size limit.

Trout Unlimited groups were instrumental in retaining the one stream under special regulations. Since it is the only stream originating from limestone soils in the Park (Conductivity of 100 micromhos per cubic centimeter) it was believed to have potential to produce substantial numbers of fish over 12" length. A final decision on specific regulations for this stream will be made after a two year evaluation.

The 110 miles of brook trout waters were closed to fishing to protect the populations from fishing pressure. This again has evoked considerable discussion among biologists and fishermen.

South Carolina

Special	-7 fish per day -artificial lures only
Special (Lake Jocasee)	-12" minimum -7 fish per day -unlawful to use corn, cheese, fish eggs, or imitations of these as bait

South Carolina special regulation streams were based upon public request rather than biological needs. The regulations on Lake Jocasee however, were intended to reduce heavy fishing pressure upon recently stocked trout. The lake is quite productive and produces fish in excess of 12" within a short time after 9" fish are stocked.

Kentucky (Cumberland Historical National Park)

Special	-12" size limit (brook trout) -2 fish per day -artificial single hook lures -4 mo. season
Special	-10" size limit (brook trout) -2 fish per day -artificial single hook lures -4 mo season

The special regulations were established on two streams in the Cumberland National Park that were considered to have the potential to produce reasonable numbers of brook trout in the 10" to 12" size class. The State feels these regulations have been successful, and plans to establish at least one more such fishery in the near future.

Arkansas

-"Herding" of trout illegal

-Chain dragging on North Fork River illegal

Arkansas, to date, feels they have no need for special regulations, other than those mentioned above. They are interested in the findings presented at this meeting however, and plan further evaluation of their regulatory needs.

"The Herding" regulation as explained earlier in the text, is an effort to reduce snagging of large brown trout.

"Chain dragging" (use of drag anchors) was declared illegal due to the mechanical damage to stands of aquatic vegetation in the tailwater.

Arkansas tailwaters, such as the White River, are very productive and consistently produce trophy fish that, on occasion, exceed thirty pounds.

Missouri

Catch and release	- flies only -year round season
Wild trout	-18" minimum -3 fish per day -artificial lures only -year round season
Trophy trout	-15" minimum -3 fish per day -artificial lure only -year round season
Trophy trout	-15" minimum -3 fish per day -any bait -year round season
Trophy trout (voluntary on Lake Taneycomo)	-Fishermen are asked to release trout ranging from 12" to 16". -year round season

Missouri although limited in mileage of trout streams, contains some of the more productive systems in this Region. They feel that with the growth potential for fish in some of their streams, establishment of special regulations should significantly enhance these fisheries by greatly increasing standing crops of fish up to the minimum sizes established.

Of special interest is the fact that the voluntary slot limit on Lake Taneycomo appears to be quite effective.

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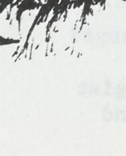

Some Trout-Flow Relationships in Montana[1]

Frederick A. Nelson[2]

The Montana Department of Fish, Wildlife and Parks has used electrofishing techniques since the late 1960s to annually estimate the standing crops of trout in sections of a number of "Blue Ribbon" rivers. Annual standing crop variations within sections have been influenced by a number of factors, including flows. This paper presents some of these trout-flow relationships.

INTRODUCTION

Many state and federal fish and wildlife agencies, particularly in the West, are engaged in programs to quantify the flows that are needed to maintain stream fisheries. Many of the instream flow methods used in the quantifications rely on hydraulic simulation models that predict the relationships between flow and various habitat parameters for the streams of interest. The underlying assumption behind these methods is that a stream's capacity to sustain fish and other aquatic life is influenced by the available habitat which in turn is a function of flow. While relationships between various habitat parameters and fish carrying capacity are well documented in the literature, studies demonstrating direct relationships between flow levels and the magnitude of the fish populations are limited.

Fish-flow studies require, in addition to a long-term commitment of funds and man-power, an ideal study site where all potential limiting factors can be tightly controlled or accounted for, and the productivity is high, thus allowing fish to grow rapidly and achieve high densities in a relatively short time period. Mother Nature must also cooperate by providing a wide range of annual flow variations and a minimum of catastrophic weather events. Because this combination is rarely achievable, fish-flow relationships are difficult to demonstrate under field conditions.

In the late 1960s, the Montana Department of Fish, Wildlife and Parks (MDFWP) began using electrofishing techniques to annually monitor the standing crops (numbers and biomass) of trout in a number of "Blue Ribbon" rivers in southwest Montana. These long-term population estimates were instrumental in instituting major policy changes regarding the stocking of hatchery trout on wild trout populations, angling regulations and flow release and storage patterns at dams. The MDFWP thus has a long-term data base that has been successfully used to document the impacts of various management and environmental changes on wild trout populations.

The factors believed to have ultimately limited the standing crops in each study section have varied over the years, depending on both management and environmental changes. The role of flow as a regulatory agent has varied, being of major importance in some low flow years and masked by other controlling factors in other years. Due to the many, ever changing factors that have periodically influenced the annual standing crop variations, the sections are far from ideal for investigating the relationships between trout and flows. Even under these conditions, some trout-flow relationships are still evident. This paper briefly discusses these relationships.

TROUT-FLOW RELATIONSHIPS

Madison River

September estimates of the standing crops of brown and rainbow trout within a 4.5 mile section (Varney section) of the Madison River downstream from Hebgen Dam are available for a 17-year period beginning in 1967. The annual standing crop variations during this period reflect a number of management changes. In 1968, the water storage policy at Hebgen Reservoir was modified, allowing water to be stored only during the May-July high flow or snow runoff period. Prior to this policy change, storage often began in winter, the period when the natural river flows are lowest for the year. As a result, winter flows in 100 miles of river were reduced by as much as 50% in some years. In 1973, the stocking of catchable-size rainbow trout, which was found to severely depress wild trout numbers, was terminated, allowing the population to increase to over three times the pre-stocking numbers (Vincent in press). Fishing pressure has also increased dramatically over the 17 years, from an estimated 650 man-days per mile in 1967 to 950 man-days per

[1]Paper presented at the Wild Trout III Symposium (Yellowstone National Park, Mammoth, Wyoming, September 24-25, 1984).

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mile in 1975. With the increase in pressure and harvest came more restrictive angling regulations. In 1978, the limit was reduced from ten to three trout, with only one to exceed 18 inches. Regulations were again modified in 1983 when the limit was increased from three to five, with only one to exceed 18 inches and only one rainbow trout allowed.

Because the trout population has reflected a variety of controlling factors throughout the 17 years, annual flow variations were expected to have little measurable impact on the standing crops. This proved true for all age-groups of rainbow trout and all but age I+ (yearling) brown trout.

September estimates of the numbers of yearling brown trout in the study section ranged from 1,580 (in 1967) to 7,876 (in 1976). When the number of yearlings was regressed against the lowest mean monthly flow during the preceding winter (December-April), a weak although statistically significant ($P<0.05$) relationship occurred (fig. 1). A weak yet significant relationship ($r = 0.50$, $P = 0.04$) also occurred between the estimated biomass of yearlings and winter flows.

Population estimates are also available for a 4.0 mile section of river (Norris section) located downstream from the Varney section. Annual estimates were made in the spring beginning in 1967. Unlike the Varney section, catchables were not planted in this section since 1960. However, standing crops have undoubtedly been influenced by other factors, including the ever increasing fishing pressure and harvest, the implementation of more restrictive angling regulations in 1978, and a thermal pollution problem which is restricted to the lower river and has at the very least retarded trout growth.

The estimated biomass of ages II and older trout in the Norris section increased, although not significantly ($P>0.05$), following the winter flow increases that resulted from the change in storage policy at Hebgen Reservoir (Vincent 1973) (fig. 2). The estimated biomass of both brown and rainbow trout increased during the 1967 to 1969 period. Due to the low densities of rainbow trout in 1967 and 1968, these estimates are not as reliable as those in later years when densities were considerably higher. These data, while far from conclusive, suggest that the reduced winter flows were the dominant controlling factor in the lower river prior to 1968.

Winter is generally considered the period most detrimental to trout survival in high elevation streams that are exposed to harsh weather conditions. In winter, trout are not only subjected to the lowest flows of the year, but also to the devastating effects of subsurface ice formation and ice-scouring. For most high elevation streams in Montana, the winter environment will ultimately limit the trout carrying capacity unless overriden by other controls, such as overharvesting by anglers or depleted summer flows.

Big Hole River

September estimates of the standing crops of brown and rainbow trout within a 4.3 mile section (Melrose section) of the Big Hole River were made in 1969-1970 and 1977-1983. Factors influencing

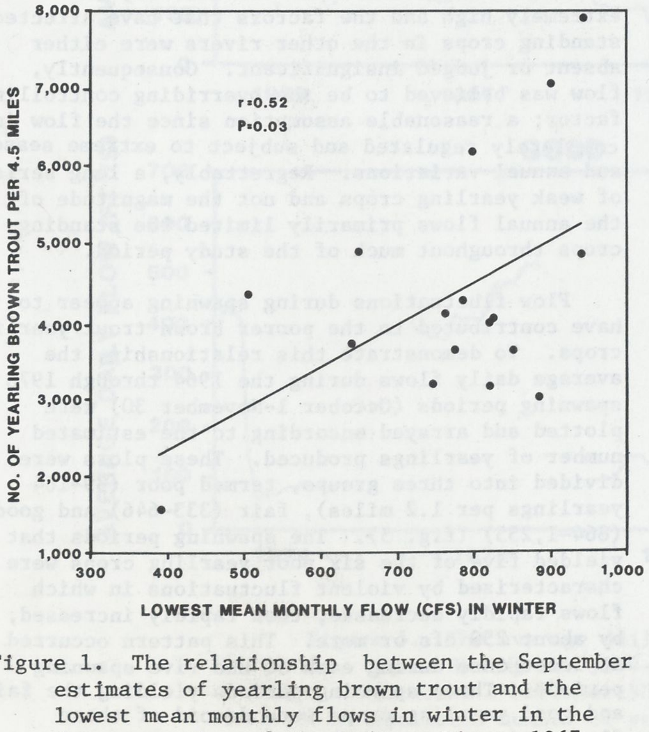

Figure 1. The relationship between the September estimates of yearling brown trout and the lowest mean monthly flows in winter in the Varney section of the Madison River, 1967-1983.

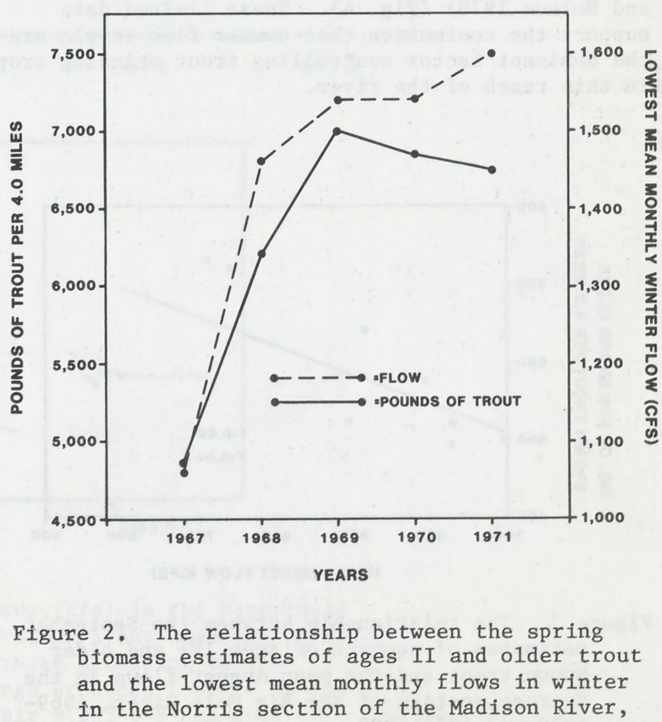

Figure 2. The relationship between the spring biomass estimates of ages II and older trout and the lowest mean monthly flows in winter in the Norris section of the Madison River, 1967-1971.

the standing crops over the years have included the stocking of catchables prior to 1974, the ever increasing fishing pressure and harvest, and the implementation of more restrictive angling regulations in 1978 when the limit was reduced from ten to five trout, with only one to exceed 18 inches.

Unlike the Madison River, flows in the Big Hole River are frequently lowest in late summer (August-September) due to irrigation depletions. In low water years, the combination of depleted flows and high August air temperatures elevates water temperatures, further stressing the trout population. August can be the most critical period of the year affecting trout survival.

The September estimates of numbers of ages IV+ and older brown trout in the study section were correlated with the magnitude of the flows during the preceding August (Wells and Decker-Hess 1981) (fig. 3). Significant relationships with other age-groups of brown and rainbow trout or total trout were not evident.

Gallatin River

Three study sections, ranging from 8,000 to 15,000 ft in length, were established in a 20-mile reach of the Gallatin River that is impacted by summer irrigation depletions. Standing crop estimates were obtained in all sections in September of 1976 and in one section in September of 1977. The lower-most study section was totally dewatered during the summer of 1977, a drought year. Like the Big Hole River, flows in the study reach are frequently lowest in late summer.

The standing crops of ages II+ and older trout (brown and rainbow) in the sections were highly correlated with the minimum summer flows (Vincent and Nelson 1978) (fig. 4). These limited data support the contention that summer flow levels are the dominant factor controlling trout standing crops in this reach of the river.

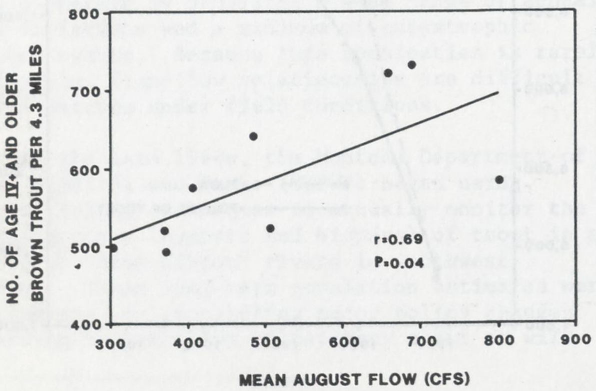

Figure 3. The relationship between the September estimates of numbers of ages IV+ and older brown trout and the mean August flows in the Melrose section of the Big Hole River, 1969-1970 and 1977-1983.

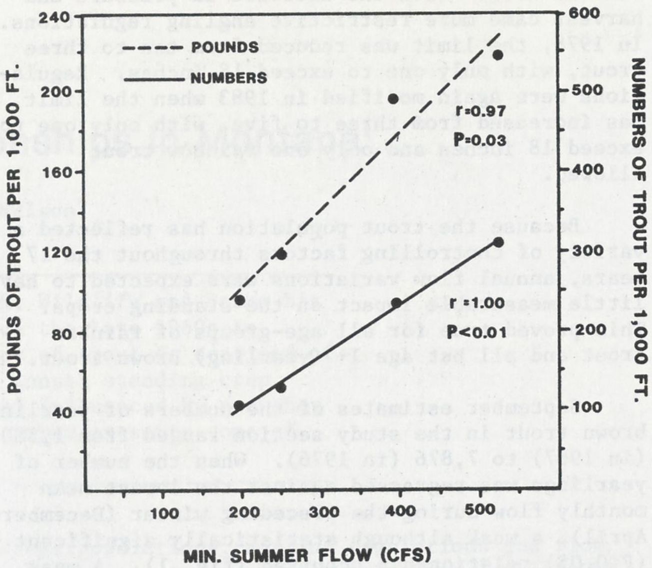

Figure 4. The relationship between the minimum summer flows (cfs) and the September estimates of numbersand biomass of ages II+ and older trout in sections of the Gallatin River impacted by summer irrigation depletions, 1976-1977.

Beaverhead River

Fall and spring estimates of the standing crops of trout in a 1.2 mile section of the Beaverhead River below Clark Canyon Dam are available for most years beginning in Fall, 1966 and ending in Fall, 1980. The Beaverhead study site was considered close to ideal for investigating trout-flow relationships. Productivity was extremely high and the factors that have affected standing crops in the other rivers were either absent or judged insignificant. Consequently, flow was believed to be the overriding controlling factor; a reasonable assumption since the flow is completely regulated and subject to extreme seasonal and annual variations. Regrettably, a long series of weak yearling crops and not the magnitude of the annual flows primarily limited the standing crops throughout much of the study period.

Flow fluctuations during spawning appear to have contributed to the poorer brown trout yearling crops. To demonstrate this relationship, the average daily flows during the 1964 through 1978 spawning periods (October 1-November 30) were plotted and arrayed according to the estimated number of yearlings produced. These plots were divided into three groups, termed poor (39-164 yearlings per 1.2 miles), fair (333-646) and good (864-1,255) (fig. 5). The spawning periods that yielded five of the six poor yearling crops were characterized by violent fluctuations in which flows rapidly decreased, then rapidly increased, by about 250 cfs or more. This pattern occurred at least once during each of the five spawning periods. Those spawning periods yielding the fair and good yearling crops were devoid of these fluctuations.

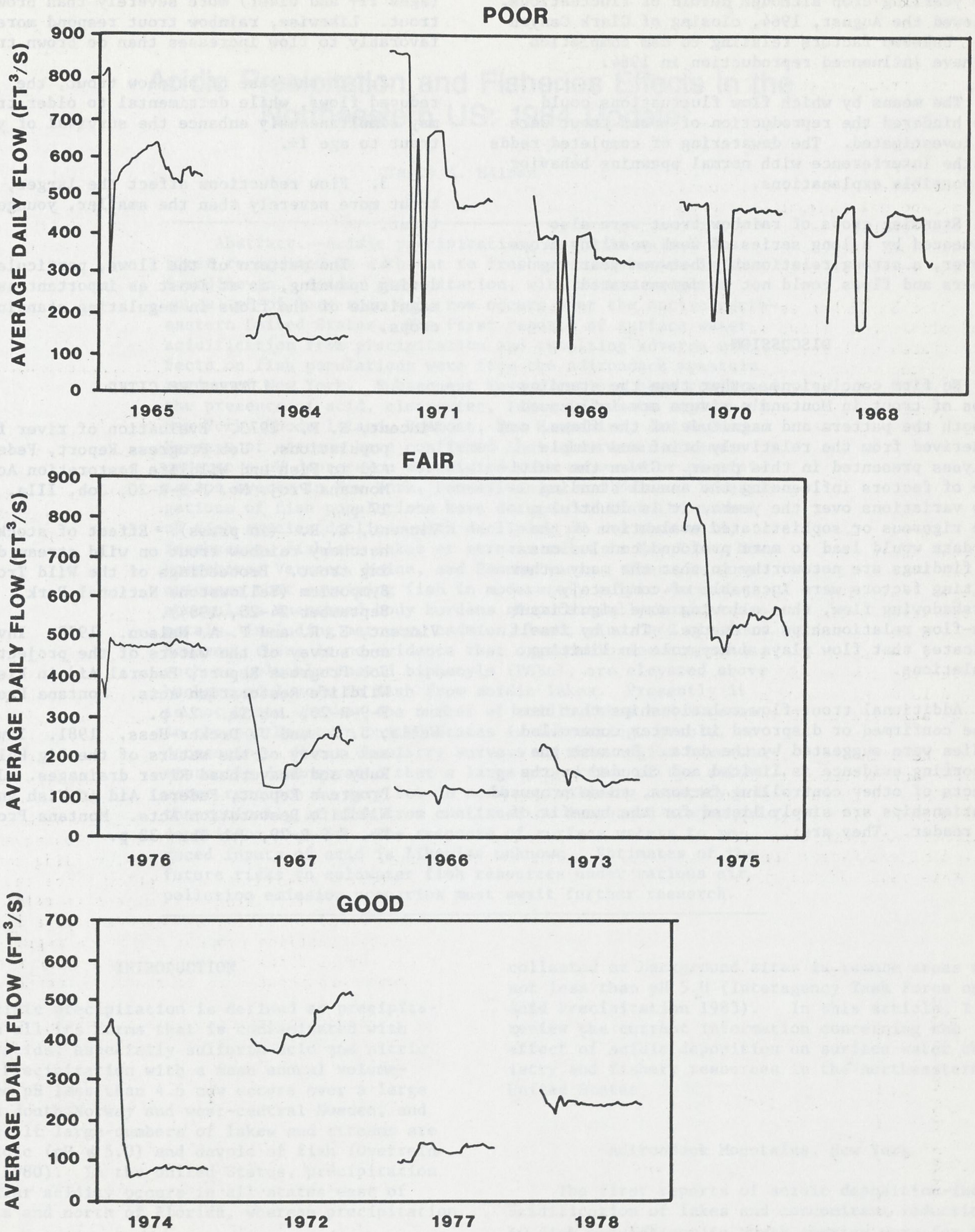

Figure 5. The average daily flows (cfs) in the Beaverhead River during the 1964-1978 brown trout spawning periods (October 1-November 30) arrayed according to the estimated number of yearlings produced (poor = 39-164 yearlings per 1.2 miles, fair = 333-646 and good = 864-1,255).

The 1964 spawning period, which yielded a poor yearling crop although devoid of fluctuations, followed the August, 1964, closing of Clark Canyon Dam. Unknown factors relating to dam completion may have influenced reproduction in 1964.

The means by which flow fluctuations could have hindered the reproduction of brown trout were not investigated. The dewatering of completed redds and the interference with normal spawning behavior are possible explanations.

Standing crops of rainbow trout were also influenced by a long series of weak yearling crops. However, a strong relationship between yearling numbers and flows could not be demonstrated.

DISCUSSION

No firm conclusions, other than the standing crops of trout in Montana's rivers are influenced by both the pattern and magnitude of the flows, can be derived from the relatively brief and simple analyses presented in this paper. Given the multitude of factors influencing the annual standing crop variations over the years, it is doubtful a more rigorous or sophisticated evaluation of the raw data would lead to more profound conclusions. The findings are noteworthy in that the many other limiting factors were incapable of completely overshadowing flow, thus allowing some significant fish-flow relationships to emerge. This by itself indicates that flow plays a key role in limiting populations.

Additional trout-flow relationships that need to be confirmed or disproved in better controlled studies were suggested by the data. Because the supporting evidence is limited and clouded by the effects of other controlling factors, these proposed relationships are simply listed for the benefit of the reader. They are:

1. Flow reductions affect rainbow trout (ages II+ and older) more severely than brown trout. Likewise, rainbow trout respond more favorably to flow increases than do brown trout.

2. In the case of rainbow trout, the reduced flows, while detrimental to older trout, may simultaneously enhance the survival of younger trout to age I+.

3. Flow reductions affect the larger, older trout more severely than the smaller, younger trout.

4. The pattern of the flows, particularly during spawning, is at least as important as the magnitude of the flows in regulating standing crops.

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Acidic Precipitation and Fisheries Effects in the Northeastern US: 1984 Update[1]

Terry A. Haines[2]

Abstract.--Acidic precipitation, or "acid rain," was first recognized as a threat to freshwater fisheries in Scandinavia. Acidic precipitation, with a mean weighted annual pH of less than 4.6, now occurs over the entire northeastern United States. The first reports of surface water acidification from precipitation and resulting adverse effects on fish populations were from the Adirondack mountain region of New York. Subsequent investigations have confirmed the presence of acid, clearwater, lakes in remote regions of New York, Rhode Island, Vermont, New Hampshire, and Maine. Surveys of streams have confirmed that clearwater streams undergo a pH depression associated with snowmelt or precipitation events in New York, Pennsylvania, and Maine. Investigations of fish populations have documented that the number of fish species declines with declining pH and that acid, freshwater, fishless lakes or streams exist in New York, New Hampshire, Vermont, Maine, and Pennsylvania. There is some evidence that surviving fish in moderately acidic waters accumulate increased body burdens of potentially toxic trace metals, including mercury, cadmium, lead, zinc, and aluminum. However, there is no evidence that organochlorine compounds, such as polychlorinated biphenyls (PCBs), are elevated above background levels in fish from acidic lakes. Presently it is not known whether the number of acidic lakes and streams in the northeastern United States is increasing, stable, or decreasing. Water chemistry surveys in this region have consistently demonstrated that a large proportion of the coldwater resource is very low in acid neutralizing capacity and theoretically at risk from continued or increased atmospheric deposition of acid. The response of surface waters to reduced inputs of acid is likewise unknown. Estimates of the future risks to coldwater fish resources under various air pollution emission scenarios must await further research.

INTRODUCTION

Acidic precipitation is defined as precipitation in all its forms that is contaminated with strong acids, especially sulfuric acid and nitric acid. Precipitation with a mean annual volume-weighted pH less than 4.6 now occurs over a large area in south Norway and west-central Sweden, and as a result large numbers of lakes and streams are now acidic (pH $<$ 5.0) and devoid of fish (Overrein et al. 1980). In the United States, precipitation of similar acidity occurs in all states east of Illinois and north of Florida, whereas precipitation collected at background sites in remote areas was not less than pH 5.0 (Interagency Task Force on Acid Precipitation 1983). In this article, I review the current information concerning the effect of acidic deposition on surface water chemistry and fishery resources in the northeastern United States.

Adirondack Mountains, New York

The first reports of acidic deposition-induced acidification of lakes and concomitant reductions in fish populations in North America were for the Adirondack Mountain region (Schofield 1965, 1973, 1976a, 1976b). Several recent survey reports (Pfeiffer and Festa 1980; Colquhoun et al. 1984) summarized recent data concerning water chemistry and fish populations in lakes within the Adirondack Ecological Zone. Schofield (1976b) surveyed 40 lakes that had been initially surveyed in the 1930s. In the 1930s three lakes had pH $<$5.0 and no fish and

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24-25, 1984.

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one lake with pH between 6.0 and 6.5 also had no fish. In 1975, 19 of these 40 lakes had pH <5.0 and had no fish. Two additional lakes with pH between 5.0 and 5.5 also lacked fish. Thus 17 lakes apparently lost fish populations during the interval between the 1930s and 1975.

In a recent survey, Colquhoun et al. (1984) found that the proportion of lakes with pH <5.0 was greater for lakes above 2,000 ft. elevation than for lakes below 2,000 ft. in the Adirondack region (Figure 1). For lakes above 2,000 ft., 44% were pH <5, whereas only 13% of lakes below 2,000 ft. elevation were this acidic. Surveys of stream water chemistry during the spring runoff period revealed that 20% of the streams in the Adirondack region (Figure 2) and 6% in the Catskill region (Figure 3) reached pH <5.0. Of 289 lakes in the Adirondack region for which both fish and water chemistry data were available, 39% of those with pH <5.0 were devoid of fish whereas only 4% of those with pH >6.0 were fishless (Table 1).

South-Central Pennsylvania

A number of studies have been conducted in the Laurel Hill area of south-central Pennsylvania by personnel from the Institute for Research on Land and Water Resources, Pennsylvania State University. A spatial association study was conducted in 61 streams on Laurel Hill (W. Sharpe, Pennsylvania State University, personal communication). Ten of the streams had cultural disturbances in the watershed (e.g., highway, industrial discharge) and were excluded from consideration for this reason. The remaining streams were surveyed for water chemistry and fish population (by electrofishing a 100 m section), and were divided into three groups: those with reproducing fish populations, those with hatchery fish only, and those with no fish (Table 2). Of the 40 streams with fish present, all but two had pH greater than 6.0. Of the two streams with pH less than 6.0, Poplar Run (pH 5.3) contained only two brook trout (one adult, one young-of-the-year) in the 100 m reach, and South Fork Blue Hole (pH 5.7) contained only six brook trout (five adults and one young-of-the-year). Three streams contained only hatchery brook trout in the reach sampled, and one had a pH less than 6.0 (North Fork Sandy Run, pH 5.5). Of the 11 streams with no fish, all but one (Strayer Run, pH 6.7) had pH less than 6.0, and eight had pH less than 5.0. Streams that contained reproducing fish populations also had aluminum concentrations (total filtrable) of 100 ug/l or less, whereas all but two of the streams lacking fish had aluminum concentrations of 300 ug/l or more. Of the streams that contained reproducing fish populations, 12 contained only one species (brook trout), 20 contained two species (brook trout plus mottled sculpin in 19 streams, brook trout plus blacknose dace in one), three streams contained three species (brook trout, mottled sculpin, plus brown trout in two streams or rainbow trout in one), and two streams contained four species (all three salmonids plus sculpin).

An intensive study of precipitation chemistry, stream chemistry, and fish populations was conducted on four streams in this area during February 1981, three of which were included in the above survey (Sharpe et al. 1984). Three of the streams were acidic, with pH declining to <5.0, and contained only a few stocked trout. One stream was well-buffered (minimum pH 5.6) and contained self-sustaining populations of mottled sculpin, brook trout, and rainbow trout. Historical fisheries data document the presence of brook trout in three of the streams prior to 1930, and the survival of stocked fish in the fourth stream in 1932. Fish kills at fish rearing facilities on two of the acidic streams (Card Machine Run and Linn Run) were recorded in the 1960s, and of adult stocked fish in all three streams in the 1970s. Two of the acidic streams (Linn Run and McGinnis Run) contain a spruce bog in the headwaters. However, the bog covers less than 1% of the area of either stream basin, and comparison of mainstem (bog influenced) with tributary stream (not bog influenced) chemistry indicated no significant differences attributable to organic acids.

An *in situ* fish toxicity bioassay was conducted on one acidic (McGinnis Run) and the non-acidic stream (Wildcat Run) (Sharpe et al. 1983). Trout fry survived only 4 to 9 days in the acidic stream, but for the duration of the experiment (36 days) in the non-acidic stream (Table 3). These results further support the hypothesis that fish population status is related to stream pH.

Vermont

A spatial association study was conducted of fish populations and water chemistry in 29 Vermont lakes (Langdon 1983; 1984). The lakes selected for the fisheries survey were selected from a larger set of lakes (Clarkson 1982) and represented the lowest alkalinity lakes in the set. Fish were collected with experimental (variable mesh size) gill nets, baited minnow traps, and seines. Two of the lakes were fishless, and 27 contained one to ten fish species. Regression of log (number of fish species + 1) on pH gave the following results (Figure 4):

$$\text{pH} = 4.70 + 1.64 \log (\text{number of species} + 1)$$

$$r^2 = 0.43,\ p = 0.0001,\ N = 29$$

Generally, lakes of lower pH contain fewer species of fish than higher pH lakes. Similarly, fish abundance, expressed as log (catch per unit effort + 1) was significantly related to lake pH (Figure 5):

$$\text{pH} = 5.02 + 0.43 \log (\text{catch per unit effort} + 1)$$

$$r^2 = 0.21,\ p = 0.012,\ N = 29$$

The regression indicates that lower pH lakes contain fewer numbers of fish than higher pH lakes, however the coefficient of determination is low.

The lakes surveyed were generally not affected by cultural disturbance. Most contained no permanent structures in the watershed, five contained seasonal dwellings, and only one contained year-round dwellings. Many of the lakes were stocked with salmonid fish, however, but only one lake contained only stocked salmonids. The two fishless lakes

Figure 1. Distribution of lake pH for 1,047 Adirondack region lakes located at elevation above and below 2000 ft. Source: Colquhoun et al. (1984).

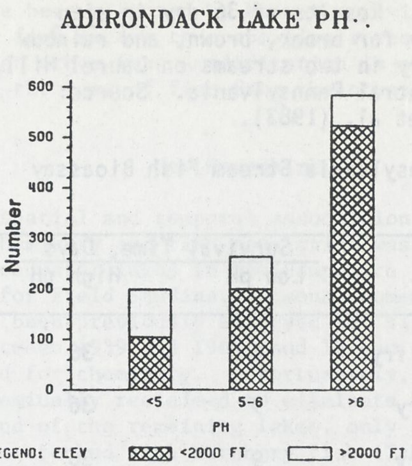

Figure 2. Distribution of spring minimum pH in 205 Adirondack region streams. Source: Colquhoun et al. (1984).

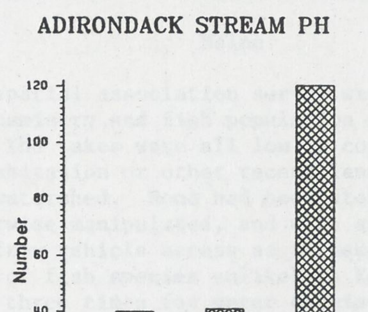

Figure 3. Distribution of spring minimum pH in 52 Catskill region streams. Source: Colquhoun et al. (1984).

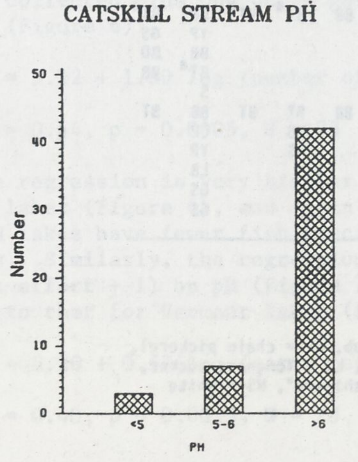

Figure 4. Regression of log (number of species + 1) on pH for 29 Vermont lakes. Source: Langdon (1983; 1984).

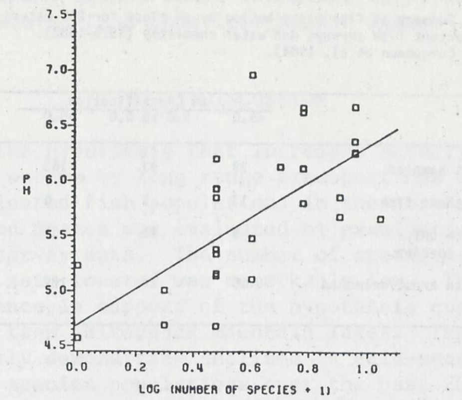

Figure 5. Regression of log (catch per unit effort + 1) on pH for 29 Vermont lakes. Source: Langdon (1983;1984).

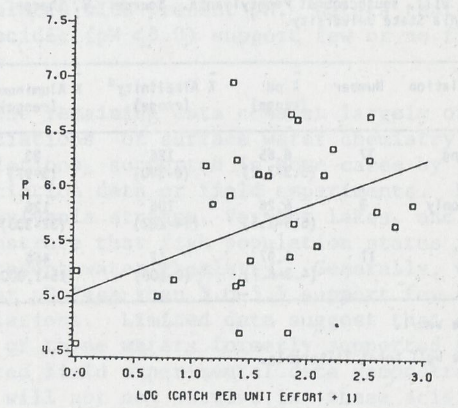

Figure 6. Regression of log (number of species + 1) on pH for 23 Maine lakes.

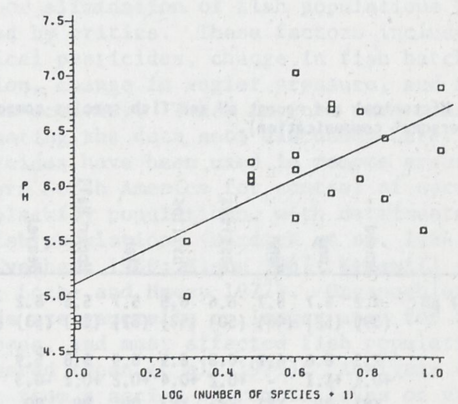

Figure 7. Regression of log (catch per unit effort + 1) on lake pH for 23 Maine lakes.

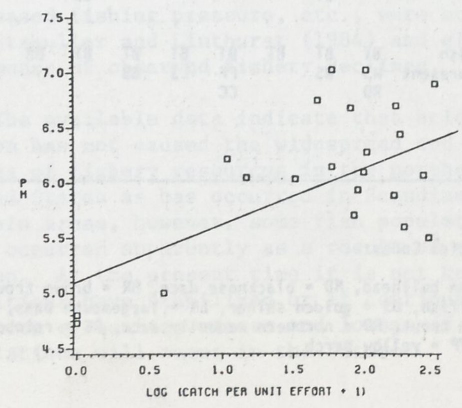

Table 1. Summary of fish distribution by pH class for 289 waters with concurrent fish surveys and water chemistry (1975-1982). (Source: Colquhoun et al. 1984).

	pH Classification		
	<5.0	5.0 to 6.0	>6.0
All waters sampled	33	93	163
Waters without fish	13	5	6
Waters with only non-trout species	5	11	35
Waters with trout/salmonid species	15	77	122

Table 2. Fish population status and water chemistry of 51 streams on Laurel Hill, southcentral Pennsylvania. Source: W. Sharpe, Pennsylvania State University.

Fish Population Status	Number	$\bar{X}$ pH (range)	$\bar{X}$ Alkalinity[a] (range)	$\bar{X}$ Aluminum[b] (range)
Reproducing	37	6.65 (5.3-7.2)	126 (0-340)	33 (5-97)
Hatchery only	3	6.26 (5.5-7.1)	106 (14-262)	126 (37-300)
None	11	4.97 (4.3-6.7)	12 (0-106)	466 (15-1,000)

[a]Units are μeq/l.

[b]Units are μg/l total filterable.

Table 3. Results of 36 day in situ bioassay for brook, brown, and rainbow trout fry in two streams on Laurel Hill, southcentral Pennsylvania. Source: Sharpe et al. (1983).

Pennsylvania Stream Fish Bioassay

	Survival Time, Days	
Species	Low pH	High pH
Rainbow fry	4	36
Brown fry	9	36
Brook fry	9	36

Low pH stream: pH = 4.8-5.9; Al = 0.18-1.1 mg/l.

High pH stream: pH = 6.1-7.0; Al = 0.01-0.14 mg/l.

Table 4. Historical and recent pH and fish species composition data for 20 New Hampshire lakes. Source: R. Singer (personal communication).

	Round	Long	Munn	Sessions	Phillips	Kiah	Upper Hall	Beaver	Echo	Cone
Historical pH (year)	7.2 (39)	5.7 (52)	6.7 (48)	6.6 (50)	6.5 (52)	5.7 (51)	5.6 (50)	6.2 (53)	6.9 (39)	5.2 (51)
Recent pH	7.3	6.8	6.7	6.8	6.9	5.9	5.8	5.9	6.9	4.5
change	+0.1	+1.1	-	+0.2	+0.4	+0.2	+0.2	-0.3	-	-0.7
Reclaimed	yes	no	yes	yes	yes	no	no	no	yes	no
Historical fish species present	BT[a] S	BB RT[a] BT[a]	BT[a]	BT[a]	BT[a]	BB BT[a]	BT[a] LT LD	BT[a]	BT[a] RS[a] RT[a]	CP BB
Recent fish species present	BT WS RD	BT WS	BT	BT FF CC	BT LS	BT BB	BT	BB	BT	

	East	Loon	Rocky	Bean	Moody	Hemingway	Blue	Caldwell	Crane	Russell
Historical pH (year)	6.5 (51)	6.1 (51)	- (52)	6.0 (52)	6.4 (37)	- (50)	6.4 (54)	6.2 (48)	6.4 (62)	6.6 (38)
Recent pH	6.3	5.3	4.9	6.2	6.5	5.8	6.6	5.1	5.8	6.3
change	-0.2	-0.8	-	+0.2	+0.1	-	+0.6	-1.1	-0.6	-0.3
Reclaimed	no	no	no	no	no	no	yes	yes	no	yes
Historical fish species present	BT[a]	BT[a]	BB	BT[a]	BR[a]	BB	BT[a]	BT[a]	CP YP BB BT[a] S	BT[a] GS BD BB
Recent fish species present	BT			BT WS GS LC	WS GS LC	BB	BT BB RS	BT	BB CP YP LB GS GS	BT

[a]Stocked

Fish Species Codes:

BB = brown bullhead, BD = blacknose dace, BR = brown trout, BT = brook trout, CC = creek chub, CP = chain pickerel, FF = fallfish, GS = golden shiner, LB = largemouth bass, LC = lake chub, LD - longnose dace, LS longnose sucker, LT = lake trout, RD = northern redbelly dace, RS = rainbow smelt, RT = rainbow trout, S = "shiners", WS = white sucker, YP = yellow perch were known to have contained fish previously. One may have been affected by beaver activity, which blocked fish access to a spawning stream. No explanation other than acidification is apparent to explain the loss of fish from the other fishless lake.

New Hampshire

A spatial and temporal association study of water chemistry and fish population was conducted in 20 headwater lakes in New Hampshire (R. Singer, School for Field Studies, personal communication). All had been previously surveyed for fish population between 1939 and 1962, and 18 had also been surveyed for chemistry. Unfortunately, eight had been chemically reclaimed to eliminate undesired fish, and of the remaining lakes, only three had not been stocked with hatchery fish (Table 4). Three of the lakes are presently devoid of fish, and are generally more acidic now than previously. However, previous water chemistry data were obtained colorimetrically, and may not be directly comparable to recent pH. The lakes included in the survey were screened to eliminate bog lakes and lakes with other sources of disturbance. Therefore the elimination of fish from 3 of 20 lakes appears to have resulted from acidification.

Maine

A spatial association survey was conducted for water chemistry and fish population in 23 lakes in Maine. The lakes were all low in color and had no human habitation or other recent land disturbance in the watershed. None had been stocked, reclaimed, or otherwise manipulated, and were sufficiently remote from vehicle access as to make casual introduction of fish species unlikely. Each lake was sampled three times for water chemistry (spring, summer and fall), and once during summer to determine fish species presence and abundance. Each lake was surveyed for fish using a standard protocol. Two experimental mesh gill nets (6 ft. high, 5 panels each 25 ft. long of square mesh sizes 3/8", 1/2", 3/4", 1", 1 1/4", and 1 1/2") were set overnight in each lake. One net was set in shallow water and one in the deepest area of the lake. Six minnow traps (1/4" square mesh hardware cloth) were baited with dog food and set in various habitat types in the littoral zone.

The regression of the log of the number of fish species collected plus one on pH gave the following results (Figure 6):

$$pH = 5.12 + 1.60 \log(\text{number of species} + 1)$$

$$r^2 = 0.44,\ p = 0.0005,\ N = 23$$

The regression is very similar to that for Vermont lakes (Figure 4), and again indicates that lower pH lakes have fewer fish species than higher pH lakes. Similarly, the regression of log (catch per unit effort + 1) on pH (Figure 7) gives results similar to that for Vermont lakes (Figure 5):

$$pH = 5.10 + 0.57 \log(\text{catch per unit effort} + 1)$$

$$r^2 = 0.40,\ p = 0.0013,\ N = 23$$

Thus, acidic lakes contained significantly fewer numbers of fish than less acidic lakes.

DISCUSSION

The hypothesis that increased acidity of surface waters by long range transport has reduced or eliminated fish populations in the northeastern United States was evaluated by examination of fishery survey data. The number of statistically valid data sets located was remarkably low. The strongest evidence in support of the hypothesis consists of data from Adirondack Mountain lakes. These data clearly demonstrate declines in acid-sensitive fish species populations over the past 20-40 years. Limited water chemistry data indicate that the water bodies in question are more acidic than formerly, and fish population status is clearly correlated with present pH. Waters that presently are acidic (pH <5.0) support few or no fish populations.

The remaining data consist largely of spatial associations of surface water chemistry and fish populations, supported in some cases by temporal association data or field experiments. Data from Pennsylvania streams, Vermont lakes, and Maine lakes demonstrate that fish population status is related to present water chemistry. Generally, waters with summer pH less than 5.0-5.5 support few or no fish populations. Limited data suggest that at least some of these waters formerly supported fish. Limited field experimental data demonstrate that fish will not now survive in these acidic waters.

Alternative factors that could result in reduction or elimination of fish populations have been raised by critics. These factors include use of chemical pesticides, change in fish hatchery production, change in angler pressure, and increased beaver activity. These factors were considered in evaluating the data sets discussed here. Chemical pesticides have been used in remote areas of northeastern North America for control of spruce budworm and blackfly populations, with detrimental effects on fish populations (Burdick et al. 1964; Anderson and Everhart 1966; Elson 1967; Kerswill and Edwards 1967; Locke and Havey 1972). Organochlorine compounds are generally no longer used for these purposes, and most affected fish populations have recovered (Dean et al. 1979). Analysis of brook trout from a series of remote lakes of varying pH in northern New England failed to detect significant organochlorine residues in any fish (Haines 1983). Other factors, such as beaver activity, increased fishing pressure, etc., were considered by Altshuller and Linthurst (1984) and eliminated as causes of observed fishery declines.

The available data indicate that acidic deposition has not caused the widespread and extensive losses of fishery resources in the northeastern United States as has occurred in Scandinavia. In certain areas, however, some fish population losses have occurred apparently as a result of acidic deposition. At the present time it is not known if conditions have stabilized or if continued acidification of surface waters and losses of fish populations will occur in the future.

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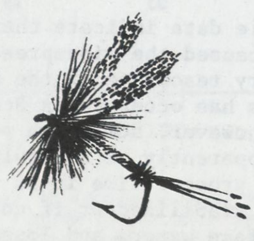

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Suckers to Trout — Effect of Habitat Restoration on Fish Populations in Rapid City, South Dakota[1]

Richard Ford[2]

Abstract.--A flood prevention project completed in 1978 severely altered an 825 yds. portion of Rapid Creek to a shallow channel, 32 yds. wide, in Rapid City, South Dakota. Subsequent agreement with the U.S. Army Corps of Engineers resulted in a stream rehabilitation project which used wing deflectors and rip-rap to restore the channel to a meandering 9 yds. wide channel. Fish population response was monitored annually using electrofishing gear. Brown trout (Salmo trutta) numbers increased 461%, while numbers of mountain suckers (Catostomus platyrhynchr) and white suckers (C. commersoni) decreased 86% and 55% respectively from 1978 to 1983.

INTRODUCTION

Rapid Creek, largest stream in the Black Hills, originates 30 mi. west of Rapid City in the central Black Hills and flows easterly through the City to the Cheyenne River approximately 30 mi. east.

During spring of 1978, a 915 yds. section of Rapid Creek in the city limits of Rapid City, South Dakota, was modified as the result of a U.S. Army Corps of Engineers flood way project. Width of Rapid Creek (in the area known locally as Baken Park) increased from 10-12 to 29-43 yds. Extensive instream habitat damage resulted and brown trout (Salmo trutta) populations and subsequent fishery drastically declined. Negotiations between the Corps of Engineers and the South Dakota Department of Game, Fish and Parks resulted in construction of stream improvement structures in the 915 yds. section (fig. 1).

Wing deflectors were designed to narrow and deepen stream channel and to guide stream into a meandering pattern. Deflectors protruded approximately 0.3 m above normal stream flows, allowing high flows to pass over. Topsoil and sod were placed on the deflector to obtain immediate vegetative cover. Stream improvement work was completed in the spring of 1979 (fig. 2). Objective of this was to determine the effects of stream rehabilitation project on natural fish population in the area.

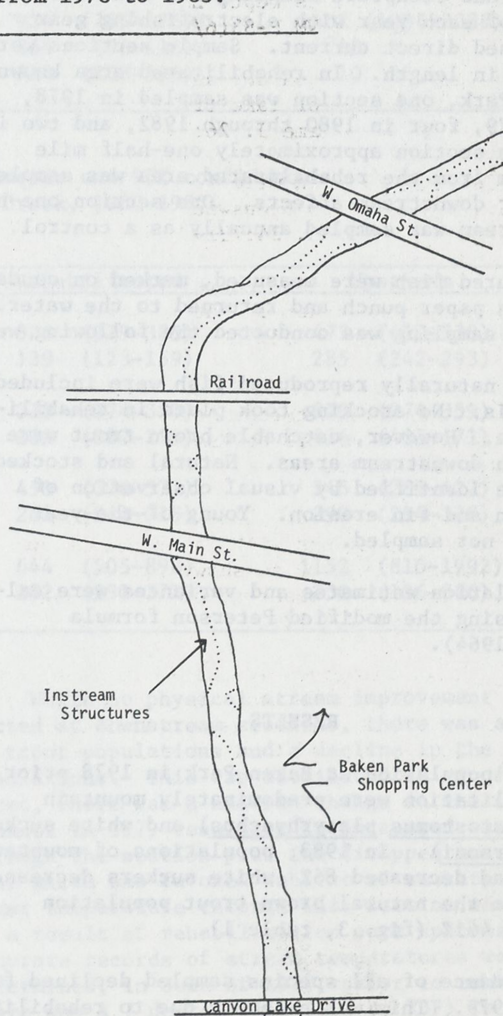

Figure 1.--Wing deflector locations on rehabilitation area (Baken Park) on Rapid Creek, South Dakota.

[1]Paper presented at Wild Trout III Symposium, Mamoth Springs, Wyoming, September 24-25, 1984.

[2]Richard Ford, Coldwater Fisheries Biologist, South Dakota Department of Game, Fish and Parks, Rapid City, S.D.

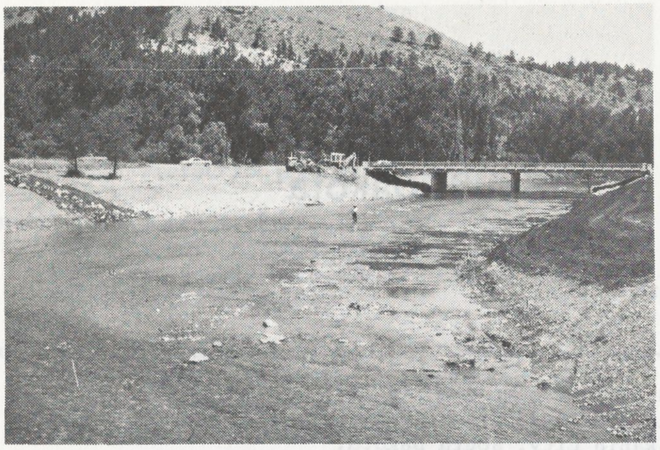 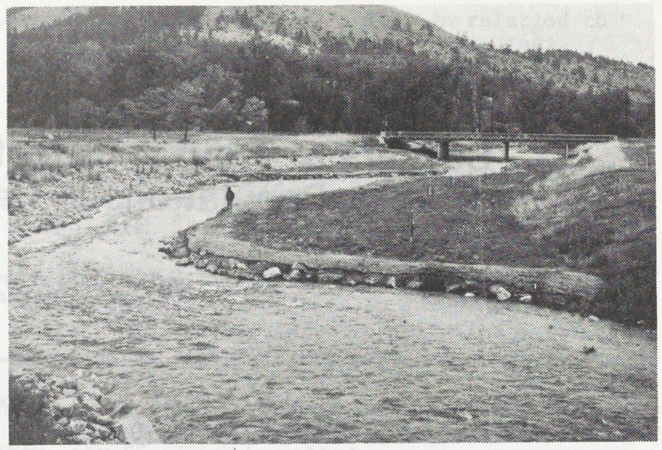

Figure 2.--Rapid Creek at lower end of Baken Park prior to (left). and after (right) rehabilitation in 1979.

METHODS

Mark and recapture sampling was conducted in the fall of each year with electrofishing gear using pulsed direct current. Sample sections were 0.10 mile in length. In rehabilitated area known as Baken Park, one section was sampled in 1978, two in 1979, four in 1980 through 1982, and two in 1983. One section approximately one-half mile downstream from the rehabilitated area was sampled to monitor downstream affects. One section one-half mile upstream was sampled annually as a control.

Captured fish were measured, marked on caudal fin with a paper punch and returned to the water. Recapture sampling was conducted the following week.

Only naturally reproduced fish were included in analysis. No stocking took place in rehabilitated area. However, catchable brown trout were stocked in downstream areas. Natural and stocked trout were identified by visual observation of coloration and fin erosion. Young-of-the-year fish were not sampled.

Population estimates and variances were calculated using the modified Peterson formula (Ricker, 1964).

RESULTS

Fish population at Baken Park in 1978 prior to rehabilitation were predominately mountain sucker (Catostomus platyrhynchus) and white sucker (C. commersoni). In 1983, populations of mountain suckers had decreased 86% white suckers decreased 55%, while the natural brown trout population increased 461% (fig. 3, table 1).

Abundance of all species sampled declined from 1978 to 1979. This was probably due to rehabilitation work which was completed in spring of 1979. Mountain sucker numbers returned to 1978 levels in 1980 and 1981, declined sharply in 1982, and remained low in 1983. White sucker populations dropped to approximately half of 1978 levels in

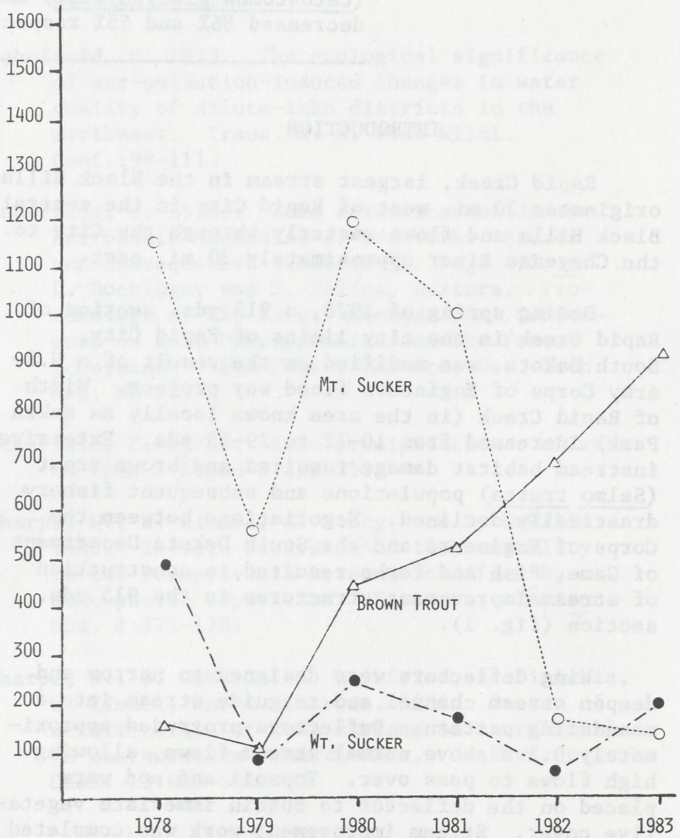

Figure 3. Estimated number of fish per 0.10 mile of Rapid Creek at Baken Park, 1978-1983.

1980, decreased slightly in 1981, declined 65% in 1982, then increased to 1981 levels in 1983. Catchable sized brown trout (greater than 8 in.) increased from 139 in 1980 (the year following rehabilitation) to 282 per 0.10 mi. in 1983. Subcatchable brown increased from 324 to 644 over the same period (table 2).

Table 1.--Fish population estimates and 95% confidence intervals per 0.10 mi. on Rapid Creek, 1978-1983.

Year	Species	Downstream		Rehabilitated		Upstream	
1978	Brown trout	181	(137-230)	165	(89-1000)	556	(447-737)
	Mt. Sucker	525	(345-851)	1144	(867-1680)	10	
	Wt. Sucker	710	(607-900)	474	(311-991)	10	
1979	Brown trout	66	(50-99)	97	(67-176)	866	(732-1067)
	Mt. Sucker	84	(52-99)	578	(502-681)	10	
	Wt. Sucker	284	(224-595)	84	(64-121)	10	
1980	Brown trout	106	(69-250)	436	(402-544)	758	(669-832)
	Mt. Sucker	865	(660-1250)	1190	(1084-1319)	10	
	Wt. Sucker	388	(288-595)	268	(236-311)	10	
1981	Brown trout	304	(223-522)	520	(461-599)	746	(679-830)
	Mt. Sucker	259	(175-499)	1010	(927-1109)	10	
	Wt. Sucker	244	(138-1019)	201	(164-259)	10	
1982	Brown trout	414	(233-2946)	712	(620-886)	635	(543-765)
	Mt. Sucker	103	(77-406)	181	(143-245)	10	
	Wt. Sucker	325	(158-5370)	69	(49-119)	10	
1983	Brown trout	3886	(3033-5406)	926	(735-1269)	1402	(1006-2338)
	Mt. Sucker	268	(187-475)	154	(96-616)	10	
	Wt. Sucker	202	(136-570)	214	(133-596)	10	

Table 2.--Brown trout population estimates and 95% confidence intervals per 0.10 mi. on Rapid Creek, 1980-1983.

Year	Size	Downstream		Rehabilitated		Upstream	
1980	20	54	(33-155)	324	(279-385)	473	(427-530)
	20	52	(36-95)	139	(123-159)	285	(242-293)
1981	20	189	(149-259)	318	(274-380)	310	(274-359)
	20	115	(74-263)	202	(187-219)	436	(405-471)
1982	20	323	(171-2777)	450	(376-571)	345	(289-427)
	20	91	(62-169)	262	(244-315)	290	(254-338)
1983	20	3715	(2898-5172)	644	(505-898)	1152	(810-1992)
	20	171	(135-234)	282	(230-371)	250	(196-346)

Brown trout numbers at the downstream section appeared to have benefited from Baken Park stream improvements. Estimated trout abundance in 1979 was 66 per 0.10 mi. This increased to approximately 414 in 1982. Numbers further increased to 3,886 in 1983 of which 171 trout were of catchable size. Trout numbers at the upstream section remained fairly stable until 1983 when they too showed a large increase.

DISCUSSION

Data clearly supports conclusion that this was a highly successful stream rehabilitation project. Natural brown trout populations increased 461% (926 per 0.10 mi. of which 282 are of catchable size).

While no physical stream improvement was conducted at downstream sections, there was an increase in trout populations and a decline in the sucker populations. This was attributed to two factors. First, there was a natural change in the stream channel in 1979 resulting in increased water velocity through the section plus the disappearance of a deep pool which was favored habitat of suckers. Secondly, water temperature through this section was lower as a result of rehabilitation work upstream. While accurate records of stream temperatures were not determined, in June of 1978, prior to rehabilitation, there was a 7 degree rise (66F to 73F) in water temperature through the 900 yd. channelized portion of Rapid Creek at Baken Park. This rise was undoubtably even greater in July and August when temperatures increased. Following rehabilitation, summer water temperature rise through the area has been less than 1 degree.

Brown trout less than 8 in., primarily age I trout, increased substantially at all sections in 1983 (table 2). Increased water flows during winter of 1981 and continuing through 1983, was a factor that may be responsible for excellent survival of 1982 year class.

While no estimates of angler pressure or harvest have been made, anglers are frequently seen fishing and success is reported to be good.

In conclusion, the study area initially had 90% suckers and 10% trout while today there is 10% suckers and 90% trout. Habitat improvement at Baken Park effectively turned a section of stream, which was poor esthetically into an esthetically pleasing area with high numbers of naturally reproduced brown trout.

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Massachusetts Coastal Trout Management[1]

Joseph D. Bergin[2]

Abstract.--The life history and migration patterns of anadromous brown and brook trout are presented. The historic record is reviewed to estimate the extent and magnitude of the "salter" brook trout fishery in the 1600's. The relationship of the "salter" fishery to the "sea trout" fishery is discussed in light of heavy angler demand.

SEA-RUN BROOK TROUT

Historic Distribution And Abundance

When the Pilgrims landed at Plymouth, they encountered vast resources of anadromous fish, among them, Atlantic salmon (Salmo salar) and sea-run brook trout (Salvelinus fontinalis). Accordingly, there are the obligatory references to spots where "salmon once ran so thick that one could almost walk across the river on their backs" (Spalding 1877). Unfortunately, these meager references tell little of their distribution or real abundance. While we may "reconstruct" the salmon runs through a combination of these records and modelling, this is not an option with our sea-run brook trout. Our forebearers left virtually no record of the fishery until 1770. For example, even though brook trout ran a stream which flowed through the heart of Plymouth Plantation, they receive no mention in the first 229 years of statutes passed protecting and regulating the brooks' herring (Alosa spp) run (Sec. of State, 1887).

The first reference to sea-run trout occurs in John Rowe's diary on May 24, 1770, when Mr. Rowe, a serious angler of the period, records catching ten salter trout in Town Brook, Plymouth, "The largest I ever saw - several of them 18 inches in length". This catch was twice his norm for the period 1764-1779, giving a first indication of the sea-run trout fisheries significance (Mullan 1960). (Smith 1833) gave the first estimate of distribution for these fish as being "fire-place" on Long Island, Martha's Vineyard, "various parts of this and the adjoining states." He held the Mashpee, Quashnet and Childs rivers in the highest regard. Another naturalist indicated sea-run brook trout were common in Sandwich with at least 45 kg sold each year (Mullan 1960). The state statutes written between 1849 and 1868 identify seven anadromous trout fisheries warranting special legal protection and adding two towns, Wareham and Bourne, to the local distribution (Sec. of State, 1887). It appears this legislation was prompted by the extinction of the Connecticut (1809) and Merrimack (1848) Atlantic salmon runs, causing the sportsmen to protect the remaining salmonid runs as best they could. Indeed, (Smith's 1833) accounts of the typical fishing, such as: "... in the middle of April 1829, there were taken by two persons, in five days fishing, 296 sea trout, weighing 191 pounds. On one of the five days the number was 82 and the weight 61 pounds, 30 fish of one of the parties weighing 30 pounds and a quarter, and the largest weighing two pounds and 11 ounces" only served to further these efforts.

This section would not be complete without mentioning the records of two private fishing clubs, the Mashpee dating from 1915 to 1958 (Mashpee Fishing Club n.d.) and Red Brook beginning in 1918 and extending to 1971 (fig. 1) (Lyman, pers. comm.). In both cases, the fishing was restricted to a few anglers and harvest records kept religiously. It is readily apparent that these records merely document the decline of a significant fishery.

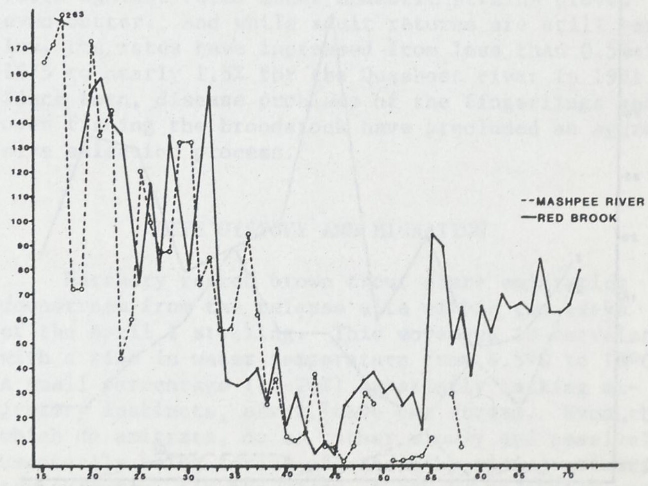

Figure 1.--Historic harvests from two sea-run brook trout streams.

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[1]Paper presented at the Wild Trout Three Symposium. (Yellowstone National Park, September 24-25, 1984).

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LIFE HISTORY AND MIGRATION

It is quite remarkable that as late as 1940, the scientific community did not know the life history of sea-run brook trout (White 1940) or that the migration habits and taxonomy was not clarified until the 1950's. Mullan (1956), working on Cape Cod, defined the basic life history for anadromous brook trout near the southern limit of the fish.

Fry emerge in late February, absorb their yolk sac in a couple weeks, then move downstream to quiet water. Later in the spring they spread throughout the river, feeding on mayflies (Ephemeroptera) and stoneflies (Plecoptera). I found many of the larger fish move into the estuary during the following spring, while Mullan (1956) felt they remained in the river for another year. When the young of the year herring move downstream to the ocean, the trout become piscivorous, preying on the abundant clupeids. In November, the herring emigration ends and the trout return to an insect diet. I have found a number of 89 to 127 mm male brook trout less than a year old, to be sexually mature at this time. Mullan (1956) found these trout do not become sexually mature for another year, developing in late summer as 1+ fish.

During the following March and April all two year olds migrate to the estuary, a few leaving their home estuary to wander along the near shore. Mullan (1958) noted 0.4% of the stocked trout wandered into other streams, with one fish travelling at least 12.8 km in the ocean. Movement was most significant between streams entering the same estuary. Within two months of their departure, many salters return to their home stream, where they spend the summer. Another group enters the stream in September, spawning in late October to early November. White (1941) also noted numerous brief migrations averaging approximately two months. My experience is that these trout spawn from September until mid October. Shortly after spawning, most leave the river to overwinter in the estuary. The remainder emigrate in the early spring, when some estuarine fish are returning (fig. 2).

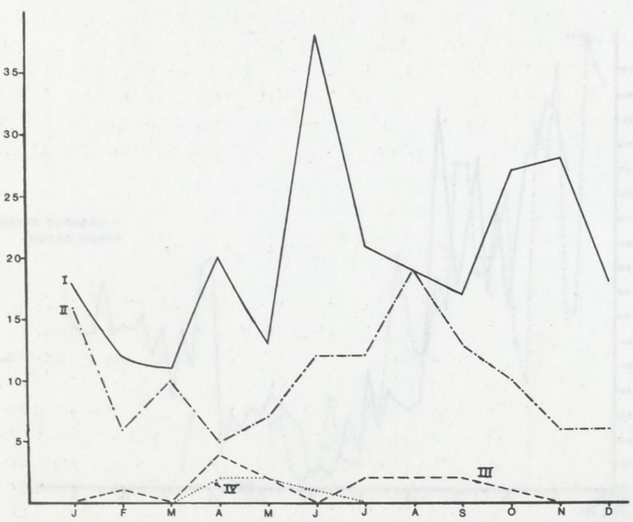

Figure 2.--Number of sea-run brook trout by year-class, Mashpee river, 1974.

AGE AND GROWTH

Mullan (1956) found native brook trout in the Mashpee river grow 76 to 127 mm during their first year and add about fifty more mm their second growing season. Yearlings stocked in Mashpee or Scorton creek gained 50 mm during the summer, averaging 165 mm. In the Santuit, stocked fish living in the freshwater portion barely grew over the summer, while those in the brackish marsh gained 50 mm between June and October (Mullan 1956). Those fish surviving for a year in Scorton attained lengths of 203 to 305 mm. One individual was captured after two seasons having reached 380 mm in size. The largest salter captured by Mullan (1956) was 432 mm long and III+ years old. Unfortunately, Mullan did not regularly record weights along with length data, noting only that the 432 mm fish was 1.1 kg and two fish 380 mm long were 0.9 kg each. (Smith 1833) indicated a 279 to 305 mm fish weighs 0.45 kg. This is consistent with Wilder's data (1952).

ANGLER HARVEST

Mullan (1958) reported that salter trout fishermen caught an average of 0.86 trout per hour in harvesting 3,484 trout from five Cape Cod streams. This rate varied widely due to degree of difficulty in fishing the stream, extent of public access and fishing pressure. This catch rate was produced by a mixed harvest of 20% natives, 67% recently stocked hatchery fish and 13% carry over hatchery trout recovered at least a year after release. Fishing pressure was highest from opening day (± April 20) to June. Harvest declined rapidly through the summer and fall.

To add an historical prespective, I have calculated the catch per day for historic records and Mullan's study (table 1). Clearly, the "modern" catch rate has dropped, even with heavy stocking. The limited catch per hour data confirms this. Six records in the 1830's averaged 3.0 trout per hour; the rate dropped from 1.26 trout per hour in 1915 to 0.17 in 1955 and stabilized under the put, grow, and take management in the mid 1950's at 1.25 trout per hour. The historic fishery yielded 0.9-1.4 kg regularly, while this size fish was seldom taken after 1940.

RECENT DISTRIBUTION

Mullan (1956) surveyed 61 streams located between the Rhode Island state line and Plymouth. He was able to identify only 15 native sea-run brook trout streams, the majority located on Cape Cod. Bergin (1976) checked 74 streams along the coast, including Mullan's streams, and found 17 native sea-run brook trout populations. Again the majority occurred on Cape Cod, however, fisheries were found on the south shore and Buzzards Bay.

COASTAL TROUT MANAGEMENT PROGRAM

Mullan (1958) concluded from the trout studies that the fabled, anadromous trout fishery of old,

Table 1.--Catch and effort data for sea-run brook trout fisheries during five periods.

Period	Number of Anglers	Effort	Harvest Number	Trout per Day/Angler
1770	1	1 day	10	10
1820-1835	10	18 days	533[1]	29.6
1836-1850	34	40 days	776[1,2]	19.4
Mashpee Fishing Club				
1915-1945[3]	12	68 days	364	5.35
1955				
Mashpee	27	119 hours	149	5.5
Santuit	17	51 hours	34	2.0
Quashnet	83	296 hours	401	4.8

[1]A catch record was indicated by total weight only, therefore I assumed an average weight of 250 gms.
[2]Three hundred thirty two fish averaged 255 gms; seven fish weighed 5.9 kg.
[3]Four typical years of harvest.

never existed. Instead, he felt the historic records were highly biased, having been written through rose colored glasses, since the five study streams produced a fine harvest of 150 to 250 mm fish at a low level of angling effort. Noting the excellent growth rate of both the stocked and native trout, the ability of domestic hatchery trout to become anadromous, and the virtually untapped coastal stream resource, Mullan developed a sea-run trout management program.

This program involved stocking catchable-size brook trout yearlings, 150 to 229 mm long, in the freshwater portion of 23 coastal streams. The average recommended stocking was 1,100 fish per stream, to be released just prior to and during the fishing season, namely March through May. Mullan suggested limited stocking of brown trout (Salmo trutta) in the larger, warmer streams, because they might better utilize this habitat. Stocking hatchery culls of both species later in the year was also considered appropriate. Finally, Mullan recommended stream improvement be undertaken subsequent to purchase of these streams.

SEA-RUN BROWN TROUT PROJECT

History

The brown trout released under the coastal trout program rapidly developed into a trophy fishery for a small group of very enthusiastic anglers. A few years later, Connecticut created an anadromous brown trout fishery in streams too warm for brook trout, using eggs from Scottish, English and Danish strains of sea-run brown trout. In light of these facts and the demand for quality angling, which the very limited potential of salter trout could not satisfy, our agency looked to sea-run brown trout as the vehicle for better utilization of our estuarine resources. Unfortunately, there was a federal ban on importation of fish or eggs which precluded duplicating Connecticuts' program. Therefore, in 1974 we began an experiment to develop a strain of sea-run trout from our domestic brown trout.

SELECTION PROCESS

Since we did not know then, anymore than we do now, which characteristics, genes, or loci are important to migration, ocean growth and survival or disease resistance, we chose to apply both artificial and natural selection to large numbers of fish each year, until return rates reach 10 to 12%. Each spring 15 to 25,000 yearling brown trout are stocked in seven coastal streams. They migrate to sea and grow for at least a year and a half. When they return as spawners, the largest individuals in the best condition are taken to the hatchery for spawning. There, only the four or five best males are spawned with the females in an effort to maximize selection and egg take too. Their progeny are raised in the hatchery for a year. The following spring, the progeny are stocked in the same seven streams and the process is repeated.

While the program has been plagued with low numbers of desirable spawners and numerous other problems, early results were gratifying. The first generation of selected fish returned as sub-adults at double (8% vs. 4.4) the rate of the parent stock. Tests against three other domestic strains proved even better. And while adult returns are still very low, the rates have increased from less than 0.5% in 1975 to nearly 1.5% for the Quashnet river in 1981. Since then, disease problems of the fingerlings and over fishing the broodstock have precluded an aggressive selection process.

LIFE HISTORY AND MIGRATION

Hatchery reared brown trout start emigrating downstream from the release site within two weeks of the April 1 stocking. This movement is correlated with a rise in water temperature from 4.5°C to 10°C. A small percentage (10-20%) apparently lacking migratory instincts, never leave the stream. Even those which do emigrate, do so rather slowly and passively, eventually being forced off shore by rising estuarine temperatures. In the ocean, there is an almost random movement pattern, with recaptures being made on either side of the estuary's mouth.

The longest migration of a tagged fish covered 39 km, from the Mashpee river eastward to a weir off Chatham.

Beginning in July of the year they are stocked, subadults home to the stream of release with less than 10% wandering to other rivers. These sexually immature fish do not ascend the stream more than 0.5 km above tidal influence. Their numbers peak by September with 10 to 16% of the stocking being accounted for. While in the stream, they exhibit a "floating home range" centering around a couple of deep pools which possess extensive overhead cover. For example, in a stream of progressively numbered pools, an individual trout might range from pool ten through 28, but prefer pools 13 and 15. These sea-run browns leave the river for the second time in November and disappear until the following August. Nothing is known of their movements at sea, or habitat preferences, but it is assumed they overwinter in the estuary and move off shore as water warms in the spring.

During the second year of their oceanic existence, sea-run browns, primarily adult males, begin reentering streams by mid August. These early fish move only a short distance up the stream, apparently waiting for appropriate water temperatures and/or mates. The main run, comprised of a few fish older than age II+, occurs in mid October. Freshets resulting from drainage of cranberry bog ponds appear to stimulate the migration. At this time fish from the early run intermingle with the newcomers; together they ascend the streams in search of suitable spawning sites. The area chosen is about seventy two meters in length and usually consists of one or two pools separated by a riffle. Redds are begun about mid-October, with spawning activities continuing into November. In late October a third and final wave of veteran spawners (age III+ or older) enters the river. These fish pair up and spawn quickly, often in the lower portions of the streams. The sex ratios of the three waves of spawners vary somewhat: the early run consists mostly of males; the main run has an even sex ratio, but during the late run, females are dominant by a ratio of 1.2 to 1.

From the time of release until their second return as age III+ adults, there is only a 1% survival rate. Natural mortality accounts for 85% of this mortality; angler harvest amounts to only 9% of this total. The remainder occurs due to broodstock handling and spawning.

DISTRIBUTION

A survey of 74 coastal streams produced three streams with wild populations of brown trout, namely the Mashpee, Childs, and Quashnet rivers all on Cape Cod. Thirteen other sea trout fisheries which are scattered along the coast are maintained by annual plants. It is anticipated the program could grow to 40 or more streams eventually.

AGE AND GROWTH

Wild brown trout attain a length of 100 to 150 mm as yearlings. The stocked fish, released as 98 gm yearlings about 175 to 200 mm long, grow 25 mm a month in saltwater. When they are feeding on herring in the river, growth drops to 12 to 18 mm per month. Those remaining in the river grow less than 50 mm in an entire season. Because of this variation, average growth rates are of little value. Instead, our selection criteria, which typifies the top 10% of the spawning population, is present in table 2.

Table 2.--Size criteria for selective breeding of exceptional sea-run brown trout.

Age	Length (mm)	Weight (kg)
I+	406	0.9
II++	508	1.7
III++	584	2.1
IV+	635	2.8
V+[1]	686	3.5

[1]The oldest fish captured thus far is V+.

ANGLER HARVEST

For the first five years of the sea-run brown trout project few anglers caught sea-run fish. Most tried for the sea-run trout in May and June or November and December when the populations were at their lowest levels. The few successful anglers were tight-lipped as to timing and technique, keeping the fishery for themselves, but gradually the fishery developed. A limited creel census from March 20, 1979 until May 30, 1979 indicated 604 anglers spent 1,389 hours in catching 1,462 brown trout. In 1978 and 1979 the Coonamessett river produced 20 to 30 broodstock. In July 1980 some fishermen found a pool the broodstock congregated in. From that date on we received reports of two to five anglers harvesting three to six pound sea-run trout each week for two months. Our broodstock collections produced only six fish from the Coonamessett that fall and four the next. Subsequently, we implemented a two fish per day bag limit and a seasonal closure from March 15 until May 30. This seemed to dampen angler interest and harvest. Under these conditions, a full scale creel census received low priority. A census is planned for fiscal year 1985.

General observations are that 60-70% of the anglers are fly fishermen. Most are looking for a challenging, unusual fishery or a trophy. The average brown trout angler fishes for one tide cycle per trip and takes a few trips each year. I feel experienced sea-run brown trout fishermen catch about one fish per trip while a novice will take only one fish per season. At this time, I know about two hundred individual anglers who pursue these fish, putting in about four thousand hours per year in harvesting about five hundred fish. The actual fishery may be twice as large.

DISCUSSION

While it may seem that the native salter brook trout have been short-changed by our experiments with sea-run brown trout, we feel it has been beneficial to the "salter." At the time we began our program, we knew of less than six streams possessing fishable stocks. Considering the low levels of exploitation which can impact a brook trout fishery, the variable recruitment and the high ocean mortality these sea-run brook trout incur, it was felt that virtually no level of harvest would be safe (Hunt et. al., 1962). Yet we have 220,000 licensed anglers, 70% living within fifty miles of the coast. Therefore, development of the brown trout fishery was viewed as an effective vehicle to utilize the resource and an alternative fishery to keep pressure off the anadromous brook trout. Accordingly, the brown trout fishery has been widely advertised while the brook trout fishery has been downplayed. And the concept works. We get far less requests for information about anadromous brook trout now than ten years ago, while fishing pressure on the sea-run brown trout streams is increasing. Only two of Mullan's (1958) five study streams are being fished for sea-run brook trout. And these two are being fished at historic levels of $\pm$ 100 angler hours. Incidentally, the heavy stocking and publicity of the brook trout study dramatically increased fishing pressure on the salter streams. Quashnet river fishing pressure rose from 199 hours in 1954 to 517 hours in 1956.

The issue of possible competition between the brown and brook trout is a classic fisheries problem (Larkin 1956). In this case, the hatchery production of yearling browns and the extensive oceanic migrations change the scope of the problem.

Since the sea-run brown trout spend their first 14 months in the hatchery, there is virtually no opportunity for competition with young of the year brook trout. The yearling and two year old brook trout avoid some competition with the sea-run brown trout by separating in time and space through species specific migration patterns. But when the two are in the river together, the brown trout occupy the larger deeper pools while the smaller brook trout frequent the ends of the large pools, some small pools and the deeper runs. If the brook trout is of a similar size to the brown, he may be found in the deep pools also. While this separation implies competition, agonistic behavior has not been noted in ten years of sampling, and the brook trout have not declined since 1974. Unlike the subadults, the mature browns establish very limited home ranges during their fall run. I have calculated the average home range of spawners as 72 m or two pools. These fish take up their station near the best cover in the deepest pools. Invariably, the only other fish taken in these pools will be a pair of large salters. The other trout take stations at the tail of these pools or in other lesser pools. Negative impacts are lessened by the moderate stream flow and abundant food, namely young of the year alewives previously noted. The final area of possible competition involves spawning sites. The salters spawn a few weeks before the sea trout, and tend to choose coarse sand and fine gravel in a few inches of water. The browns invariably select substrate twice as coarse and usually choose a site in much deeper water. I have never observed destruction of one species redd by the other. While my remarks are basically downplaying the issue, I would not recommend routinely stocking brown trout on anadromous brook trout because the neutralizing factors, namely an abundant forage base and abundant habitat beyond the scope of the brook trout to utilize, may not be present in other streams. Also, as the brown trout return rate rises over time, the presently vacant habitat may be filled quite quickly, forcing competition.

The third area of interest involves the historic anadromous brook trout fishery's magnitude and possibilities for restoration. Mullan (1958) felt the historic salter fishery was grossly exaggerated, both in extent and abundance. Apparently he did not have access to the historic records I analyzed. Figure 1 clearly shows that Red brook and the Mashpee river had significant fisheries which were already in decline by 1915. The log of the Mashpee Fishing Club (table 1) provides a clear description of the miniscule effort directed at catching 0.4 kg to 1.8 kg sea-run brook trout. And (Smith's 1833) notes on the fishery confirm the Mashpee records while showing other rivers produced just as many fish, and some of these fish were up to 3.6 kg. Actually the catch rates for the 1820's (table 1) show a better fishery than in the 1850's, let alone the twentieth century. Even if the fishery occurred only in the three streams noted by Smith (1833) and Red brook, it would be a significant fishery.

When the streams known to contain anadromous brook trout, either through the historic record (Smith 1833; Sec. of State, 1887) or field surveys (Mullan 1956; Bergin 1976) are analyzed for physical characteristics, three traits dominate; coldwater during summer, an abundance of spawning substrate and a highly productive estuary. While recent stream surveys (Bergin 1969; Bergin 1976; Schlotterbeck 1954; Bridges 1955) of eastern Massachusetts waters clearly show that low flows and clay or mud bottoms preclude wild trout in most streams north of Plymouth, they did encounter a few fisheries. But most of the historic salter habitat was located between Rhode Island and Plymouth. Applying the three traits noted previously to the streams and estuaries of this region and allowing for human perturbations such as warm-water ponds and mosquito control ditches, I feel 70 streams in this area may have supported anadromous brook trout populations. Adding another ten streams between Plymouth and New Hampshire, this becomes a large and extensive fishery for Massachusetts. Unfortunately, many of these are lost forever, such as Scussett creek during construction of the Cape Cod canal while others have been dramatically altered like Town brook, Plymouth. Thus, we are left with Bergin's (1976) 17 existing salter streams and perhaps five or six others which are restorable. At this level, Mullan (1958) is correct in describing it as a limited fishery.

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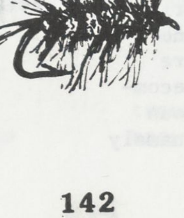

Restoration of a Spring Creek[1]

John W. Kiefling[2]

Spawning activities are limited in the Snake River, and are largely restricted to adjoining spring creeks. Renovation of spawning gravels and enhancement of habitat for young of the year cutthroat trout has resulted in a significant increase in spawning cutthroat trout returning to Three Channel Spring Creek.

The Snake River is managed under the species concept, which is primarily concerned with providing fishermen with the opportunity to catch Snake River cutthroat trout (Salmo clarki ssp.) from a population sustained by natural reproduction. However, we are dealing with the management of a wild population of cutthroat trout in an environment which is hardly natural. Jackson Lake Dam serves as a source for irrigation needs in Idaho and Wyoming, and also as a flood control structure. In the 1960's during the fall inspection period, reservoir release patterns averaged slightly more than 30 days in which the flows were less than 100 cfs, while spring flows approach 5,000 cfs. Such extreme discharge rates reduce environmental stability and may result in increased natural mortality of young age classes of cutthroat due to reduced winter habitat.

The construction of levees in the late 1950's by the U.S. Army Corp of Engineers were designed to control river flow and assist in bank stabilization. Impermeable levees have been constructed parallel to the shoreline of the river proper. Jetties, composed of large boulders, have been placed at various locations perpendicular to the bank in order to reduce velocities, protect the bank, and to contain or even change the thalweg of the stream (Kiefling, 1978). The present levee design promotes almost annual channelization which will ultimately determine the quantity and distribution of fish within the system.

Spawning activities are limited in the river proper, and are for the most part restricted to adjoining spring creek tributaries. Initial investigations of spawning tributaries by Hayden (1967) suggested a low density of spawning cutthroat trout which led to the stocking of fingerlings. This program proved to be unsuccessful. At this point the tributaries were studied to determine the potential to increase and stabilize the spawning run with eyed egg plants. During these investigations redds were mapped on Three Channel Spring Creek and counted to determine the status of present use. As a result, this was the first tributary selected for intensive spawning channel improvement. This spring fed tributary enters the Snake River from the east, while its confluence lies immediately upstream from that of the Gros Ventre River (Figure 1).

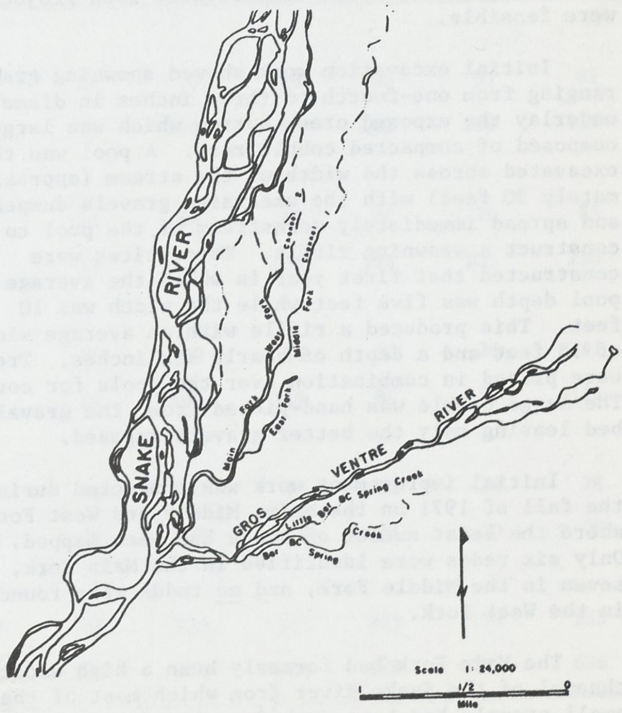

Figure 1. Three Channel Spring Creek complex, Teton County, Wyoming.

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[1] Paper presented at the Third Wild Trout Symposium. Yellowstone National Park, Mammoth, Wyoming, September 24-25, 1984.

[2] John W. Kiefling is Fisheries Biologist for the Wyoming Game and Fish Department, Jackson, Wyoming.

The creek is surrounded by private property with limited public access. The riparian habitat receives heavy livestock use. The creek also receives overflow irrigation waters. Habitat has been considered marginal to good, with much of the stream composed of compacted cobbles with limited spawning potential.

The creek has a gradient of 13 feet per mile and a riffle velocity of .9 to 2.5 feet per second. The average volume flow is 40 cubic feet per second. The flows will change somewhat in each fork of the creek during the irrigation period.

This spring creek system is stable and is not influenced by a run-off period. Such stability does have its drawbacks when you consider no spring flows means no cleansing of silts and no recharge of gravels within the system.

Redd count data indicated spawning activities were largely centered on the East Fork with lesser activities noted on the upper section of the Middle Fork. After spawning activities ceased, redds were counted and mapped in 1970 to determine relative abundance and use patterns within the system. A total of 38 redds were counted in the East Fork and 17 in the Main and Middle Forks. An estimated 50 and 112 cutthroat were utilizing the Main, Middle and East Fork respectively at this time. These observations indicated cutthroat trout were using all of the gravel riffles available and in many cases there was a serious superimposition of redds (Erickson, 1980). Eyed egg stocking was not deemed feasible since the present spawning areas were being used to the fullest extent. As a result, a decision was made to rejuvenate the riffles void of gravels and provide additional spawning habitat if the response demonstrated such projects were feasible.

Initial excavation work showed spawning gravels ranging from one-fourth to three inches in diameter underlay the exposed creek bottom which was largely composed of compacted cobble rock. A pool was then excavated across the width of the stream (approximately 30 feet) with the excavated gravels dumped and spread immediately downstream of the pool to construct a spawning riffle. Three sites were constructed that first year in which the average pool depth was five feet while the width was 10 feet. This produced a riffle with an average width of 18 feet and a depth of nearly six inches. Trees were placed in combination over the pools for cover. The large cobble was hand-picked from the gravel bed leaving only the better gravels exposed.

Initial improvement work was conducted during the fall of 1971 on the Main, Middle and West Forks where the least number of redds had been mapped. Only six redds were identified in the Main Fork, seven in the Middle Fork, and no redds were found in the West Fork.

The Main Fork had formerly been a high water channel of the Snake River from which most of the small gravels had been washed away prior to the construction of flood control dikes along the river into the early 1960's. The first three riffle sites were constructed on this segment and signficant use was not anticipated for several years, however, all of the newly constructed riffles were used by spawning trout the following spring whereas the number of redds increased from six to 20 (233 percent). This prompted the construction of eight additional riffle-pool sites by 1976. Riffles were also constructed in the remaining complex with the exception of the East Fork which was held in abeyance as a control for comparison purposes.

Table 1 indicates the number of redds in the Main Fork increased over 4,100 percent in 10 years, while the estimated minimum total number of spawning cutthroat trout increased from 5 to 230 (4,500 percent) in the same period of time.

The Middle Fork was a more typical spring creek environment comparable to the East Fork. The channel proper is relatively narrow (10 to 20 feet) with a limited number of pools and spawning gravels. Very little overhead cover is afforded spawning fish for protection from avian predators. A total of 28 logs were placed over existing pools and holes, and along the east bank as deflectors and to provide cover for young trout in 1971. Three sites were selected for gravel rejuvenation activities (riffle-pool construction) and additional logs were added in 1972 and 1974. Although no additional gravel rejuvenation was needed, 9 sites were stocked with 125.2 tons of commercial washed gravels at $4.30 a ton in 1980. These new riffle sites were constructed by excavating a shallow hole approximately one foot in depth then filling it with the commercial gravel. In some cases these new gravels were dumped and spread above natural gravels to simply recharge the section with new gravels.

The increased spawning activities in the Middle Fork was equally dramatic in comparison to the Main Fork. In 10 years there was a 720 percent increase in the number of redds and a 692 percent increase in the minimum total estimated number of spawners (Table 1).

The West Fork is quite similar to the Main Fork. It also had been a former high water channel of the Snake River. Several areas were excavated to provide available spawning gravels in areas which were compacted and void of proper sized gravels. In addition to this, a beaver dam which acted as an upstream barrier to migrant spawners was removed near the mouth of the West Fork. However, although this tributary was believed to be spring fed, the removal of beaver dams several miles north of this section led to a loss of water for this channel. Evidently the source of water was from an overflow of the dams and sub-irrigation. This channel has been abandoned to further study.

Channel One of the Middle Fork has also experienced a significant increase in spawning activities due to its proximity to the Middle Fork (Table 1). This section was further enhanced by the construction of four new spawning riffles with 41.2 tons of commercial gravels in 1980.

No habitat improvement work was initiated on the East Fork until late summer in 1975. Until this date this particular area was used as a control for comparative reasons. This section of the creek had supported the majority of spawning activities for a number of years in the past. In 1975 three new riffle-pool complexes were excavated with an immediate response by spawners the following year (Table 1). In 1979 a total of 110.8 tons of commercial washed gravels were used to construct five new spawning riffles. The following year 53 redds were found on the five newly constructed riffles. This accounted for 45 percent of the total East Fork redd count.

In general, the increased number of redds in Three Channel Spring Creek was believed to be indicative of improved spawning conditions. Better distribution of spawners should decrease the superimposition of redds resulting in decreased hatching mortality, and the increased recruitment of cutthroat trout fry to the Snake River proper. The survival of increased numbers of Three Channel Spring Creek imprinted cutthroat trout is quite evident from the significant increase in numbers of spawners utilizing this particular spring creek complex.

The increased availability of improved gravels for spawning has resulted in an increased numbers of spawners returning to these tributaries and more importantly a corresponding increase in stock density levels of the Snake River. The potential improvement of similar sections of the remaining tributaries is nearly limitless though urban sprawl and housing development on select spring creeks is a great concern for the future of the tributaries and their role as a spawning and nursery areas. An ongoing program of habitat stabilization and improvement coupled with eyed egg stocking has enhanced the maintenance of this rather special wild trout fishery.

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Kiefling, John W. 1978. Studies on the ecology of the Snake River cutthroat trout. Wyoming Game and Fish Department, Fisheries Technical Bulletin No. 3, Project Completion Report F-37-R, 198 p.

Table 1. Total number of redds and estimated minimum number of spawning cutthroat trout as determined by redd size, Three Channel Spring Creek, 1970-1980.

	YEAR										
Section (length-feet)	*1970	**1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
East Fork (4,353)											
No. redds	38	57	35	44	56	26	77	69	60	51	81
No. spawners	103	154	95	119	151	70	208	186	162	138	219
Main Fork (2,315)											
No. redds	2	6	20	16	16	23	64	65	80	76	85
No. spawners	5	16	54	43	43	62	173	176	216	205	230
Middle Fork (1,482)											
No. redds	5	7	13	6	10	11	39	44	32	26	41
No. spawners	14	19	35	16	27	30	105	119	86	70	111
Middle Fork I (1,945)											
No. redds	10	14	18	12	18	14	40	47	31	26	28
No. spawners	27	38	49	32	49	38	108	127	84	70	76
Totals (10,095)											
No. redds	55	84	86	78	100	74	220	225	203	179	235
No. spawners	149	227	223	210	270	200	594	608	548	483	636

* Pre-improvement ** Initial improvement (Main and Middle Forks)

Monitoring Levels of Fine Sediment Within Tributaries to Flathead Lake, and Impacts of Fine Sediment on Bull Trout Recruitment[1]

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Thomas M. Weaver, and Michael D. Enk

Abstract.--Streambed samples from known bull trout spawning areas in four tributaries to the North Fork of the Flathead River, Montana demonstrated that spawning areas in one of the tributaries (Coal Creek) contained significantly higher percentages of fine sediment than the other three tributaries. Bull trout embryo survival and subsequent fry emergence success was highly correlated (r^2=0.87) to the percentage of material less than 6.4 mm within the streambed of Coal Creek. A significant correlation (r^2=0.40, p<0.001) was found between substrate score and densities of juvenile bull trout (fish longer than 75 mm) in 26 Swan River tributary reaches. Increase in estimated sediment loads attributed to road development (expressed as percentage over natural) was significantly correlated (p<0.001) with three different expressions of substrate composition (substrate score, percentage of material less than 6.4 mm, and percentage of material less than 2.0 mm) for 46 Swan River tributary reaches.

INTRODUCTION

A trophy bull trout (Salvelinus confluentus) fishery supported entirely by wild production is popular in the upper Flathead River Basin in Montana and British Columbia. Anglers annually catch adult bull trout up to 9 kg (800 mm) with many exceeding 5 kg. These adfluvial adults mature at five or six years of age (400-500 mm) and migrate as far as 230 km upstream from Flathead Lake to spawn in upper basin tributaries (Shepard et al. 1984). Young bull trout rear from one to four years in their natal tributaries before emigrating downriver to Flathead Lake. Upon reaching Flathead Lake, growth rates increase as the piscivorous bull trout find abundant prey (Leathe and Graham 1982).

The Montana Department of Fish, Wildlife and Parks (MDFWP) closed four bull trout spawning tributaries to fishing and set a 457 mm minimum size limit for bull trout in 1951. In 1978, the Environmental Protection Agency funded the MDFWP to conduct baseline fishery investigations in the Flathead Basin because of the potential for development of an open pit coal mine in the upper Flathead Basin in British Columbia, increasing oil and gas exploration throughout the basin, and rapid population growth and land development in the area. The information collected during this five year study (1978 to 1982) identified important bull trout spawning and rearing habitat in headwater tributaries, documented the life history of the native bull trout, estimated annual harvest and catch statistics, estimated the value of water-based recreation, and recommended a monitoring program to gauge the impacts of development on the fishery (Shepard and Graham 1983a; Shepard et al. 1984).

This study found that bull trout consistently selected specific areas for spawning. Of 185 stream reaches surveyed covering 750 km, bull trout redds were located in only 48 reaches covering 215 km (28%). The fact that bull trout spawning occurs in limited areas suggests that degradation of these spawning grounds could have a significant impact on bull trout populations. A segment of the monitoring program involved sampling streambed composition in high density bull trout spawning areas. This streambed monitoring indicated an excessive amount of fine sediment was present in the streambed of several important bull trout spawning areas. We were concerned about the effect fine sediment might have on bull trout embryo survival and rearing capacity. Several researchers have documented

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the impacts of fine sediment on the spawning success of salmonids (Cardone and Kelley 1961, Cooper 1965, Koski 1966, Gibbons and Salo 1973, Phillips et al. 1975, Hausle and Coble 1976, Iwamoto et al. 1978) and on rearing capacity (Bjornn et al. 1977, Reiser and Bjornn 1979, Adams and Beschta 1980, Crouse et al. 1981).

Two additional studies were initiated in the Flathead Basin which allowed us to explore these relationships for bull trout. The USDA Forest Service, Flathead National Forest, contracted with the Montana Cooperative Fisheries Research Unit to determine the effects of forest development on spawning and rearing habitat in Coal Creek, a tributary to the North Fork of the Flathead River, and the Bonneville Power Administration contracted with MDFWP and the U.S. Forest Service to determine the potential cumulative impacts of several proposed micro-hydroelectric projects on the fishery in the Swan Lake drainage (which ultimately drains into Flathead Lake). This report documents our efforts to quantify levels of fine sediment within bull trout spawning and rearing areas, estimate impacts of fine sediment on bull trout embryo survival and juvenile rearing capacity, and predict impacts of land development on bull trout recruitment through a sediment response model.

STUDY AREA DESCRIPTION

Flathead Lake, the largest natural freshwater lake (based on surface area) west of the Mississippi River, drains a 18,353 km^2 area of northwest Montana and southeast British Columbia (fig. 1). The Flathead and Swan rivers are the only major tributaries to Flathead Lake and have drainage areas of 16,444 and 1,909 km^2, respectively. Five major tributaries join the Flathead River before it enters Flathead Lake from the north. These tributaries are the Stillwater River, Whitefish River, and the North, Middle and South forks of the Flathead River. The South Fork of the Flathead River was isolated from the rest of the system by Hungry Horse Dam in 1951. Our investigations were conducted primarily in tributaries to the North and Middle Forks of the Flathead River and tributaries to the Swan River.

The Lewis Overthrust Fault extends through most of the upper Flathead River Basin and is responsible for layers of Precambrian argillite, quartzite and carbonate rocks overlying younger sedimentary limestones, dolomites, shales and sandstones deposited during the more recent Paleozoic and Mesozoic eras. Consequently, the surface geology in the basin is dominated by those Precambrian rock types with sedimentary rock types occasionally found near the surface. Quaternary glacial deposits cover most of the valley bottoms. Water quality of tributaries in the basin is generally excellent and typical of unproductive mountain streams.

Gamefish species present in tributaries include westslope cutthroat trout (Salmo clarki lewisi), Yellowstone cutthroat trout (Salmo clarki bouvieri), bull trout (Salvelinus confluentus), brook trout (Salvelinus fontinalis), rainbow trout

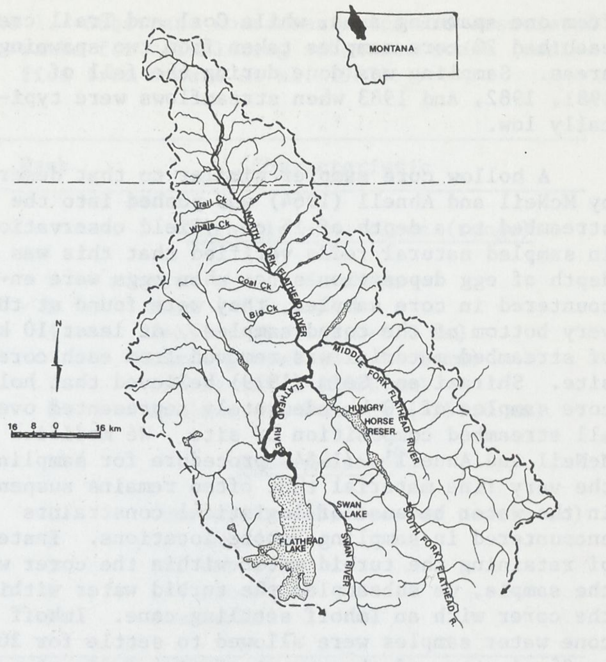

Figure 1.--Map of the upper Flathead River Basin, Montana.

(Salmo gairdneri), and mountain whitefish (Prosopium williamsoni). Cutthroat and bull trout were the most abundant species found in tributaries to the Upper Flathead River, while these two species and brook trout dominated fish populations in tributaries to the Swan River. In the Flathead Lake/River system both cutthroat and bull trout follow an adfluvial life history pattern described by Behnke (1979). The adults mature in Flathead Lake, spawn in small headwater tributaries, their progeny rear in natal tributaries for one to four years, and then emigrate downstream to Flathead Lake (Shepard et al. 1984). While the majority of bull trout in the basin follow an adfluvial pattern, cutthroat trout may be either adfluvial, fluvial, or resident. Cutthroat trout populations in the Swan River drainage are comprised mostly of resident fish inhabiting high gradient headwater areas of tributary streams. Both westslope cutthroat and bull trout are native to the basin.

METHODS

Streambed Composition of Spawning Areas

Field Sampling

Sample sites were located in Big, Coal, Whale, and Trail creeks, tributaries to the North Fork of the Flathead River (fig 1). Sampling stations were established in areas where high densities of bull trout redds were observed during annual fall redd counts. Two or three permanent transects perpendicular to the streamflow were set up in each monitored spawning area. Four sites were sampled across each transect. Cored sites were generally at equal distances across the stream channel, but an effort was made to sample spawning bed material. Big and Whale creeks each had 12 core samples taken from one spawning area, while Coal and Trail creeks each had 20 core samples taken from two spawning areas. Sampling was done during the fall of 1981, 1982, and 1983 when streamflows were typically low.

A hollow core sampler similar to that described by McNeil and Ahnell (1964) was pushed into the streambed to a depth of 15 cm. Field observation in sampled natural redds verified that this was the depth of egg deposition since when eggs were encountered in core samples, they were found at the very bottom of the cored samples. At least 10 kg of streambed material was removed from each cored site. Shirazi and Seim (1979) believed that hollow core samples of 10 kg adequately represented overall streambed composition by site. We modified McNeil and Ahnell's (1964) procedure for sampling the very fine material that often remains suspended in the water because of logistical constraints encountered in sampling remote locations. Instead of retaining the turbid water within the corer with the sample, we subsampled the turbid water within the corer with an Imhoff settling cone. Imhoff cone water samples were allowed to settle for 20 to 25 minutes and the amount of fine sediment was recorded as milliliters of sediment per liter of water. Imhoff cone samples of stream water outside the corer produced undetectable amounts of fine sediment. Water depth in the corer was measured to the nearest centimeter allowing us to calculate intra-corer water volume.

Laboratory Analysis

Streambed samples were oven dried and shaken through a sieve series containing 76.2, 50.8, 16.0, 6.4, 2.0, and 0.063 mm mesh screens. We found that by excluding water from within the corer, oven drying time was reduced by as much as 12 hours. The material retained on each sieve and in the pan (material less than 0.063 mm) was weighed to the nearest gram. The estimated weight of the fine material sampled with the Imhoff cone was added to the weight of material less than 0.063 mm. To estimate the dry weight of sediment suspended in the water within the corer, we used the following estimator:

$$Wt_{sediment} = (Vol_{water})*(Vol_{sediment})*0.27$$

Where: $Wt_{sediment}$ = Dry weight of sediment suspended within corer.

Vol_{water} = Volume of water (in liters) within corer.

$Vol_{sediment}$ = Volume of sediment in the one liter Imhoff cone.

0.27 = Factor to convert wet volume of sediment to dry weight.

To determine the wet volume to dry weight conversion factor for fine material sampled by the Imhoff cone, we collected 11 water samples from within the corer at the time Imhoff cone samples were taken. These water samples were filtered through a 0.45 micron filter and oven dried. Dry weight of the fine sediment retained on the filter revealed that wet volume could be converted to dry weight by using a conversion factor of 0.27 (range: 0.23 to 0.33) (Shepard and Graham 1982). Streambed compositions were reported as percentage of each size class by weight.

A Kruskal-Wallis one-way analysis of variance by ranks test (Daniel 1978) was conducted to determine if significant differences existed between creeks by year for percentages of fine material less than 6.4 mm and less than 2.0 mm. If a significant difference was found, Mann-Whitney tests (Daniel 1978) were run on each pair of creeks by year.

Streambed Composition and Bull Trout Embryo Survival

In early September, 1983 eight artificial redds were constructed in a bull trout spawning area in Coal Creek. Each artificial redd had a tailspill area approximately 2.0 m long when completed, similar to the size of a natural redd (Shepard et al. 1984). A streambed sample was removed from each tailspill area, using methods described above, prior to planting fertilized eggs.

Adult bull trout were captured and spawned on 12 September, 1983. The ripe fish were anesthetized and eggs were taken dry, fertilized, and allowed to water harden. One hundred fertilized eggs and some natural stream gravels were placed in each of 32 fiberglass screen bags. Half the bags were stapled shut and planted approximately 15.0 cm deep in the four downstream redds. These closed bags were used to monitor embryo survival and development. The other 16 bags were left open at the top, allowing fry to emerge, and placed in the four upstream redds. Care was taken to ensure that each open egg bag remained upright during the planting procedure. Cylinders of wire screen were placed around each open egg bag to prevent lateral emigration of emerging fry.

Gravel was placed over each artificial redd after egg bags were planted and the tailspills were covered with 12.7 mm mesh screening to prevent natural spawning activity from disturbing artificial redds. This screening was removed after natural spawning was completed.

Survival and Development

On 24 October, 1983; 13 January, 1984; 20 February, 1984; and 6 March, 1984 egg bags were removed from the four downstream redds. Live and dead embryos from each bag were enumerated and preserved. Once embryos reached the alevin stage, 40 alevins were measured at each sampling period. A thermograph recorded water temperatures throughout the incubation period.

Fry Emergence

In late February 1984, emergence traps (Phillips and Koski 1969, Fraley and Graham 1982) were placed over all open egg bags. These traps were placed on the wire screen cylinders to ensure all emerged fry were captured. Emergent fry were enumerated and a subsample of up to 50 fry were measured and preserved. Three egg bags were excavated on 23 April, seven were excavated on 18 May, four were excavated on 28 May, and the remaining two were excavated on 18 June. All live and dead embryos remaining in the egg bags were enumerated and recorded by life-stage (ie. dead eggs, dead alevins, live alevins). Streambed samples were again taken with the corer.

Temperature units required for each stage of development were estimated using daily mean temperatures from thermograph records. The relationship between fry emergence and percentage of streambed material less than 6.4 mm was evaluated using a regression computer program (Lund 1983).

Juvenile Rearing Versus Streambed Composition

Relationships between juvenile bull trout rearing capacity and streambed composition were examined as part of the Swan River drainage study. Aerial pre-surveys were conducted for all streams in the Swan River drainage during the summer and fall of 1982 to delineate stream reach boundaries. Reaches were defined as continuous stream sections having "a repetitious sequence of physical processes and habitat types" (Chamberlin 1981). Changes in channel gradient and stream habitat uniformity were the two predominant factors defining reach boundaries.

Streambed Composition

Physical stream habitat surveys were conducted by crews of two technicians on a one or two kilometer section of each reach. Representative survey sections were located during aerial surveys. Fifteen randomly selected channel cross sections were sampled in each survey section as described by Shepard and Graham (1983b). Ocular streambed composition estimates were made for a minimum of five equally spaced cells across each transect. Within each cell we recorded the dominant and subdominant particle size classes and ranked the extent to which the dominant particles were embedded in sand and silt (table 1). The ranks for each of these three substrate characteristics within each cell were added together to produce a modified version of substrate score (Crouse et al. 1981).

A combined frequency distribution for dominant and subdominant particle size groups was used to determine the streambed composition (in percent) within each reach. Reach substrate scores were calculated by averaging the substrate scores for all cells examined in the reach. Generally, substrate composition estimates were made for 80 to 120 cells within each reach.

Juvenile Fish Population Estimates

Fish population estimates were made in 100 to 150 m long sections within each habitat survey section. Electrofishing sections were isolated by blocking their downstream boundary by 12.2 mm mesh nylon netting or hardware cloth. Upstream movement was prevented by a natural velocity barrier or a block net.

Table 1.--Substrate characteristics and associated ranks for calculating substrate score (modified from Crouse et al. 1981).

Rank	Characteristic
	Particle size class (range)
1	Silt and/or detritus
2	Sand (<2.0 mm)
3	Small gravel (2.0-6.4 mm)
4	Large gravel (6.5-64.0 mm)
5	Cobble (64.1-256.0 mm)
6	Boulder and bedrock (>256.0 mm)
	Embeddedness[a/]
1	Completely embedded (or nearly so)
2	3/4 embedded
3	1/2 embedded
4	1/4 embedded
5	Unembedded

a/ Extent to which dominant sized particles are buried in sand and silt (see Bjornn et al. 1977 for an illustration).

Electrofishing was done using a gas powered backpack electrofishing unit in smaller streams and bank electrofishing gear on large (streamflow higher than 0.6 cms) accessible streams. Population estimates were calculated for fish 75 mm and larger using primarily the two-sample removal method, or occasionally using three-sample or mark-recapture techniques (Seber 1973). A more detailed description of estimation techniques can be found in Leathe and Graham (1983). Juvenile bull trout density (number of fish longer than 75 mm per 100 m^2 of stream surface area) was regressed against substrate score (Lund 1983).

Estimation of Sediment Loads to Swan River Tributaries

Annual sediment loads were estimated for 78 stream reaches in the Swan River drainage using erosion coefficients developed by soil scientists and hydrologists of the Flathead National Forest. These sediment delivery coefficients were based on a landtype classification system which accounts for variability in vegetation, soil characteristics, and physical slope functions. Both natural and man-induced erosion was simulated. Roads and timber harvest were the sources of man-induced erosion. Road sediment coefficients were based on ground exposed in road surface, cut slope, fill slope, and drainage ditches. Logging-related sediment was estimated by considering skid trail requirements for various size clearcuts. Recovery of disturbed sites was accounted for in the analysis by decreasing sediment coefficients as age of disturbance increased. Sediment produced in areas upstream from the reach of interest was routed to the reach using delivery ratios based on drainage area (Cline et al. 1981).

Road building and timber harvest histories were assembled into a chronological database for the study area. Records were available for all transportation system roads. Clearcut logging was the only type of timber harvest assumed to produce significant amounts of additional sediment. Clearcut information was available for the previous six years. A computer program was developed to calculate annual sediment loads by reach. The program applied appropriate sediment coefficients for land within each drainage and summed both natural and man-induced sediment loads delivered to each stream reach.

Using a multiple regression program (Lund 1983), relationships between sediment loads and existing substrate conditions were examined. Forty-six individual reaches were included in the analysis. Stream channel characters such as channel gradient, number of pools, and debris frequency were also tested as determinant variables in the prediction equation. Three expressions of streambed composition were entered as dependent variables: percentage of fine material less than 2.0 mm, percentage of fine material less than 6.4 mm, and substrate score.

RESULTS

Streambed Composition of Spawning Areas

The streambed monitoring program for tributaries to the North Fork of the Flathead River identified significant differences in percentages of material less than 2.0 mm between creeks all three years, and significant differences in percentages of material less than 6.4 mm between creeks in 1982 and 1983 (table 2). Spawning areas in Coal

Table 2.--Mean and median percentages of streambed material less than 2.0 mm and less than 6.4 mm in bull trout spawning areas of Big, Coal, Whale and Trail creeks during 1981 through 1983 with results of Kruskal-Wallis one-way analysis of variance by ranks tests between creeks.

	Percent material <6.4 mm				Percent material <2.0 mm			
	Big	Coal	Whale	Trail	Big	Coal	Whale	Trail
1981								
n[a/]	11	20	13	20	11	20	13	20
Mean	26	34	25	26	8	16	8	11
Median	25	34	27	25	9	16	6	11
Ranks [b/]	314.5	879.5	323.5	562.5	229.5	923.5	281	646
H[c/]		5.7 n.s.					19.5 **	
1982								
n	10	20	11	19	10	20	11	19
Mean	28	38	32	23	9	18	12	10
Median	31	39	31	22	10	17	11	10
Ranks	246.5	904.5	344	335	211.5	885	303	430.5
H		25.7 **					19.4 **	
1983								
n	12	20	12	12	12	20	12	12
Mean	28	37	33	28	11	18	13	13
Median	28	39	32	27	11	18	12	13
Ranks	211	779.5	369	236.5	223.5	789.5	286	297
H		17.3 **					15.1 **	

a/ Sample size (n) is the number of cores.
b/ Ranks is the sum of ranks for each creek.
c/ "H" is the test statistic for the Kruskal-Wallis one-way analysis of variance by ranks and is distributed approximately as a chi-square with k-1 degrees of freedom. Levels of significance are: 99 percent (**), 95 percent (*), and not significant (n.s.).

Table 3.--Results of Mann-Whitney[a/] tests for percentages of fine material less than 6.5 mm and less than 2.0 mm between Big, Coal, Whale, and Trail creeks by year (1981-1983).

	Percent material <6.4 mm			Percent material <2.0 mm		
	1981[b/]	1982	1983	1981	1982	1983
Coal versus						
Big	--	**	**	**	**	**
Whale	--	*	n.s.	**	*	**
Trail	--	**	**	**	**	**
Big versus						
Whale	--	n.s.	*	n.s.	n.s.	n.s.
Trail	--	n.s.	n.s.	*	n.s.	n.s.
Whale versus						
Trail	--	*	n.s.	*	n.s.	n.s.

a/ Levels of significance are: 99 percent (**), 95 percent (*), and not significant (n.s.).
b/ Two-way comparisons were not done for material less than 6.4 mm in 1981 because the Kruskal-Wallis test showed no significant difference between creeks.

Creek had significantly higher percentages of fine material than the other three creeks during all years (table 3). Material less than 6.4 mm consistently comprised 34-39% of Coal Creek's spawning areas, while material less than 2.0 mm made up 16-18%. Spawning areas in the other three creeks contains 25-33% less than 6.4 mm and 8-13% less than 2.0 mm. Within creeks, no significance between year differences were found except for material less than 6.4 mm in Whale Creek between 1981 and 1982 ($p<0.025$).

Relationship Between Streambed Composition and Bull Trout Embryo Survival

Streambed Composition in Artificial Redds

The streambed in eight artificial redds in Coal Creek prior to planting egg bags contained an average of 42%, by weight, of material smaller than 6.4 mm (range: 36-50%) and 19% material smaller than 2.0 mm (range 15-23%). The core samples taken from artificial redds were found to contain higher percentages of fine materials than core samples taken from the surrounding undisturbed streambed. These higher percentages of fines in the artificial redds may reflect a trapping of fine sediments during construction of the redds.

Survival and Development of Trout Embryos

Two sealed egg bags were removed on 6 March, 1984. Eye-up and hatching were estimated to occur after 35 and 113 days, respectively, or after accumulating 200 and 350 temperature units, respectively. Length of alevins averaged 19.3 mm (n = 40) on 13 January, 23.6 mm (n = 40) on 20 February, and 26.6 mm (n = 20) on 6 March. Average survival observed in sealed egg bags was 71% to the eyed stage and 60-64% to hatch. Subsequent calculations for emergence success assumed 71% of the eggs in each open egg bag were viable.

Emergence of Bull Trout Fry

Fry emerged from 23 April through 28 May. Fry emergence was first observed and the majority of fry emerged (83%) in a four-day period from 23

April to 27 April during and following a preliminary spring peak flow. Approximately 634 temperature units had accumulated during the 223 day incubation period. During the first day of emergence sampling (following the preliminary peak event), 315 fry were captured, averaging 27.2 mm (n = 50). More than half of these emerged fry were dead, indicating emergence had probably occurred during the previous three days of high flows. Overall emergence success from artificial redds in Coal Creek was 53%. Embryo survival and subsequent fry emergence success was highly correlated ($r^2 = 0.87$) to percentage of fine material less than 6.4 mm within the streambed (fig. 2). Ninety dead alevins were found in excavated egg bags indicating entombment and/or crushing may have occurred.

Juvenile Rearing Versus Streambed Composition

Relationships between juvenile bull trout density and streambed characteristics were determined using information collected during 1982 and 1983 in 26 stream reaches in tributaries to the Swan River. These reaches were selected because they were accessible to migratory bull trout. Juvenile bull trout densities (fish 75 mm and longer) in these reaches ranged between three and 270 fish per 300 m of stream length and from 0.1 to 12.4 fish per 100 m^2 of wetted stream surface. Percentage of fine material (less than 6.4 mm) ranged from 4-89% and substrate scores ranged from four to 15.

Significant statistical relationships were observed between the logarithm of juvenile bull trout densities (fish per 100 m^2 of wetted stream surface) and both the percentage of streambed material less than 6.4 mm and substrate score. The correlation between juvenile bull trout density and substrate score ($r^2 = 0.40$, p <0.001; fig. 3) was more significant than was the relationship between juvenile bull trout density and the percentage of material less than 6.4 mm in the streambed ($r^2 = 0.33$, p = 0.002).

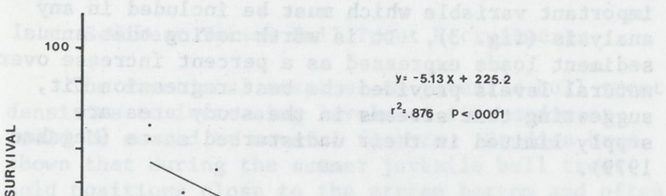

Figure 2.--Relationship between percentage of fines (material less than 6.4 mm) within the streambed and percentage survival of bull trout embryos through emergence in Coal Creek, a North Fork Flathead River tributary, during 1984.

Estimation of Sediment Loads to Swan River Tributaries

Natural sediment loads estimated for Swan River tributaries in 1983 were roughly proportional to drainage basin size and varied from 173 to 8,810 tons per year. Road construction and maintenance accounted for the majority of man-induced sediment loads to streams. In 1983, roads produced 0.2 to 303 tons of sediment in the 46 study reaches, representing from 0-79% over natural sediment loads. Logging-related sediment varied from 0.9 to 160 tons per year representing 0-5% over natural sediment loads.

Increase in sediment loads due to road development (expressed as a percentage over natural after Stowell et al. 1984) was correlated (p<0.01) with three different expressions of substrate composition (substrate score, percentage of streambed material less than 6.4 mm, and percentage of streambed material less than 2.0 mm). Stream gradient was inversely related to streambed composition (p<0.001). No other stream variables tested were significantly related to streambed condition nor was the association between sediment yield and clearcutting a significant variable in any of the regression.

The highest coefficient of determination ($R^2 = 0.56$) was obtained by regressing percentage increase in sediment over natural due to roads and a logarithmic transformation of stream gradient

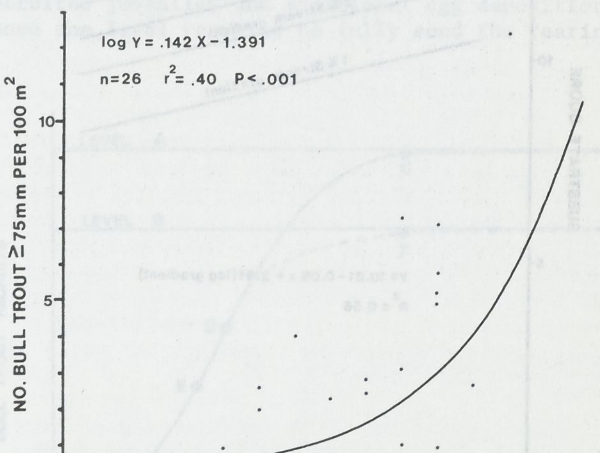

Figure 3.--Relationship between juvenile bull trout density (fish ≥75 mm per 100 m^2 of stream surface area) and streambed substrate score for 26 stream reaches in the Swan River drainage, Montana.

against substrate score (fig. 4). The regression coefficient for sediment produced from road development was associated with decreased substrate scores. Decreasing scores are associated with increasing levels of fine sediment (illustrated by a strong inverse linear regression: $r^2 = 0.91$) and increased embeddedness.

DISCUSSION

Streambed Composition versus Bull Trout Spawning Success and Rearing Capcity

Streambed sampling allowed us to document the relative condition of bull trout spawning areas in four Flathead River tributaries (Trail, Whale, Coal and Big creeks). Based on these samples and using estimated fry emergence success computed by Tappel and Bjornn (1983) for chinook salmon, we estimated bull trout fry emergence success would be between 40% and 60% in Coal Creek (Shepard and Graham 1983b). Actual bull trout emergence success in Coal Creek averaged 53%.

Based on the results from artificial redds in Coal Creek, survival of bull trout embryos through emergence appeared to be unaffected when the percentage of material less than 6.4 mm comprised up to 30% of the streambed. However, at levels of fine sediment above 30%, embryo survival through emergence dropped off sharply. When the streambed

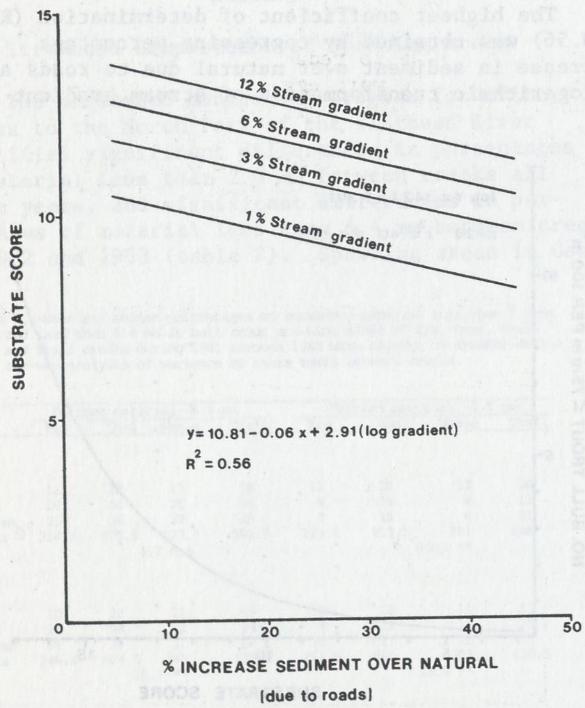

Figure 4.--Predicted response of streambed substrate score in streams of various gradients to changes in sediment loading rates (expressed as percent increase above natural levels) attributed to the construction and maintenance of roads in tributary drainages of the Swan River, Montana.

contained nearly 40% fine material, survival to emergence fell below 20%. Bull trout embryos incubated in Coal Creek appeared to be more tolerant of fine sediment than cutthroat trout (unpublished data, Idaho Cooperative Fisheries Research Unit, University of Idaho, Moscow, Idaho), steelhead trout (Tappel and Bjornn 1983), and brook trout (Hausle and Coble 1976), although bull trout embryo survival appeared to be similar to survival reported for chinook salmon embryos (Tappel and Bjornn 1983).

Densities of juvenile bull trout declined sharply when substrate scores fell below 12 (or when the streambed contained more than 30% material less than 6.4 mm). Bjornn et al. (1977) found that when embeddedness levels increased, summer and winter rearing capacity generally decreased for juvenile steelhead trout and chinook salmon. Crouse et al. (1981) found that increased sedimentation suppressed production of juvenile coho salmon.

Land Use and Stream Sediment

The significant relationship between road development and stream substrate score found for tributaries to the Swan River is in agreement with previous studies that suggested roads were the major source of sediment produced during timber harvest activities (Megahan and Kidd 1972, Gibbons and Salo 1973, Anderson et al. 1976). Mass soil movements caused by changes in soil hydrology and loss of root cohesion after timber harvest reported to occur in other regions (Swanston 1970 and 1971, DeGraff 1979) have not been documented in the Flathead River Basin.

In spite of the multitude of hydrologic variables affecting sediment dynamics of mountain streams, increased sediment loads attributed to road development accounted for a significant portion ($p<0.001$) of the variation in streambed composition. Stream channel gradient was also an important variable which must be included in any analysis (fig. 3). It is worth noting that annual sediment loads expressed as a percent increase over natural levels provided the best regression fit, suggesting that streams in the study area are supply-limited in their undisturbed state (Megahan 1979).

Limitations of Sampling

We can document the streambed composition in spawning areas, but we presently have no quantitative data describing the source of fine sediments found in these spawning areas. The results from this streambed sampling program illustrated the ability of streambed monitoring in spawning areas to quantify changes in levels of fine sediments between creeks. We assume that long-term monitoring would detect changes in streambed composition over time.

The Coal Creek emergence success study was conducted in a relatively narrow range of streambed compositions (levels of material less than

6.4 mm ranged between 31% and 44%). To best quantify the relationship between fine sediment and bull trout spawning success, tests should be conducted in spawning gravels containing a wide range of fine sediment. The spawning area in Coal Creek where the field experiment was conducted has an unknown amount of groundwater entering the creek. This groundwater may have moderated the effect of fine sediment by flushing metabolic wastes away from the embryos and delivering oxygen to the embryos, although we did not measure the amount of dissolved oxygen carried by this groundwater.

The relationship between juvenile bull trout rearing capacity and substrate score developed in the Swan River drainage was based on the validity of ocular estimates of streambed condition and our assumption that observed densities of juvenile bull trout represented carrying capacity. Platts et al. (1983) found that some difficulty existed in accurately estimating particle sizes and embeddedness using ocular surveys. We have no way of verifying whether study streams were fully seeded with bull trout fry from natural reproduction. Regardless of these two problems, we obtained a significant correlation relating juvenile bull trout density to streambed condition. We recognize the fact that streambed condition was not the only physical habitat variable controlling juvenile bull trout densities, but it is a variable related to land-use practices.

The use of substrate score to describe streambed condition versus juvenile bull trout density resulted in a stronger correlation ($r^2 = 0.40$) than using percentage of material less than 6.4 mm or 2.0 mm (r^2's of 0.33 and 0.32, respectively). The advantage of using substrate score is that it can be obtained using ocular surveys, so it is a quick and inexpensive way to estimate streambed condition. The disadvantage is that it is not as easy to quantify as replicated streambed samples using a hollow core sampler.

Sediment Versus Bull Trout Recruitment

The functional response of juvenile bull trout densities to increasing levels of fine sediment could be caused by several factors. Studies have shown that during the summer juvenile bull trout hold positions close to the stream bottom and often seek cover within the substrate itself (Griffith 1979, Oliver 1979, Pratt 1984). Any loss of interstitial space or streambed complexity through the deposition of fine sediment would result in a loss of summer habitat. Winter habitat used by juvenile bull trout has not been identified, although studies of other salmonids have suggested deep pools (Lewis 1969, Chapman and Bjornn 1969, Bjornn et al. 1977) or streambeds composed of rubble and gravel (Everest 1969, Bustard and Narver 1975, Bjornn et al. 1977) provide important winter habitat. Deposition of sediment on the streambed reduces streambed complexity and pool volume and may lower winter carrying capacity (Bjornn et al. 1977). Food production in the form of aquatic invertebrates may also be reduced by sedimentation (Gibbons and Salo, 1973, Bjornn et al. 1977, Iwamoto et al. 1978).

The manner in which bull trout recruitment is affected by fine sediment can be evaluated by examining the relationship between the number of eggs deposited in a stream and the subsequent number of juvenile bull trout recruited to the lake population. This relationship can be described using a Beverton-Holt (Ricker 1975) stock-recruitment curve (fig. 5). Deposition of fine sediment lowers rearing capacity (shifting the upper limit of the curve from level A down to level B) because it reduces summer and winter habitat capacity and limits aquatic insect production. Deposition of fine sediment in spawning gravels decreases egg-to-fry survival which would limit juvenile bull trout recruitment only if egg deposition was at the asymptote of the curve (point C or F on fig. 5) or below. If the number of spawning adults returning to the stream deposited fewer eggs than were required to fully seed the stream, the effects of fine sediment on egg-to-fry survival would be more important than effects on juvenile rearing capacity (a reduction in number of recruited juvenile bull trout from point D to point E on the curve in fig. 5). If egg deposition was in excess of the number required to fully seed the stream (more than point C or point F on the curve in fig. 5) then the number of recruited juvenile bull trout would be controlled by the amount of rearing habitat available. If escapement of adults provided just enough eggs to fully seed the stream (point C or F on fig. 5) at levels of fine sediment which were not impacting egg-to-fry survival and additional fine sediment was deposited in the spawning areas, the only way to ensure that fry production remained adequate would be to reduce the harvest on adult spawners to allow more eggs to be deposited. The reduction of rearing habitat caused by sedimentation will ultimately reduce the potential number of recruited juveniles and additional egg deposition above the level required to fully seed the rearing

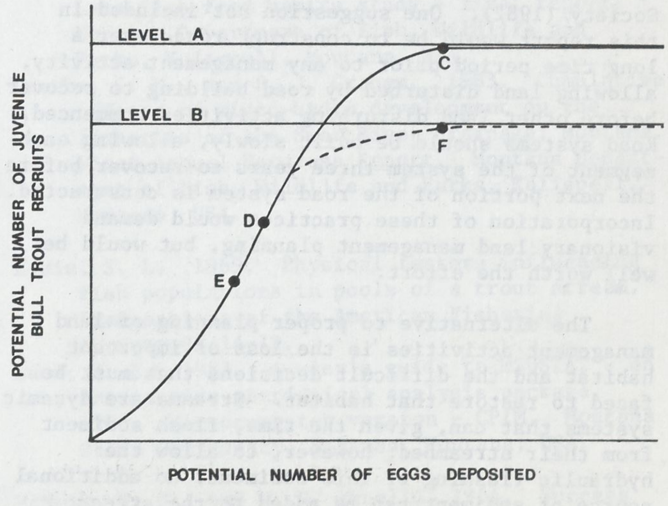

Figure 5.--Theoretical relationship between the number of bull trout eggs deposited and subsequent number of juvenile bull trout emigrating from a tributary stream. Adapted from Beverton-Holt (Ricker 1975).

habitat (point F on the curve) will not result in any additional juvenile bull trout recruited to the population. Land managers could possibly return the stream to its full potential for producing recruits through an intensive habitat enhancement program or by restricting land disturbing activities in a drainage allowing fine sediment to be flushed out of the streambed. Reducing recruitment of juvenile bull trout from a single tributary may not, by itself, represent a significant loss to an adfluvial lake population; however, the cumulative reduction of recruitment from a number of tributaries could result in a significant loss.

Management Implications

Increasing levels of fine sediment in bull trout spawning and rearing streams might significantly impact adfluvial bull trout populations by reducing the number of bull trout recruited from sediment-impacted streams. Land managers should be made aware of the consequences of increasing sedimentation rates in these sensitive drainages and consult fisheries professionals when land development activities are proposed. For their part, fisheries professionals should monitor streambed composition in important spawning and rearing tributaries and provide justification for any fisheries constraints placed on land management.

Sediment models, such as the one described above, can be used as a management tool for evaluating impacts of resource development on streambed composition. Coupled with predictive equations to estimate fry production and juvenile recruitment, this sediment model would allow land managers and fisheries biologists to develop management strategies which minimize or prevent unacceptable fisheries losses while maintaining the production of commodities. These strategies should include management practices described by the Western Division of the American Fisheries Society (1982). One suggestion not included in this report would be to construct roads over a long time period prior to any management activity, allowing land disturbed by road building to recover before other land disturbing activities commenced. Road systems should be built slowly, allowing each segment of the system three years to recover before the next portion of the road system is constructed. Incorporation of these practices would demand visionary land management planning, but would be well worth the effort.

The alternative to proper planning of land management activities is the loss of important habitat and the difficult decisions that must be faced to restore that habitat. Streams are dynamic systems that can, given the time, flush sediment from their streambed; however, to allow the hydraulic flushing of this sediment, no additional source of sediment can be added to the stream channel (Megahan et al. 1980). This can only be accomplished by instituting a moritorium on land activities for up to 20 years (ibid).

Recommendations

1. Streambed monitoring of known salmonid spawning areas should be included as part of any monitoring program established to evaluate the impact of land management activities on salmonid populations.

2. Regional intensive long-term watershed studies are needed to determine the sources of sediment from various land management activities (road building, various timber harvest prescriptions, grazing, etc.), delivery of that sediment to stream channels, and routing of that sediment through the stream channel including where that sediment is deposited and streamflows required to flush sediment out of stream gravels.

3. The relationship between streambed composition and bull trout embryo survival and fry emergence needs to be better defined over a wide range of streambed compositions. A laboratory study is presently underway at the Montana State Cooperative Fisheries Research Unit to develop predictive "survival bands" for bull trout incubation and emergence versus streambed composition similar to those developed by Tappel and Bjornn (1983).

4. The influence of groundwater on bull trout embryos needs to be better understood to fully evaluate the impacts of fine sediment on bull trout embryo survival because bull trout appear to spawn in areas influenced by groundwater (Graham et al. 1981).

5. How sediment impacts juvenile rearing capacity needs to be further investigated to determine what functional aspects of rearing habitat (summer rearing habitat, food production habitat, overwinter habitat, etc.) limits rearing capacity and what, if any, habitat improvement measures might mitigate sediment impacts.

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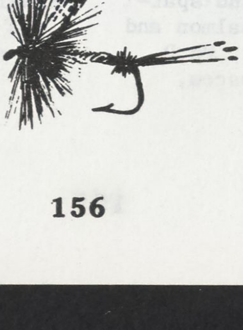

Acid Rain and Atlantic Salmon[1]

Walton D. Watt[2]

Abstract.--Acid rain has caused many Nova Scotian rivers to decline in pH to the point where their Atlantic salmon stocks have been destroyed or much diminished. The eradication of salmon from such large regions will hinder future programs to reestablish the species in their former range when pollution of the atmosphere is eventually brought under control. Present plans are for a liming program to establish a series of refuges for the preservation of nuclei of native salmon stocks.

INTRODUCTION

Alarmed by the declining pH's reported for eastern Canada Precipitation in the mid 1970's, the Department of Fisheries and Oceans began, in 1977, to examine surface water data in the Maritime Provinces for indication of acidification. A resurvey by Watt et al (1979) of 22 Nova Scotian lakes which were first examined in 1955 by Gorham (1957) showed that 16 of these lakes were still in a relatively undisturbed state except for atmospheric input and that all 16 had lower pH's.

During 1978-79, we conducted a more extensive survey of water chemistry in the Atlantic salmon rivers of the Maritimes area; this was reported by Farmer et al. (1980) and Watt (1981). The survey revealed that the only severely acidified area in the Maritimes was the Atlantic Upland area of Nova Scotia. This is an area of shallow soils and poor drainage, underlain by granites and metamorphic rocks lacking in basic minerals. The area contains 42 rivers of which 13 were found to have mean annual pH's less than 4.7, 13 had pH's in the range of 4.7-5.0, eight had pH 5.1-5.4 and eight were of pH greater than 5.4.

Our next step was to examine the chemistry of these rivers in detail to see how such acidification had come about. During 1980-81, monthly samples were analyzed from 23 rivers flowing through the Atlantic Upland, and the results were reported by Watt et al. (1983). A close correlation with geology was confirmed as was the relationship between pH and discharge.

CHEMISTRY

New data from the daily sampling of East River St. Margaret's (Fig. 1) illustrate the same seasonal pattern of river pH variation as reported by Watt (1981) and Watt et al. (1983) from monthly sampling. Minimal pH's typically occur in mid-winter and then rise gradually throughout spring and summer until the onset of autumn rains when pH falls dramatically. The range of seasonal variation is always less than 1 pH unit. The total range of pH variation in East River St. Margaret's in 1983 was 0.65 pH units from the low of pH 4.77 on March 5 to 5.42 on November 1. The steepest rate of decline was in the period November 1-12 when pH fell 0.32 units (average decline of 0.03 units per day). The greatest 24 hour variations observed were a fall of 0.17 pH units on November 10-11, 1983 and a rise of 0.20 pH units which occurred on April 21-22, 1984. We have never encountered any evidence in our monthly or daily data of significant episodic pH depressions such as have been reported elsewhere in North America and Scandanavia under snowmelt conditions.

A plot (Fig. 2) of daily data from East River St. Margaret's vs instantaneous flows at the time of sampling reveals some details of the nature of the relationship between H^+ concentration and discharge. At higher flows (greater than $3m^3S^{-1}$) the apparent straight line relationship breaks down, and so very

[1]Paper presented at the Wild Trout III Symposium. (Yellowstone National Park, September 24-25, 1984).

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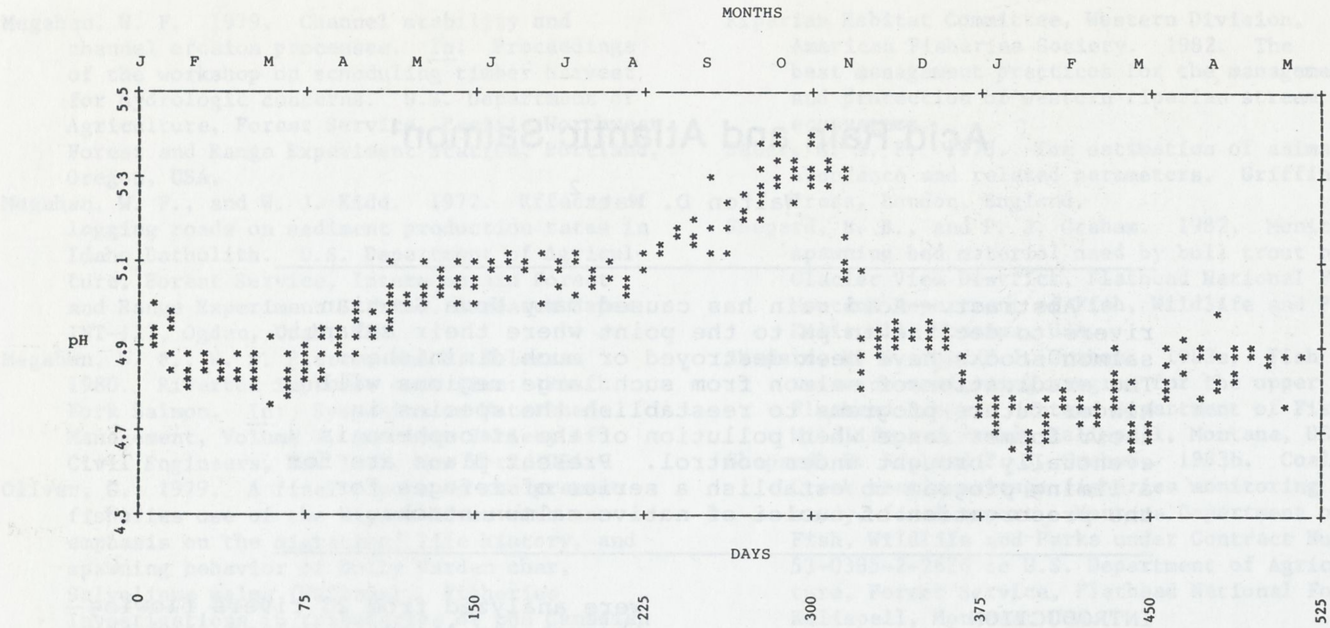

Figure 1.--Daily (winter) and trice weekly (summer) pH record from East River St. Margaret's from January 1, 1983 to May 31, 1984.

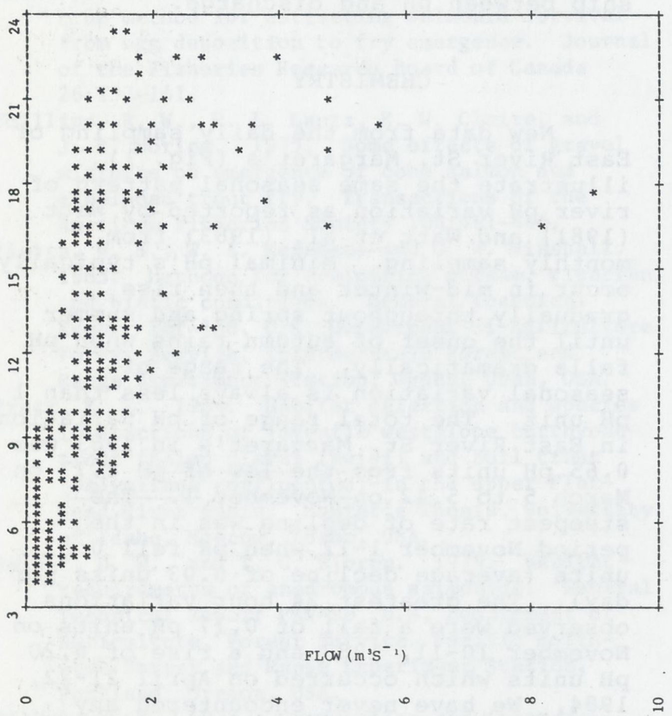

Figure 2.--Relationship between hydrogen ion concentrations and instantaneous flows (within one hour of sampling) in East River St. Margaret's.

high episodic flows do not cause pH depressions. For the East River St. Margaret's data most flows greater than $3m^3S^{-1}$ occurred in the months of March and April after heavy rainfall and/or snowmelt. Under these conditions the

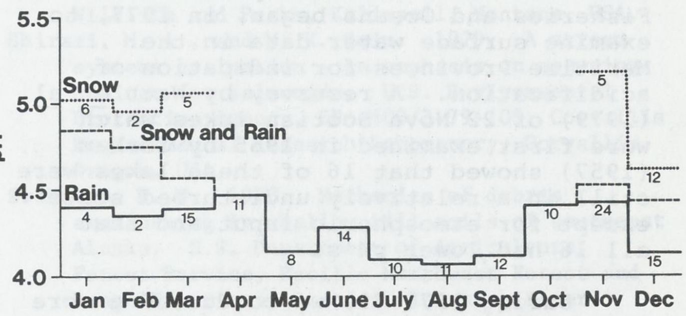

Figure 3.--Snow (melt water), rain, and total precipitation pH's in Nova Scotia during 1980-81.

highest H+ ion concentration reached was 24 μeq/l (pH 4.6) and this appears to have been near an upper limit, probably set by the pH of winter and early spring rainfall which is also near 4.6 in Nova Scotia (Fig. 3).

The seasonal variation in the pH of precipitation in Nova Scotia and the relationship between precipitation pH and wind direction are illustrated in Figures 3 and 4 which are based on data reported by Castell et al (1984). It is notable that snowfall melt water is always higher in pH than rainfall. Chemical analyses indicate that this is due to the extremely low ionic concentrations occurring in snow, rather than the presence of any acid buffering capacity. The effect of a snowmelt in Nova Scotia is typically to dilute acids present in the rain and

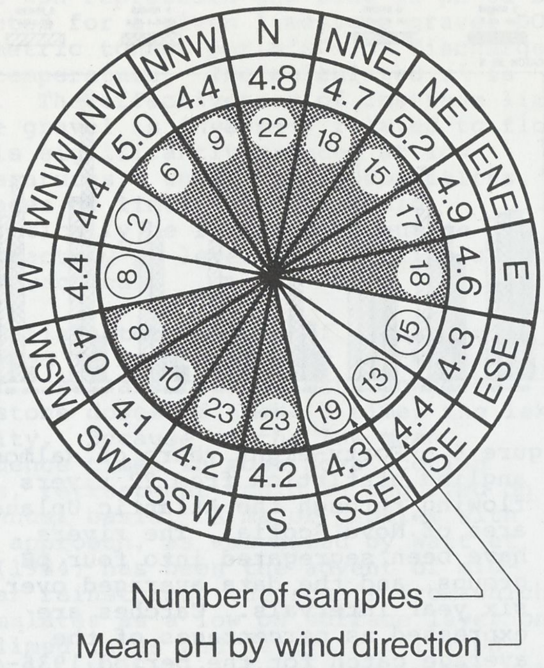

Figure 4.--The pH of 226 precipitation events occurring in 1980-81, arranged according to local wind direction.

surface waters, thus causing a slight rise in river pH's. In general, however, snowmelts are not major sources of run-off in the Atlantic Upland rivers, and most freshet flows are the result of direct runoff of rain. The pH of precipitation varies seasonally, being much lower in summer than in winter. As Figure 4 illustrates, the lowest pH precipitation is usually carried in winds from the southwest quadrant, which is the prevailing wind direction in summer and also the direction of the major pollution sources in the eastern U.S.A. The highest pH's occur in precipitation from the northeast (i.e., from the North Atlantic and Newfoundland) which is our commonest wind direction for snow.

For five rivers, the monthly data collected in 1980-81 can be compared to similar monthly data collected by Thomas (1960) in 1954-55. All five show a fall in pH over this 26 year period, though only for the four lower pH rivers is the decline statistically significant (p less than 0.01). Unfortunately, two points in time are not adequate to prove a trend and for most sites that is all that we have at present. By a fortunate coincidence, however, Thomas' (1960) site on the Medway River was also sampled monthly during the period 1965-78 by Environment Canada as part of a surface water quality monitoring program. Figure 5 illustrates the declining pH

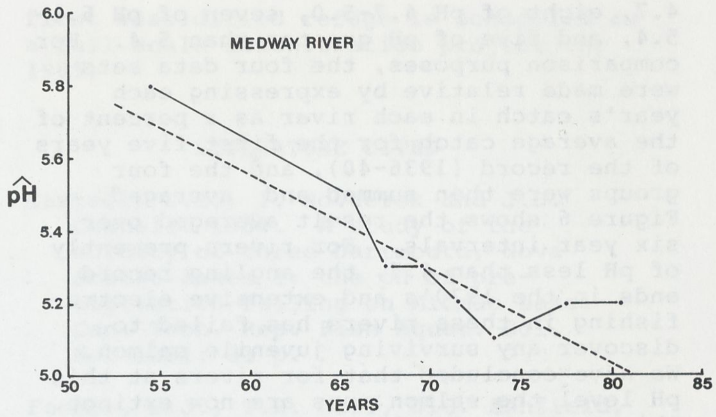

Figure 5.--The pH trend in Medway River between 1954 and 1980. The data points have been corrected for year to year variation in discharge. The least squares regression (dashed line) accounts for 80.3% of the variance (p less than 0.01).

trend in the river for the period 1954-81. The data illustrated have been corrected for year to year variation in discharge levels. A simple regression on the uncorrected data also confirms the declining trend (p less than 0.01), though the fit is less exact.

SALMON

All 42 of the rivers flowing through the Atlantic Upland area of Nova Scotia have probably supported Atlantic salmon stocks. In 1935, a concerted effort was made by the Department of Fisheries to establish a uniform system of reporting for Atlantic salmon angling statistics. As a result, nearly continuous salmon angling records are available from 1936 to the present for 27 of the Atlantic Upland rivers. Significant dam construction and/or removal and/or hatchery stocking have occurred on five of these rivers, but 22 of them remain in a state which is very similar to their condition as it was 48 years ago. The major industry is still forestry, and though the frequency of cutting has increased due to a change over from lumber to pulp as the final product (which has resulted in younger forests), the extent of forest cover is still much the same. Agriculture has never been a significant industry on the impoverished Atlantic Upland soils, and industrialization and urbanization are coastal phenomena occurring near the river's mouths.

To examine the impact of acidification on angling catch, the rivers were divided into 4 groups based on their present (1983) mean annual pH's: two of pH less than

4.7, eight of pH 4.7-5.0, seven of pH 5.1-5.4, and five of pH greater than 5.4. For comparison purposes, the four data sets were made relative by expressing each year's catch in each river as a percent of the average catch for the first five years of the record (1936-40), and the four groups were then summed and averaged. Figure 6 shows the result averaged over six year intervals. For rivers presently of pH less than 4.7, the angling record ends in the 1970's and extensive electrofishing in these rivers has failed to discover any surviving juvenile salmon. We have concluded that for rivers at this pH level the salmon runs are now extinct. This accounts for 13 rivers in the Atlantic Upland. For another 13 rivers in the pH range 4.7-5.0 the angling catch has declined to about 10% of levels prevalent during the 1936-53 period. Electrofishing data from these rivers usually indicates the presence of small populations of salmon juveniles, commonly in higher pH tributaries which function as natural refuges. The decline in salmon angling returns was simultaneous in the rivers of pH less than 4.7, and in the pH 4.7-5.0 rivers. Between 1948-53 and 1954-59, both of these lower pH river groupings suffered a 60% decline in angling success. The salmon stocks of the rivers in the pH less than 4.7 group have since disappeared, because of lower acid neutralization capacity in their catchment basins which has resulted in the present lethal levels of acidity.

The 16 rivers in pH categories 5.1-5.4 and greater than 5.4 show no sign, yet, of an impact of acidification on angling returns, though there is electroseining and toxicity evidence of acidification impacts occurring now and limiting juvenile salmon production in the lower pH tributaries (pH near 5.0) of some of these rivers.

The Atlantic salmon has now been exterminated from 13 rivers and if the acidification is permitted to proceed at the same rate as in the recent past, then we must expect to loose the salmon stocks from another 13 rivers for a total of 26 extinct stocks by about the year 2000. In addition, we can expect that one-half of the remaining rivers (the 8 now in pH range 5.1-5.4) will suffer stock reductions on the order of 90%.

Each salmon river has its own genetically unique native stock. The extinction of a river's native stock is an irreversible impact. Experience has shown that it is very hard to reestablish self-sustaining populations of salmon using parental fish which have been transplanted long distances between rivers. Therefore, the eradication of salmon from such large regions of Nova

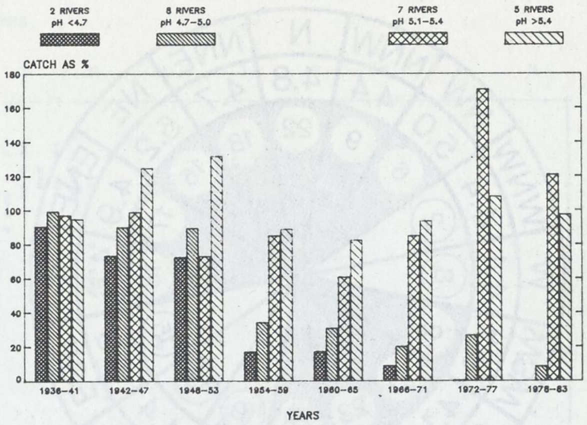

Figure 6.--Forty-eight years of salmon angling statistics from 22 rivers flowing through the Atlantic Upland area of Nova Scotia. The rivers have been segregated into four pH groups, and the data averaged over six year intervals. Catches are expressed as percentages of the average catch for the period 1936-40.

Scotia will probably hinder future programs to reestablish salmon in their former range when pollution of the atmosphere is eventually controlled and the acidity of rain reduced.

LIMING

The Department of Fisheries and Oceans has undertaken experiments (Watt et al. 1984) to test the feasibility of establishing high-pH refuges in some acid rivers by addition of limestone or other substances to lakes or streams. This technique is being considered as an interim measure to preserve the genetic characteristics of the salmon populations that will be needed in the future to recolonize our former salmon rivers in the Atlantic Upland region of Nova Scotia.

The experiments conducted to date indicate that the pH of salmon streams can be adjusted to satisfactory levels by liming, but that fresh lime must be added annually and in some cases, twice annually. Various different liming methods have been tested and estimates have been made of the relative costs and effectiveness. The two liming approaches most thoroughly investigated to date are: the use of instream limestone gravel deposits, and the liming of headwater lakes.

Watt et al. (1984) reported on three years of experiments with instream limestone gravel. The results can be expressed in the form of the following equation:

$$\Delta pH = 0.237 (\log_e DOSE) + 0.008(^{o}C) - 0.809$$

where ΔpH represents the rise in pH to be expected for a given limestone gravel DOSE (in metric tonnes per m^3S^{-1} of discharge) and temperature. The calculated r^2 is 0.84. The effectiveness of instream limestone gravel is inversely related to flow and is significantly reduced at low temperatures. Under winter conditions, tonnages of limestone that would theoretically be required to ensure satisfactory pH levels are so high as to be impractical.

Satisfactory levels of pH can be achieved in salmon streams if the headwater lakes are treated with powdered limestone doses of about 3 times the lake acidity. Because of the low mean residence times in most Nova Scotian lakes, retreatment would be required on an annual basis. A major problem with this approach, as was noted by Watt *et al*. (1984) has been the advent of midwinter rainstorms, the runoff from which accumulates as a low pH surface layer on the limed lakes and delivers a low pH shock to the salmon juveniles in the outlet streams. During the winter of 1983-84, this problem was overcome by the expedient of spreading a layer of powdered limestone over the ice. When a heavy rainstorm occurred in February, the first runoff entering the lake was from off of the ice, and this in turn caused the surface pH of the lake and the pH of the outlet stream to rise and remain up in spite of very low pH's in the inlet streams.

This has also led us to the discovery that winter liming with tractors is faster and cheaper than summer liming from boats, hence we now plan to change our entire operation over to winter liming, though we shall be monitoring the results carefully to see how our percent dissolution efficiencies (near 60% with summer liming) are affected.

In terms of relative costs, the instream limestone gravel approach would cost approximately $500 per returning salmon in Nova Scotia rivers while the headwater lake liming costs are about $150 per returning adult salmon. Even at $150 per salmon, it is evident that this approach is not economically feasible for a full scale salmon restoration effort in all of the 26 salmon rivers presently impaired by acid rain.

The feasibility studies having been completed, it is now the Department of Fisheries and Oceans intention to proceed with the establishment of deacidified refuges. The current plan calls for at least three refuges on tributaries of 20-40 km^2 drainage and physical potentials of 100-200 annual returning Atlantic salmon. Establishment of the first deacidified refuge is scheduled as a full scale demonstration project for 1985.

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PANEL: People, Politics, and Pesos[1]

Linda Morgens[2]

The scientific insights and innovations in wild trout fisheries management, many of which have come to light at these symposia, must ultimately be put into practice if they are going to have any effect on the quality of our fishing experience. For example, it was through a previous Wild Trout Symposium that the concept of catch-and-release management was broadly exposed for the first time. Now, as we have heard in several previous panels, it has become an important fisheries management tool. It was also at a Wild Trout Symposium that the first convincing evidence was presented on the negative effects of stocking on top of wild trout populations. As a result, fewer and fewer states continue this practice in their management programs.

This panel discusses how we implement changes such as these in the management of our fisheries. Change must invariably deal with three important considerations: economics, politics, and most importantly, the desires of the angling population at large.

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[1] Discussion leader's introductory remarks of the Session People, Politics, and Pesos at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 25, 1984.

[2] Linda Morgens, an active member of several conservation organizations, is a National Director of Trout Unlimited from South Norwalk, CT.

Lake Trout Futures in the Great Lakes[1]

Carlos M. Fetterolf, Jr.[2]

Abstract.—There are signs of success in the 30 year effort to control the sea lamprey and reestablish self-sustaining populations of lake trout in the Great Lakes. In remote areas of Lake Superior up to 90% of the lake trout are naturally-produced and about 40% are naturally-produced in some nearshore areas. Lake trout fry are frequently found in Lake Michigan, fry and wild yearlings have been collected in Lake Huron, and a single fry has been found in Lake Ontario.

A number of actions indicating consensus toward lake trout rehabilitation are in evidence. In 1980 the fishery agencies produced a Strategic Plan for Management of Great Lakes Fisheries with a goal of securing fish communities based on foundations of stable, self-sustaining stocks. The Commission, working with fishery agencies, developed a policy statement which stresses commitment to reestablishment of a self-replenishing lake trout resource. The lake committees of the Commission, whose members are management agency representatives, are developing tactical lake trout management plans to achieve this goal in each of the lakes. A Commission conference in 1983 examined current strategies for reestablishing lake trout, identified hypotheses to be tested, outlined the associated experimental designs dealing with the issues to be overcome, and recommended priorities for research. The first order research focuses on improving production of detectable recruitment from spawners of hatchery origin.

The Commission's cooperators agree that reduction of total mortality to ensure accumulation of an adequate number of fish in multi-aged spawning stocks to meet optimum reproductive needs is necessary to achieve self-sustaining lake trout populations. Many fishery agencies have further restricted catch regulations, others are in the process or committed, and all will review their regulations when the lake committee lake trout management plans are completed.

INTRODUCTION

Let's get acquainted with the Great Lakes (fig. 1) from left to right Superior, Michigan, Huron, Erie and Ontario. Tucked away on the boundary between Ontario and the northcentral states, the lakes don't really impress North Americans outside the basin because their lives aren't touched directly by them. If you're one of the unimpressed, do you realize the lakes' coastline is longer than the distance from Maine to Mexico, that the lakes contain 1/5 of the world's fresh surface water, cover 95,000 square miles, and hold enough water to cover the United States to a depth of 12 inches? The basin is home to 37 million people, and the lakes supply drinking water to 23.5 million. The Sault Locks between Lakes Superior and Huron pass more tonnage than the Suez and Panama Canals combined.

If you're still unimpressed, I'll help you imagine what it would be like to have the lakes in your home territory. If we were able to move them around they would stretch from Michigan to Florida, or from South Dakota to Louisiana. Stretched along the Mexican border they would take the ichthyologists' minds off the desert pupfish and produce a gusher called the St. Lawrence River with a mean flow of 250,000 cfs of sweet water right in the middle of Texas. Along the West Coast the lakes would stretch from Washington to Arizona, and in the wheat country they would reach from British Columbia almost back to Ontario. Superior is the deepest, 406 meters, and Erie is the shallowest, 64 meters in the eastern basin, with extensive areas of the western basin less than 8 meters deep.

ARTIFACTS AND ISSUES

For over a century after development of the Great Lakes Basin in the early 1800s the lakes supported a large and successful commercial fishery for a variety of species, most notably lake trout (Salvelinus namaycush), whitefish (Coregonus clupeaformis), and lake herring (Coregonus artedi). However, a wide range of activities

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[1]Paper presented at Wild Trout Three, Yellowstone National Park, September 24-25, 1984.
[2]Carlos M. Fetterolf, Jr., Executive Secretary, Great Lakes Fishery Commission, Ann Arbor, Mich.

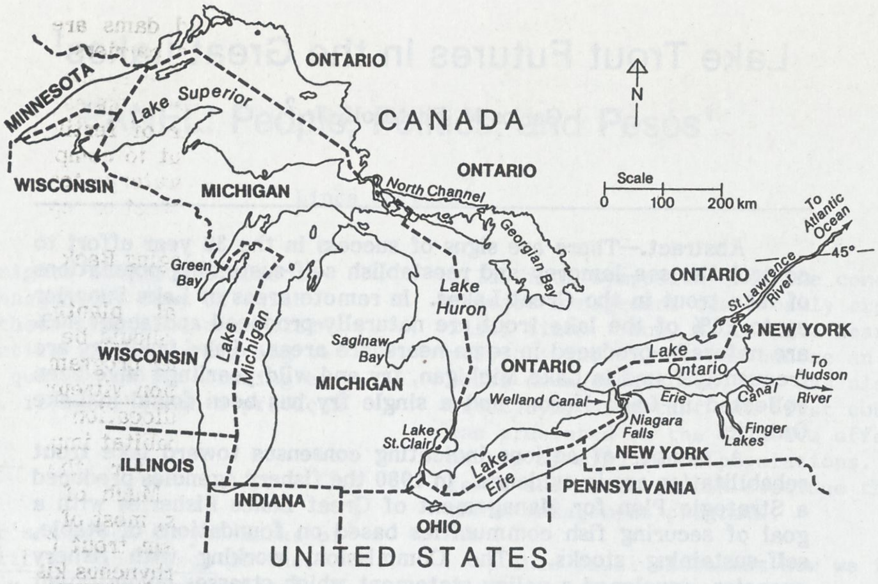

Figure 1.—Fishery jurisdiction in the Great Lakes. The boundary between Ontario and various states is also the international boundary between Canada and the United States.

has changed the lakes, their basin and what was formerly a simple, slowly evolving flora and fauna to the point that Richard Stoffle, a social scientist from the University of Wisconsin-Parkside, speaking at the 1984 American Fisheries Society meeting, called Lake Michigan one of man's largest artifacts. I don't totally agree or like the analogy, but he could have applied it to the whole of the Great Lakes and their basin. Mankind influences and attempts to manage the whole system from air quality to water quality, from agriculture to urban runoff, from fisheries and wildlife to water levels, and from industrial development to population growth. Because the management decisions affect our taxes, our income, our health, and our recreation, the lakes are vulnerable to economic, political and social forces as well as natural forces.

The legitimate conflicting demands result in intense public debates, and policies are often set in an emotionally charged environment. Fishery interests are currently involved in questions over diverting water to the south and west, extending the navigation season to eleven months, negotiating Indian treaty fishing rights, dewatering the rapids at the outlet of Lake Superior to produce hydropower, modernizing the management of commercial fishing by, in part, establishing quotas and limited entry; taking the confusion out of public health advisories on consumption of Great Lakes fish with residues of several environmental contaminants; extending sea lamprey (Petromyzon marinus) management into Lake Erie; phasing out gill nets in favor of more selective gear; developing a trout and salmon fishery in eastern Lake Erie where Ontario commercial interests now harvest some 40 million pounds of smelt (Osmerus mordax) which would be excellent forage for the introduced salmonines; and, of interest to attendees at Wild Trout Three, planning the future of lake trout in the Great Lakes.

A Question of Restoration

Five years ago Joe Kutkuhn (1980) posed a question to you, "Great Lakes lake trout: Have we really lost what we are trying to restore?" Dr. Kutkuhn was then Director of the Fish and Wildlife Service's Great Lakes Fishery Laboratory. His paper is an excellent summary of lake trout biology, the history of the experiment to restore the lake trout to self-sustaining populations, the problems that beset the fishery scientists in research, hatcheries and management, and the decisions they face regularly on how to and whether to continue the 30 year effort to reestablish self-reproducing stocks of lake trout. I will try to tell you about the policy, management, and research frameworks designed to answer Dr. Kutkuhn's question, and to support the efforts to achieve reestablishment.

DECLINE OF THE FISHERY

Lake Ontario's Atlantic salmon (Salmo salar) began to decline as early as 1830 (Christie, 1973) and shortly after that the governments of Canada and the United States became concerned about the welfare of Great Lakes fisheries (Fetterolf, 1980). Between 1870 and 1952 there were several pessimistic reports and unsuccessful attempts to establish joint fishery commissions and/or effective regulations, but by 1900 the sturgeon and blackfin cisco were missing from Lake Ontario and a series of species losses from Lake Erie commenced which culminated in the loss of the blue pike in the early 1960s (Hartman, 1973).

Sea Lamprey

The sea lamprey, native to the Atlantic Ocean, feeds by attaching to other fish with its suctorial mouth, and extracting body fluids. It probably entered

Lake Ontario via the Hudson River and its extension, the Erie Canal, opened to Lake Ontario in 1819, and gained access to Lake Erie via the Welland Canal around Niagara Falls in 1829 (Lamsa, 1980). It moved slowly through Lake Erie and then spread quickly throughout the upper three lakes by 1946. Through a combination of heavy commercial fishing and sea lamprey predation the lake trout catch of Lakes Michigan and Huron dropped from over 10 million pounds a year to zero (Baldwin et al. 1979). Extinction was an academic question in the mid to late 1950s.

Formation of Great Lakes Fishery Commission

The tragedy of the sea lamprey provided the final impetus for Canadians and Americans to complete the Convention on Great Lakes Fisheries in 1955. The Contracting Parties to the Convention, recognizing that joint concerted efforts were essential to obtain optimum sustained productivity of any stock of fish of common concern to the fisheries, established the Great Lakes Fishery Commission. They charged it with formulating the necessary programs; determining the best measures; coordinating, and if necessary, conducting research; controlling sea lamprey; recommending measures; and advising the Parties. The Commission's mandate is to improve and perpetuate the Great Lakes fishery resources: rehabilitation is a key word.

This formidable task could only be accomplished by working with the Commission's principal cooperators, the eight Great Lakes states and the Province of Ontario which have fishery management and regulatory authority, and the federal agencies with responsibility for research, assessment, lake trout hatcheries, and the general welfare of Great Lakes fisheries.

The Commission functions with advisors and a seven person Secretariat by contracting with Fisheries and Oceans Canada and the U.S. Fish and Wildlife Service for sea lamprey control and research which costs about $7 million annually. This program is funded 69:31 (U.S.:Canada) on the basis of the lake trout and whitefish catch value in pre-sea lamprey days. Costs of administration are split 50:50.

Sea Lamprey Management

The primary technique in the management of sea lamprey is control of the larvae. Adults spawn in tributaries of the Great Lakes and the larvae can live there as long as 20 years as harmless filter-feeders where they can be treated with the lampricide, TFM. The larvae normally transform into the parasitic phase and move to the lakes after 3-6 years in the tributary.

The program has been very successful to date as reflected in the numbers of spawning sea lamprey returning to assessment weirs and traps. Lamprey populations throughout most of the system have been reduced to levels which allow satisfactory growth and survival of desirable fish. However, there are indications that sea lamprey numbers are too high in northern Lake Huron, eastern Lake Erie, and Lake Ontario. Dependence of fishery rehabilitation on a single technique for sea lamprey control is untenable. The new emphasis is on integrated management in which management of fish stocks will be closely coordinated with lamprey control efforts. Several supplemental control techniques are bring tested and developed. Migrating spawners are trapped and removed. Specially designed low head dams are constructed on selected streams to act as barriers which keep lamprey from reaching spawning areas. Experiments underway include the release of sterile males into spawning streams to reduce the number of fertile eggs, stocking different strains of lake trout to compare survival from lamprey attack, and laboratory testing of odor producing materials which attract or repel lamprey.

Bringing Back the Fishery

Large annual plantings of hatchery-reared salmonines, which should be better coordinated among agencies, and smaller programs for other species such as walleyes (Stizostedion vitreum vitreum) combined with regulation and allocation of catch, sea lamprey management, and habitat improvement form the fishery management base for the rehabilitation program (Fetterolf 1984). Much of the rainbow trout (Salmo gairdneri) stockings, most of the brook trout (Salvelinus fontinalis) and brown trout (Salmo trutta), and all the coho salmon (Oncorhynchus kisutch) and chinook salmon (Oncorhynchus tshawytscha) plantings are aimed at the put-grow-take recreational fishery. On the other hand, stocking of most lake trout and splake (lake trout x brook trout) and backcrosses are intended for development of self-sustaining stocks. Fisheries management is moving rapidly to the more comprehensive fish community/ecosystem management approach advocated in the Strategic Plan described below. The commercial and recreational fisheries have responded to management so that their total economic value was estimated at $1.16 billion/year in 1979 (Talhelm et al. 1979).

COORDINATING FISHERY MANAGEMENT PROGRAMS

Committee Structure

The Commission pursues the remainder of its program through a committee structure involving the academic community and representatives of the agencies with fishery mandates (fig. 2). Central groups (Fish Habitat Advisory Board, Board of Technical Experts, and the Sea Lamprey Committee) are appointed by the Commission and include participation by Commissioners. The Commission has long recognized the importance of habitat quality and quantity in prevention or achievement of fishery management goals. In many instances fishery interests lack jurisdiction or authority in habitat issues and are unable to influence environmental and other resource agency decisions of great importance to fisheries. The Fish Habitat Advisory Board is charged to stimulate decision-makers to fully consider the potential impacts of their activities and decisions on fishery needs and to make the choice beneficial to fisheries.

The Commission depends in part on its Board of Technical Experts for advice, synthesis of scientific, social, and economic opinion, the vetting of research proposals, and recommendations on publication.

The Sea Lamprey Committee is developing methods to measure the efficiency and effectiveness of the control program and is attempting to match the needs of the fishery with the level of lamprey control. At what point, for example, is it economically and

Figure 2.—Organization chart of the Great Lakes Fishery Commission.

biologically sound to cut back on control and simply stock more fish?

Technical Committee members are appointed by the fishery agencies. The Fish Disease Control Committee deals with fish health policies and programs at federal, state, provincial and private hatcheries. The committee has developed a Model Fish Disease Control Program for everyone's guidance in this sensitive interstate-international issue.

The lake committees and the Council of Lake Committees have a major role in transboundary issues. A lake committee is made up of a senior staff member from each agency administering the fishery, assisted by experts and advisors from all agencies concerned. Lake committees are on the management/research firing line. They develop and coordinate studies and encourage implementation of their findings. The members appoint internal technical committees to advise them on issues such as coordination of forage base assessment and stocking programs, calculation of total allowable catch for critical species, determining minimum size restrictions, allocating harvest among jurisdictions, choosing genetic strains for stocking purposes, and developing tactical management plans for various species.

Developing the Strategic Plan

A few years ago the lake committees petitioned the Commission to create a Council of Lake Committees to address those matters of concern on more than one lake. Recognizing that threats to the fishery resource and opportunities for managing the fishery require greater capability than any one agency or government can provide, the Council's first recommendation was that the Fishery Commission develop a strategic plan for management of Great Lakes fisheries. As in so much of its work, the Commission agreed to facilitate the joint efforts of its cooperators by providing guidance at the policy level and a neutral, resource-oriented forum in which mutually beneficial programs could be developed. The Commission established a Committee of the Whole made up of eleven agency directors/ministers. The committee, which had veto power over the final product, committed to support development of the plan by personnel from their own agencies. Two years later in Ottawa, the agency leaders signed the Joint Strategic Plan for Management of Great Lakes Fisheries (Canada Department of Fisheries and Oceans, et al. 1980). The popular acronym is SGLFMP (siggle-fump).

The plan strives: "To secure fish communities, based on foundations of stable self-sustaining stocks, supplemented by judicious plantings of hatchery-reared fish, and to provide from these communities an optimum contribution of fish, fishing opportunities and associated benefits to meet needs identified by society for: wholesome food, recreation, employment and income, and a healthy human environment."

The agencies identified five general issues: lost fishing opportunities, unstable fish communities, inadequate environmental quality, conflicts and competition among users, and inadequate access to the resource.

The plan provides four strategies for dealing with the issues and achieving the goals: consensus, accountability, environmental management involvement and shared management information. Strategic procedures and responsibilities are assigned to lake committees, fishery agencies and the Commission. Using this plan for guidance, the agencies and Commission can ensure that the public's fishery resource receives full consideration with other uses of our Great Lakes. In the words of our keynote speaker quoting Starker Leopold, "Fishery interests will be at the table when the high stakes games are played."

Lake Trout Rehabilitation Policy

Working with its cooperators, the Commission has developed a policy to address the transboundary issue of rehabilitation of self-sustaining populations of lake trout. The policy statement emphasizes that the primary purpose in selecting stocking sites should be to obtain successful reproduction. A secondary purpose may reflect immediate-term social and economic considerations, but put, grow and take stocking practices which raise user expectations for the long term should be avoided.

The policy acknowledges substantial stocks of hatchery lake trout have been established in Lakes Superior, Huron and Michigan, but concludes that the present stocking program (which must be developed cooperatively) combined with total mortality is currently inadequate to establish the desired level of natural reproduction. The policy goes on to state that the genetic constitution of broodstock should be reviewed periodically along with behavioral characteristics of progeny, and that research priority should continue to be on factors limiting natural reproduction. In the area of management, the policy highlights control of exploitation, adequate escapement of mature fish, adoption of allocation criteria among users, and maintenance of monitoring programs necessary to meet objectives. That policy was developed in 1976 and updated with minor changes in 1982. It was needed because, much to everyone's surprise, the massive Great Lakes lake trout stocking program had not yet resulted in self-sustaining populations. Exploitation by recreational fishermen and Indian treaty fishermen plus illegal commercial take was considerably higher than anticipated.

LAKE TROUT REHABILITATION

Stocking Program

Over 125 million fingerling/yearling lake trout have been stocked since 1958 in Lake Superior, since 1965 in Lake Michigan, since 1973 in Lake Huron and Lake Ontario, and since 1975 in Lake Erie (Great Lakes Fishery Commission, 1983). The great majority have been produced by the U.S. Fish and Widlife Service and allocated among the states. Every lake trout stocked is fin clipped for identification from wild fish. The early thinking was that the fish would mature at age 6 to 8 depending on lake and area, seek historically successful spawning sites, and reproduce. The fish grew well, matured as expected, but unfortunately did not seek the historically successful spawning areas. Many returned to the vicinity where they were stocked and spawned opportunistically on a variety of substrates. Reproductive success was very poor.

Reproductive Success and Failure

In an attempt to improve spawning and reproductive success, most lake trout are now planted in areas where the opportunity for reproduction is greatly improved. Highly successful reproduction has occurred only in Lake Superior where naturally reproduced fish make up as much as 90% of assessment catches in remote offshore areas where remnant populations of wild trout exist. In many nearshore areas about 40 percent of assessment catches are naturally reproduced from both stocked and wild lake trout (Peck 1984). In Lake Michigan small numbers of fry have been collected for several years (Jude et al. 1981) (Wagner 1980) and increasing numbers of unclipped mature fish are being taken, but no one has yet concluded that this represents significant reproduction and the beginning of a return to self-maintenance. In Lake Huron lake trout fry have been collected since 1982 and in 1983 a few unclipped yearlings obviously different from hatchery fish were found (Nester and Poe 1984). Because lake trout were expected to begin spawning at age seven and because the first stocking was in 1973 this is especially encouraging news. In spring 1982 one lake trout fry was collected in Lake Ontario, evidence that environmental contaminants had not hindered the process to that stage of development. These are meager results to report for a multimillion dollar program, but they're positive findings from what has been an agonizingly slow process.

Why don't the lake trout reproduce more successfully? Dr. David J. Jude and his coworkers at the University of Michigan cited in a recent research proposal some of the reasons suggested by several authors (table 1). A consensus has not been reached.

COORDINATING LAKE TROUT RESEARCH

Unfortunately, the rehabilitation effort has not proceeded on a scientific experimental basis (Pycha 1982) although it was originally conceived and continues to be perceived by some as a very large experiment. The program became static while most everyone kept hoping that the few strains of lake trout, reared to a common life stage under similar hatchery regimes, and planted within a narrow range of densities, would somehow suddenly begin to reproduce.

Table 1.—Summary of some proposed causes for lake trout reproductive failure in the upper Great Lakes (adapted from Jude et al. 1984).

1. Inadequate numbers of spawners (Peck 1974; Rybicki and Keller 1978)
   a. Inadequate numbers of fish stocked or occurring on spawning reefs
   b. Inadequate lamprey control
   c. Overexploitation by commercial and sports fishermen
2. Reduction of egg viability (Martin 1957; Foster 1977; Stauffer 1979; Mac et al. 1980; Willford 1980; Martin and Olver 1980)
   a. Pollutants such as DDT or PCB—internal burden developed in adults is transferred to embryo, or assimilated by developing eggs and fry directly from environment
   b. Plant toxins (e.g. Cladophora)
   c. Disease—bacterial or fungal (Saprolegnia)
3. Predation (Scott and Crossman 1973; Stauffer and Wagner 1979; Horns and Magnuson 1981)
   a. By fish and invertebrates on eggs and fry
4. Eutrophication of spawning habitats (Martin 1957; Martin and Olver 1976; Stauffer et al. 1976; Manny 1983)
   a. Siltation—increased BOD, decreased circulation leading to suffocation and increased vulnerability to disease, production of hydrogen sulfide
   b. Periphyton—similar effects as with siltation
5. Inappropriate fish stocking methods (Pycha 1972; Rybicki and Keller 1978)
   a. Inappropriate locations—non-traditional reefs, fish stocked near shore spawn there in harsh conditions for incubation
   b. Planted at wrong age (planted after imprinting stage)
6. Maladaptation (behavioral, anatomical, physiological) for reproduction in the selected habitat (Swanson 1973; Loftus 1976; Scholz et al. 1976; Horrall 1977)
   a. Failure to return to appropriate spawning locations—lacking or inappropriate imprinting pheremones, redolence of reef or spawning area
   b. Spawning and incubation of eggs in areas of excessively harsh environmental conditions - wave action, currents, turbulence, ice scour, abrasion by sediments
   c. Spawning and incubation in areas of highly variable water temperatures
   d. Mixing of gene pools in hatcheries resulting in loss of area-specific adaptations and increased egg mortality
7. A combination of the above factors—e.g. numerical insufficiency, habitat degradation, and maladaptation to a specific set of environmental conditions

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Strategies for Rehabilitation Research

Much fishery research has been done, part of which was based on the 1964 Prospectus for Investigations produced cooperatively by the Fishery Commission and the state, provincial and federal fishery agencies (GLFC 1964), but in recent years research has not been pursued systematically from an established set of priorities. To remedy this the Great Lakes Fishery Commission sponsored the Conference on Lake Trout Research in 1983. CLAR's goal was to recommend priorities for lake trout research, identify hypotheses to be tested, outline the associated experimental designs, and encourage a sharing of the tasks among the Great Lakes agencies and institutions (Eshenroder et al. 1984).

The conferees divided the overall problem into seven areas: population dynamics and species interactions, stocking practices, genetics, physiology and behavior, contaminants, habitat, and socio-economics. From their deliberations an overall research strategy has been developed which attempts to preclude failure of the lake trout rehabilitation program because of inadequate science. The first priority research will focus on producing detectable recruitment from spawners of hatchery origin. Second priority research will focus on enhancement of recruitment from spawners of hatchery origin. The distinction is one of urgency. Continued public and agency acceptance of the attempt to secure self-sustaining populations of lake trout in the face of very limited success requires great faith, great patience and large amounts of money.

There are substantial stocks of hatchery reared lake trout in four of the lakes and agencies have continued to place ever-increasing restrictions on harvest. Of all the theories proposed for reproductive failure the most widely accepted is that an inadequate number of fish are being allowed to accumulate in multi-aged spawning stocks to achieve optimum reproductive needs.

This was the conclusion reached by Joe Kutkuhn (1980) at this conference in 1979. He expressed himself strongly, and concluded that there appear to be two essentially uncompromisable options for future management of the Great Lakes lake trout resource:

" - Promote put-grow-take fisheries like the costly ones now being enjoyed, thereby foreclosing the trout's widespread reestablishment and risking the loss of what is viewed by many as a commendable intergovernmental initiative;

OR

- Prohibit the withdrawal of lake trout while their populations are being rebuilt, thereby greatly enhancing the likelihood of the species' restoration to complete and cost-free self-sustainability."

The agencies appear to be opting for reestablishment, and recognizing the need for reduced catch.

MANAGEMENT PLANS FOR LAKE TROUT

Each lake committee has created a lake trout technical committee which is drafting a management plan to achieve self-sustaining stocks. The plans recommend broodstock strains, size and age for planting, habitat selection and planting sites, development of refuges and rehabilitation zones, stocking densities, species interaction guidelines for prey fish and sea lamprey, allowable catch and bycatch, methods of evaluating the experimental management initiatives, and methods of evaluating overall performance.

In the plans each committee explicitly identifies unacceptable levels of exploitation and total mortality. In all but a few areas of the Great Lakes annual mortality rates reported were much higher than 50%, the upper limit reported by Healy (1978) for optimum self-sustainability in wild populations. In the final plans expected in March 1985, each will recommend the survival rate needed to achieve self-maintenance. If the plans are accepted by the lake committees it will then become the decision of the management agencies whether to reduce the catch and by how much.

In 1984 the Fishery Commission wrote each Great Lakes agency which can implement measures to reduce lake trout catch and encouraged them to do so. Several agencies had previously reduced their bag limits and taken steps to reduce the bycatch of lake trout in commercial gear. Other agencies are in similar processes at this time and others have committed to future reviews of regulations. The overall goal of the Fish and Wildlife Service 1981 national plan is to rehabilitate lake trout populations of the five Great Lakes such that the spawning stock in each encompasses a wide range of year classes, sustains itself at a relatively stable level by natural reproduction, and produces a usable annual surplus. The agencies all seem to be in agreement.

ECONOMICS: PUT-GROW-TAKE VS. RESTORATION

There's another reason to support reestablishment on a self-sustaining basis, the economics of producing lake trout in hatcheries on a put-grow-take basis versus the restoration strategy. The Fish and Wildlife Service (Cameron 1983) compared the economics of the alternative management strategies which could be applied to the lake trout production anticipated from its new Iron River National Fish Hatchery in Wisconsin, which, by the way, is designed to produce at least four different generic strains simultaneously. The analysis was based on the following assumptions: Iron River will produce 3.5 million lake trout annually, costs will inflate at 5% annually, operations are supported by 9% federal borrowing, capital costs are ignored, fish are harvestable at 3 pounds and 5-6 years of age, survival of yearlings to critical sizes is 4.5%, recreational catch is valued at $26 per fish in 1983 dollars, period of analysis is 50 years (the expected useful life of the hatchery), and, of course, that the lake trout reproduce successfully.

As with any model there are unlimited questions about the assumptions, but the anticipated results are extraordinary. Restoration costs end after 15 years. Put-grow-and take costs go on the entire 50 years, and the fish are removed at a 50% annual rate. Restoration stocking ends after 15 years, but the established population will continue to expand until year 28 when it exhausts habitat carrying capacity and the decendants of Iron River fish begin introducing 33.6 million yearlings annually into the population. The benefit/cost ratio for the restoration strategy over 50 years is $209 million to $7 million, (30.46) and for put-grow-take $68 million to $15 million (4.6).

The annual catch (estimated at 80% recreational and 20% commercial) associated with the restoration strategy increases slowly until in year 20 harvest rate is allowed to double to 20% until it stabilizes in year 33 at 5.5 times the number of fish caught under put-grow-and take.

The 50 year cumulative catch statistics under the two strategies in millions of fish would be:

	Recreational	Commercial	Total
Restoration	13.6	3.4	17.0
Put-Grow-Take	3.8	1.0	4.8

CONCLUSION

In conclusion, I am convinced that the agencies responsible for the welfare of Great Lakes fisheries are making a renewed commitment to the goal of achieving rehabilitation of lake trout populations to self-sustaining status. The agencies and the Commission, with the support of the public, can work together under the Strategic Plan for Management of Great Lakes Fisheries toward this goal using tactical lake trout management plans developed by the lake committees, and using the research strategies developed by the Conference on Lake Trout Research.

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The Pacific Fishery Management Council's Role in Salmon Management[1]

Joseph C. Greenley[2]

Abstract.--This paper compares the status of Pacific salmon today with ten years ago, and describes the role and problems of the Pacific Fishery Management Council in maintaining and restoring the salmon resources. There is a question as to whether Pacific salmon can continue to provide viable commercial, recreational, and Treaty Indian fisheries in the ocean and rivers of Washington, Oregon, California, and Idaho. The impacts of habitat degradation, dams, and water diversions have not been offset by artificial production or restrictive ocean and in-river harvest regulations. More comprehensive management is necessary and is now possible because of recent Federal legislation.

INTRODUCTION

The problems and complexities of salmon management have been well documented over the past years by many individuals, agencies, and institutions. You have heard papers presented in both Wild Trout I and II on Atlantic and Pacific salmon management issues as well as various papers on steelhead trout which face the same freshwater management problems as salmon.

At Wild Trout I, when Wilfred Carter was describing to this group the problems of Atlantic salmon management and the essential ingredients for successful restoration of the species, the commercial and recreational fishermen of Washington, Oregon, and California were enjoying essentially restriction-free fishing for chinook and coho salmon, and Idaho had a recreational salmon season.

Five years later at Wild Trout II, when John Hough was presenting to this group the results of the Presidential Task Force examination of the then famous Judge Boldt Decision on Treaty Indian fishing rights, and Lawrence Stolte was analyzing the management and utilization of Atlantic salmon, Idaho was facing a resource crisis. In its first year of a total closure on recreational salmon fishing, Idaho was suing the states of Oregon and Washington in the U.S. Supreme Court for an equitable apportionment of anadromous fish in the Columbia-Snake system. The Columbia River Compact (Washington and Oregon) was tightening down on in-river fisheries due to the depressed status of some stocks and Treaty Indian obligations; and the commercial and recreational ocean fisheries, recently brought under federal management with passage of the Magnuson Fishery Conservation and Management Act (MFCMA), were being more tightly regulated for the same reasons.

Now, after another five years, the Idaho recreational salmon season is still closed and the most restrictive ocean and in-river salmon seasons on record are in place in Washington, Oregon, and California. Many people seriously question whether this resource can continue to provide viable commercial, recreational, and treaty fisheries throughout its recent historical range in these states, and, if so, at what level and cost. In this regard, I'm here to try to put into perspective, the role and problems of the Pacific Fishery Management Council (Council) in maintaining and restoring the Pacific salmon resources.

COUNCIL'S SALMON MANAGEMENT PLAN

The Pacific Council, one of eight Regional Fishery Management Councils established under the MFCMA, is responsible for the development of management plans for anadromous fish as well as other marine fish. The initial salmon plan was developed by the Council in 1977. It was followed by a new plan, Fisheries Management Plan for Commercial and Recreational Salmon Fisheries off the Coasts of Washington, Oregon, and California Commencing in 1978, which subsequently was implemented by the Secretary of Commerce and amended each year to and including 1983 to establish annual ocean fishing regulations. The 1984 seasons were established by emergency regulations without plan amendment.

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[1] Paper presented at Wild Trout III Symposium, Mammoth, Wyoming, [September 24-25, 1984].

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The Council is required to manage the salmon resource according to seven national standards as defined in the MFCMA. These state, in part, that conservation and management measures shall: (1) prevent overfishing while achieving the optimum yield (OY) from each fishery; (2) be based upon the best scientific information available; (3) to the extent practicable, manage an individual stock of fish as a unit throughout its range; (4) not discriminate between residents of different states; (5) where practicable, promote efficiency in the utilization of fishery resources; except that no such measure shall have economic allocation as its sole purpose; (6) take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches; and (7) where practicable, minimize costs and avoid unnecessary duplication.

In regard to standard number one, OY with respect to a fishery means the amount of fish which (1) will provide the greatest overall benefit to the Nation, with particular reference to food production and recreational opportunities; and (2) is prescribed as such on the basis of the maximum sustainable yield from such fishery, as modified by any relevant economic, social, or ecological factors.

Management Objectives

In concert with the MFCMA and related laws, Indian treaties and state policies, and in recognition of the management problems, the Council has adopted general management objectives in its salmon plan which address (1) harvest, (2) environment, and (3) natural and artificial production.

Harvest objectives, include: (1) providing for optimum spawning escapements for both natural and hatchery stocks; (2) providing fair and equitable harvest allocations between ocean and inside commercial and recreational fisheries, with the interests equitably sharing the obligation of fulfilling any treaty or other legal requirements for harvest opportunities; (3) minimizing fishing and other related mortalities; (4) considering the quantity and value of food produced, the recreational value, and the social and economic values of the fisheries; and (5) achieving long-term coordination with the management entities responsible for salmon habitat or production.

Although inland environmental matters have been considered as outside the Council's jurisdiction, environmental objectives have been included in the salmon plan. These merely encourage the entities responsible for habitat management to protect or restore water and watersheds, and provide safe passage for anadromous salmonids.

Production is another area outside of Council jurisdiction, but is also addressed in the salmon plan. These objectives encourage the responsible entities to restore natural production; seek full mitigation for lost habitat or obstructions; replace losses in kind, quantity, and in the same location when possible, and in a timely manner; and avoid the negative aspects of hatchery-produced salmon on other stocks.

In regard to the objective to restore natural production, it is the policy of the Council to restore or maintain important natural spawning stocks of salmon. This policy is a reflection of state policies such as those declared by Oregon and Idaho. Oregon's Wild Fish Management Policy declares in part:

"Wild fish are highly valued and the benefits of preserving them are great. The protection of wild fish preserves genetic diversity and reserves management options for the future. Managing wild fish encourages man to do what is best for the resource and promotes environmental concerns such as good water quality and healthy ecosystems."

Idaho, the state that depends the most upon the genetic integrity of its long-run salmon and steelhead, declares in its recently adopted Anadromous Fish Management Plan policies:

"Wild (naturally-produced, unassisted by artificial propagation) salmon and steelhead populations will receive priority consideration in all fisheries management decisions.

"In the event of a conflict between management for wild fish and management for hatchery fish, wild fish will be given first consideration. In most cases, the preservation of the genetic characteristics of these wild stocks is very important to the future of Idaho's anadromous fish management program. Certain streams such as the Middle Fork Salmon River will be designated as wild fish production areas, and will not be stocked with hatchery fish....

"Preserving genetic integrity within and among our anadromous stocks will have priority over maximizing harvest potential. Anadromous fish from Idaho are subject to an imposing and ever-changing array of obstacles to their survival. Both naturally spawning and hatchery reared fish must be capable of overcoming these obstacles if we are to preserve a healthy, harvestable resource. Where possible, we will maintain some completely wild native runs without artificial supplementation. Where this is not possible, we will manage more than one distinct hatchery stock and continually integrate our hatchery and naturally spawning broodstock to maintain a hatchery stock which is capable of successfully surviving through natural production."

THE PROBLEMS IN SALMON MANAGEMENT

The two fundamental and interrelated problems of Pacific salmon management are: (1) conservation of the salmon resource, and (2) allocation of the resource among fishery participants.

These two problems are not unique to salmon. They also must be addressed in other fisheries, and, in fact, must be addressed by all public renewable-resource managers to some degree. With salmon, however, these problems are compounded because of (1) the many political jurisdictions and management entities involved in its management, (2) the various ocean, inland, and Indian fisheries involved in its harvest, (3) the mix of natural and hatchery stocks, and (4) the continuous alteration of watersheds and, therefore, its freshwater environment.

From an ocean management standpoint, the overlapping of many salmon stocks[3] creates a major harvest control problem which makes it extremely difficult to either adopt sound conservation policies or allocate the resource equitably. The abundance of stocks may vary from year to year. Weak and strong runs can occur simultaneously in offshore areas. The natural mixed stock problem has been dramatically compounded by the superimposition of hatchery stocks. Hatchery stocks, capable of sustaining high harvest rates, are intermingled with naturally-produced stocks which do not share this capability.

Hatchery stocks have been introduced to mitigate passage mortalities and lost habitat resulting from dams or diversions, or to generally enhance various stocks; or, more recently, to produce a product for the market through aquaculture. Although hatchery-produced salmon may have served to maintain some stocks, they also may be held accountable for the demise of some natural runs.

The Council has addressed the mixed-stock problem by time and area closures, gear restrictions, and harvest quotas. Only a limited amount of stock separation in the harvest can be made by the current management measures in the ocean fisheries. Factors such as lack of sufficient biological data and difficulty of predicting abundance of chinook and some stocks of coho undermine the effectiveness of the Council's management measures. These problems have been lessened since the MFCMA has been in effect due to better coordination between the states and federal agencies and additional funding for research and data collection.

The effectiveness of ocean management measures to conserve and allocate the resource will depend upon our ability to accurately predict abundance and to selectively harvest or protect various stocks. The effectiveness of Oregon and Washington coastal and Columbia River chinook management measures will also depend upon the implementation of a U.S./Canada salmon interception agreement. This agreement is essential to achieve coordinated coastwide chinook management with Canada and Alaska.

From the inland standpoint, conservation of the resource is even more complex. In-river fisheries, artificial production, stream barriers, water diversions, and habitat modifications are all conservation factors with the latter three being the least controlled and most devastating of all the inland and ocean factors combined. While spawning habitat has been maintained and even increased in a few drainages, overall the amount of habitat available to salmon in the Pacific Council states has been drastically reduced and degraded during the 20th century. The major salmon producers, including the Sacramento-San Joaquin, Klamath and upriver Columbia (above Bonneville Dam) and Snake rivers, have suffered the greatest losses from degradation of habitat, construction of dams, and water diversions.

Mitigation for federal water projects has taken the form of artificial production to theoretically replace the losses caused by dams. Many hatcheries were constructed on the Sacramento, Klamath, and Columbia systems. Increasing numbers of smolts have been released yet we still have the most serious salmon crisis in recent history on the Pacific Coast.

The Council intends to become more actively involved in inland habitat and production issues. The fishermen have been asking for it. The National Oceanic and Atmospheric Administration adopted a national policy for the conservation of America's living marine resources and their habitats. That policy statement directs the National Marine Fisheries Service to ensure that habitat considerations are incorporated in fishery management plans developed by Regional Fishery Management Councils.

Other significant national legislation addressing anadromous fish and its habitat includes: (1) The Northwest Power Act of December 5, 1980 (Public Law 96-501). This Act established the Northwest Power Planning Council and directed that it develop a program "to protect, mitigate, and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries." In my view this is the most significant anadromous fish legislation ever passed by Congress. It is intended to ensure that fish and wildlife resources are accorded co-equal status with other uses in the management and operation of hydroelectric projects in the region. The fish and wildlife program developed by the Power Council appears to be carrying out that mandate. (2) The Salmon and Steelhead Conservation and Enhancement Act of 1980 (P.L. 96-561). This act authorized the Secretary of Commerce to establish a Commission to prepare a report for the Secretary of Congress containing: "...conclusions, comments, and recommendations for the development of a management structure for the effective coordination of research, enhancement, management and enforcement policies for the salmon and steelhead resources of the Columbia River and Washington Conservaton Areas, and for the resolution of disputes between management entities that are concerned with stocks of common interest." It appears that the recently adopted report of the Commission offers some logical solutions to these perplexing problems.

CONCLUSION

The Pacific Council's salmon plan is basically an ocean management plan. Ocean harvest regulations, as important as they may be in conserving

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[3] Stocks are defined by species (coho, chinook, or pinks), hatchery or naturally produced, river or system of origin, time of entry into the river (spring, summer, or fall runs), and distance upriver or spawning site (upper or lower river).

and allocating the harvestable surplus of salmon stocks, cannot conserve the resource without comparable management of the inland and ocean factors outside of the Council's jurisdiction. These include in-river fisheries, artificial production, habitat degradation, dams and water diversions, and interceptions in the ocean by Alaskan and Canadian fisheries.

It is possible that by the time Wild Trout IV comes around, the fish and wildlife program of the Northwest Power Planning Council will be producing results on the Columbia River, the management structure developed under the Salmon and Steelhead Advisory Commission will be functioning, the United States and Canada will have a treaty on salmon interceptions, artificial production will be coordinated to complement rather than conflict with natural stocks, and natural production will be enhanced. If so, the salmon picture, at least in the northwest, will be bright. The degree to which the above are achieved will determine how bright the picture will be.

Changes in the Trout Fisheries of the Lower Colorado River and Arizona[1]

Bruce D. Taubert[2]

Water needs for domestic use, changes in hydroelectric generation technology, expansion of the distribution of exotic fishes, and protection measures for endangered species are currently changing or have the potential to negatively impact the quality of the trout fisheries in the lower Colorado River (downstream from Glen Canyon Dam) and in Arizona.

The trout fisheries within the interior of Arizona are being threatened by the Central Arizona Project (CAP). CAP water will be transported from Lake Havasu on the Colorado River to the Phoenix and Tucson metropolitan areas. As a result of this "new" water, water exchanges will take place within Arizona that have the potential to reduce the flow in trout streams or to seasonally dry these streams.

INTRODUCTION

Between the 1930's and 1960's the Colorado River was tamed by the construction of dams for flood control, domestic water storage and hydroelectric power generation. The construction of these dams changed the Colorado River from a typically warm water river with dramatically changing seasonal flows to one whose flows were very predictable, at least until 1983, and a river that had very different habitats. These new habitats were made up of cold water tailraces, warm water rivers, and large impoundments. As a result, the fish faunas changed and many native fishes became endangered. In response to the changing habitats wildlife agencies stocked exotic species with the hope that they would provide stable fisheries to the burgeoning populations of the Southwest. Many of these introductions were failures in that they further destroyed the native fisheries or they did not adapt well to the new environments. In many cases, especially the salmonids, the introductions were extremely successful in that they have not been shown to have negatively impacted the native or exotic sport fisheries and they provided a quality fishery that was not previously available. These new trout fisheries extended from Glen Canyon Dam just south of the Arizona-Utah border on the Colorado River to just below Davis Dam near the border of California and Nevada on the Colorado River (fig. 1).

The trout fisheries I will be discussing in the interior of Arizona are limited to the East Verde and the Black Rivers. Historically, the East Verde was a native fishery without salmonids. This fishery now consists of a naturally reproducing population of brown trout (Salmo trutta) and stocked rainbow trout (Salmo gairdneri). In contrast the Black River (eastern portion) had native Arizona trout (Salmo apache). This population was eliminated through continued hybridization with stocked rainbow trout. Currently a naturally reproducing population of brown trout and rainbow trout exists and catchable sized rainbow trout are stocked during peak summer fishing periods (fig. 1).

During the past 15 years changes in the Colorado River have seriously reduced the extent and quality of the trout fishery. In addition, there are changes that will happen in the near future that may further affect the quality of the trout fisheries in the Colorado River, the East Verde and Black Rivers. As usual, the past and future changes in these trout fisheries are taking place, or have taken place, because of changes in the needs of the population of the Southwest in relation to water and electrical power and not as a response to the anglers needs or desires. The one exception to this is the stocking of striped bass (Marone saxatilis).

For purposes of discussing the effects of people, pesos, and politics on the above fisheries I will discuss the development of each of these fisheries in detail and attempt to show what changes have taken place or will take place.

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[1] Paper presented at the Wild Trout III Symposium, Yellowstone Park, Wyoming, September 24-25, 1984.

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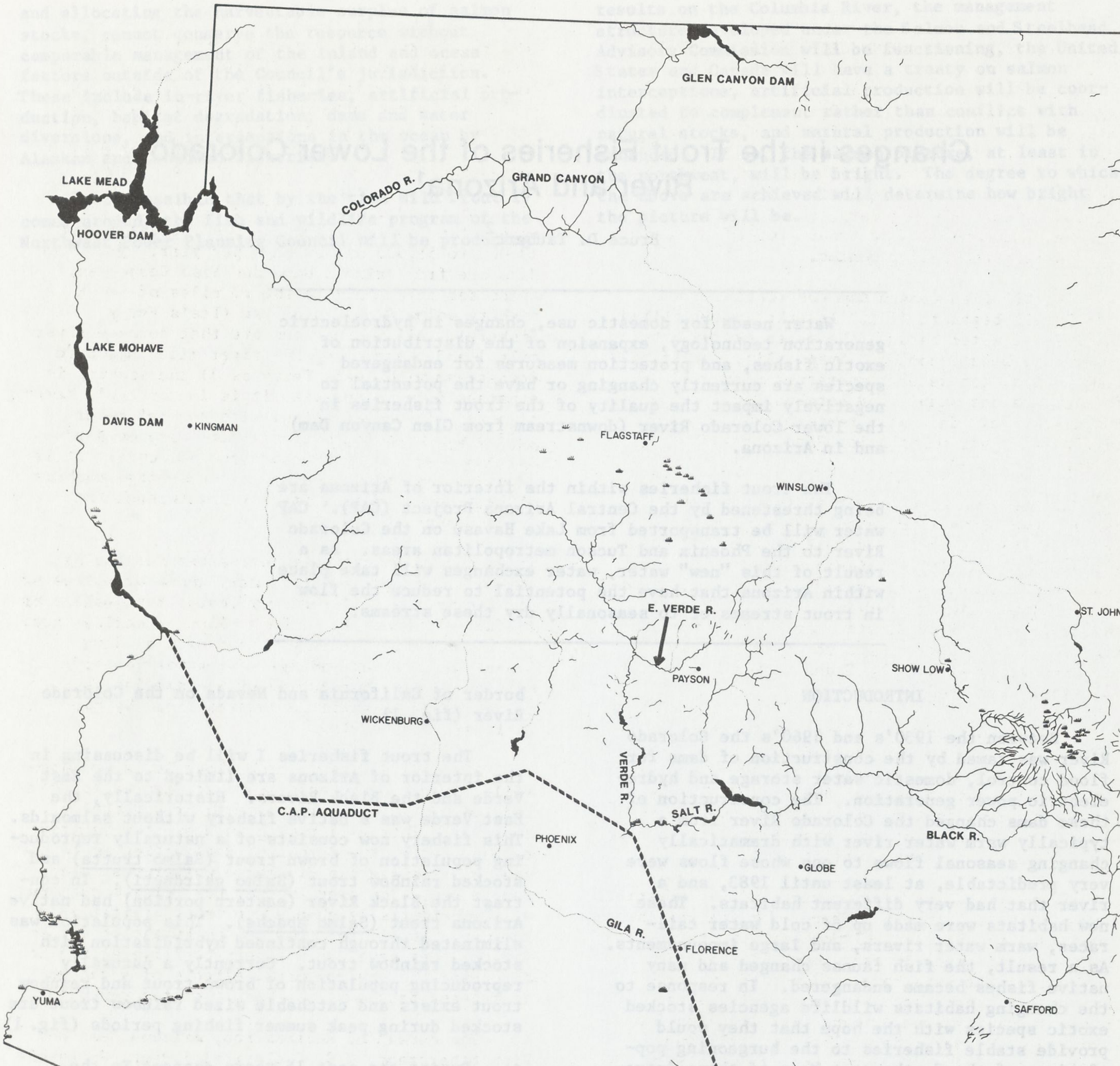

Figure 1.--Map of Arizona showing the geographic position of the Grand Canyon, Lake Mead, Hoover Dam, Lake Mohave, Davis Dam, East Verde River and Black River trout fisheries. The Central Arizona Canal is also shown.

LEE'S FERRY AND THE GRAND CANYON TROUT FISHERY

Historically, the Colorado River at Lee's Ferry and through the Grand Canyon was extremely unique. Water flows ranged from very low during drought years to well over 100,000 cfs when spring runoff was high. Before 1963 the fish fauna consisted of several endemic native fish and some exotic fishes including carp, channel catfish, walleye, and some rainbow trout stocked as catchables during the colder months.

In 1963 Glen Canyon Dam was completed and Lake Powell began to fill. As Lake Powell filled, the release water through the seven hydroelectric generators became cooler. Eventually, during the late 1960's, the water temperature decreased further and has stabilized between 46-48°F from the discharge. The water temperature approximately 240 river miles below Glen Canyon Dam seldom reaches 60°F.

At the same time that the discharge water cooled, Lake Powell began to act as a sediment trap and the sediment load fell from 15,000 to 7 ppm. As a result, the discharge water is clear and its potential to carry sediment is high. Due to the high sediment carrying capacity of discharge waters the substrate near Lee's Ferry and throughout the upper 100 or so miles of the Colorado River within the Grand Canyon has become relatively armoured.

As a result of harnessing the Colorado River for hydroelectric power generation, the flows stabilized and the discharge rates dropped from over 100,000 cfs to between 800 and 37,000 cfs. The new release pattern, in conjunction with the armouring of the substrate, stabilized and changed the habitat within the river itself.

Finally, as the water cooled and the substrate changed, the relative abundance of algae and invertebrates also changed. Cladophora spp. became the dominant algae and, in fact, most of the armoured portions of the substrate are covered by large mats of Cladophora spp. In response to this change in habitat the Arizona Game and Fish Department stocked several invertebrates including the fresh water shrimp (Gammarus lacustris). With the Cladophora to feed on the Gammarus populations have exploded.

In order to take advantage of this apparently perfect trout habitat the Arizona Game and Fish Department initiated an annual stocking program in 1964. From 1964-1974 catchable sized rainbow trout (8") were the most frequently stocked fish. After 1974 the Department changed its strategy and since then only fingerling (3-4") trout have been stocked. We have also diversified and since 1974 have stocked brook, rainbow, and cutthroat trout. One stocking was made of 20,000 fingerling coho salmon in 1971.

From these stockings and those made earlier (1940-1950) into Grand Canyon tributaries by the U.S. Fish and Wildlife Service a fantastic trout fishery has developed. Natural reproduction takes place immediately below Glen Canyon Dam and within several of the Grand Canyon tributaries. The average weight of the fish caught has increased from about 0.3 pounds in 1964 to 2.7 pounds in 1983. It is now common to catch 5-7 pound rainbow trout with recorded record at slightly less than 20 pounds. Brook trout are commonly over 2 pounds and the record is well over 6 pounds. Catch rates have declined from a high of 1.1 fish per hour to approximately 0.17 fish per hour. During the last 10 years use has increased from 10,000 to 55,000 angler days per year. The above data are from Arizona Game and Fish Department files and only apply to the 17 miles of trout fishery below Glen Canyon Dam (Lee's Ferry fishery). All indications are that between river mile 1 and river mile 150 (river miles measured downstream with Lee's Ferry as 0) the fishing is substantially better than it is in the Lee's Ferry fishery. In conversations with several river guides and with the National Park Service and Arizona Game and Fish Department personnel, it is apparent that it is common to catch large numbers of large trout during river trips through the Grand Canyon.

It is indeed unfortunate that after developing this truly trophy trout fishery there are plans or actions in the mill that may reduce its quality or in fact eliminate it. These plans or actions are: (1) a change in the release patterns of Glen Canyon Dam, (2) an endangered species jeopardy opinion against the Bureau of Reclamation, and (3) a change in attitude towards trout by the National Park Service.

Due to a change in technology it is now possible to rewind the generators at Glen Canyon Dam and, as a result, to increase their generating capacity. This will result in a greater latitude on the part of the Bureau of Reclamation as to how they will manage the discharge patterns at Glen Canyon Dam. The fear is that new release patterns will substantially change the trout habitat below the dam. In all fairness to the Bureau of Reclamation, they have taken a very positive action to determine the environmental effects of a change in release patterns as a result of the rewinding.

The Bureau of Reclamation, Arizona Game and Fish Department, U.S. Geological Survey, National Park Service, and other agencies are currently involved in a \$4 million study to determine how a change in release patterns will affect the aquatic and terrestrial systems, and the recreational benefits of the river and canyon. This study is entitled the "Glen Canyon Environmental Study" and is the first cooperative venture of this magnitude in the lower Colorado River. The product of the Glen Canyon Environmental Study is to be a unified recommendation on the types of flows and flow patterns that will best preserve the current "good" qualities of the affected portion of the river, while at the same time take into account the need to produce more and less expensive electricity from Glen Canyon Dam. If this task can be accomplished, it will not only be a miracle, but possibly the salvation of this trophy trout fishery.

A second, and possibly greater, threat to the trout fishery at Lee's Ferry and within the Grand

Canyon is an endangered species jeopardy opinion that the Bureau of Reclamation has been given by the U.S. Fish and Wildlife Service. The theory is that because of the current operation of Glen Canyon Dam the habitat is deteriorating for three endangered fish; the humpback chub (Gila cypha), bonytail chub (Gila elegans), and Colorado River squawfish (Ptychocheilus lucius). When given a jeopardy opinion the agency or individual is directed to reverse the deteriorating trend that they have caused. In other words, the Bureau of Reclamation has been directed to improve the discharge out of Glen Canyon Dam or habitat within the river in favor of these three species. Unfortunately, the three endangered species in question are warm water fish and an "improved" habitat for them will, in all likelihood, not be advantageous to the trout.

One option to improve the habitat for the endangered fish is to put movable penstocks in the dam and discharge warmer water during critical times of the year. Other options, such as providing warm backwaters for rearing areas, are being considered, but do not appear to be as feasible. Again, in all fairness to the Bureau of Reclamation and the U.S. Fish and Wildlife Service, there is going to be extensive study into this problem and the trout fisheries will be given its fair chance during the decision making process.

The final threat, at this time, to this fishery is a change in the National Park Service attitude towards the trout fishery within the Grand Canyon. Trout have not been mentioned as a species of concern in any of the National Park Service documentation that I have seen concerning the Glen Canyon Environmental Study or the National Park Service planning process. In conversations that I have had with National Park Service personnel they simply state that trout are not native to the Grand Canyon and that for fisheries purposes native fish are their real concern.

LAKE MEAD TROUT FISHERY

Lake Mead began to fill in 1935 after the completion of Hoover Dam. The changes in fish species composition were quite dramatic and the construction of Hoover Dam was probably the cause for a major decline in the native fish fauna - all warm water species. As Lake Mead filled the water of the turbid Colorado River cleared and a 63,902 ha. reservoir was formed. Hundreds of thousands of largemouth bass (Micropterus salmoides) and other Centrarchids were stocked between 1935 and 1942. By 1963 the catches of largemouth bass neared 800,000 and it was the number one most sought after fish. Unfortunately, for the bass fishery, Glen Canyon Dam closed during 1963. As a result of the construction of Glen Canyon Dam the amount of water entering Lake Mead was reduced. Even more problematic was the nutrient block caused by Glen Canyon Dam which reduced the nutrient input (primarily phosphorus) to Lake Mead by approximately 90%. As a result of these changes, the catch of largemouth bass is currently less than 100,000 fish per year.

In 1969 a new species, the striped bass, was stocked to provide a pelagic predator that would take advantage of the abundant threadfin shad (Dorosoma petenense). By 1972 striped bass were becoming an important part of the fishery and in the late 1970's thousands of striped bass were being harvested. It was obvious that the striped bass had begun reproducing in the fresh waters of Lake Mead during the early 1970's. Unfortunately, the outstanding striped bass fishery of Lake Mead was short-lived and by 1980 the catches had crashed and today few striped bass are creeled in Lake Mead. At the same time the striped bass populations exploded, the populations of threadfin shad, its main food source, decreased and it is believed that the striped bass literally ate itself out of house and home. Because Lake Mead has become oligotrophic since the closure of Glen Canyon Dam, the threadfin shad have not bounced back after the reductions of their population numbers due to predation by striped bass and, as a result, the striped bass populations are held at a low level due to forage limitations. As a point of interest, the water is so oligotrophic in Lake Mead and fish production so low that plans are being made to artificially fertilize this huge reservoir.

Because Lake Mead was cold during the winter months, and because the hypolimnion was cold and well oxygenated during the summer months, both Arizona and Nevada stocked rainbow trout. Although trout were caught earlier the first solid stocking records were from 1969. Since 1969 millions of trout, mostly rainbow, have been stocked into Lake Mead and these stockings resulted in an outstanding fishery. Trout were commonly caught in excess of 3-4 pounds and during the mid 1970's harvests reached 130,000 trout per year. Unfortunately, after 1975 catches dropped off significantly and today only a few trout are caught in Lake Mead.

There appears to be one reason for the decline of the Lake Mead trout fisheries - the stocking of striped bass. Some biologists suggest that the closure of Glen Canyon Dam in 1963 and the resultant nutrient block affected the trout fishery. This explanation would be palatable if there had not been a dramatic increase in the trout fishery from 1968-1974 and if the decline in the trout fishery had not occurred at the same time as the striped bass population began to explode. Also, it is hardly coincidental that during 1976 stomach contents of striped bass contained 26% trout. Because of the reproducing population of striped bass in Lake Mead it is doubtful if an excellent or even marginal trout fishery will ever be reestablished in Lake Mead.

LAKE MOHAVE FISHERY

Lake Mohave was formed by the closure of Davis Dam in 1951. As usual the closure of this dam negatively affected the warm water native fishery and further tamed the Colorado River. Unlike Lake Mead, Lake Mohave is long and narrow and much of the water between Hoover and Davis

Dams is very riverine like. In addition, nutrient levels are adequate for good fish production in Lake Mohave. Soon after closure Lake Mohave was stocked with warm water species, mostly Centrarchids, and trout were first stocked in 1935. For all practical purposes the best trout fishery in Lake Mohave is from the tailrace of Hoover Dam to just upstream of Lake Mohave. Of the trout harvested approximately 70% are taken upstream from Lake Mohave and 30% in the lake proper. Of the over 1,000,000 trout stocked between Hoover and Davis Dams 35% are harvested. A majority of these fish are stocked as catchable sized trout. Harvest rates of these fish approach 0.5 fish per hour.

Until 1980 there were no identified threats to the Lake Mohave trout fisheries and, in fact, plans were being made to increase stocking rates. Unfortunately, in 1980 striped bass were first found in Lake Mohave and since then their frequency of occurrence has increased to the point where anglers are going to Lake Mohave to fish for striped bass. In addition, preliminary information indicates that striped bass are preying heavily on the stocked trout. Striped bass were not stocked into Lake Mohave, but probably drifted through Hoover Dam from Lake Mead.

If striped bass start, or are found to be spawning in Lake Mohave, then this trout fishery will probably go the way of Lake Mead. There may be a salvageable trout fishery immediately below Hoover Dam and, since 70% of the trout currently harvested are from this area, there may not be a pronounced decline in angler use of this trout fishery. Investigations are currently under way to determine the life history of striped bass in Lake Mohave.

DAVIS DAM TROUT FISHERY

After closure of Davis Dam a cold water tailrace trout fishery was available. Trout were first stocked into this area in 1951. In 1962 striped bass were stocked into Lake Havasu below Davis Dam. Sound like a familiar story? Well, luckily the trout fishery below Davis Dam appears to be reacting differently than those in Lake Mead, and probably Mohave, in response to cohabitation with striped bass.

During those times of the year when striped bass are absent from the cold waters below Davis Dam the stocked trout grow fast on black fly larvae and an excellent trout fishery is provided. In a normal year about 600,000 subcatchable (5-6") and 100,000 catchable trout are stocked below Davis Dam. Some data indicate that return rates are good and about 15 fish are creeled for every pound of subcatchables stocked.

When the striped bass move into the waters below Davis Dam there is a noticeable change in the characteristics of the fishery. Obviously, the catch rates of striped bass increases, but a noticeable decline in the catch of trout parallels this increase in catch of striped bass. It is probable that predation by striped bass is the reason for much of the decline in trout catches during this time of the year.

Fortunately, the trout fishery below Davis Dam is only affected by the striped bass for a few months of the year. With proper timing of stocking and better selection of size of fish stocked the management agencies can probably sustain this trout fishery at a level that will be acceptable to the angler.

EAST VERDE AND BLACK RIVERS

The East Verde River in central Arizona was historically a cool to cold water river with native, nonsalmonid fishes only. The records that I have indicate that rainbow trout were first stocked in the East Verde in 1964 although data from previous surveys showed their presence in 1959. Brown trout were first stocked in 1966. Currently, the East Verde River has a limited naturally producing population of brown trout and possibly rainbow trout. Because most of the East Verde River is quite accessible, fishing pressure is high and a majority of the rainbow trout (and some infrequent brook trout) stockings have been with 8-12" fish. For example, in 1983 over 30,000 catchable sized rainbow trout were stocked into the East Verde River.

The Black River is in eastern Arizona and is a cold water stream that historically held a population of the native Arizona trout. Again, the first records I have show that stocking of rainbow trout began in 1964. In addition, brown trout and grayling have been stocked into the Black River. Currently, naturally reproducing populations of brown trout and rainbow trout exist. The native Arizona trout no longer appears in the Black River. The Arizona trout and the stocked trout hybridized and the integrity of the Arizona trout gene pool has been lost. The Black River is also quite accessible and receives heavy fishing pressure. In 1983 the Black River received over 45,000 catchable sized rainbow trout.

The anticipated threats to the trout fisheries of the East Verde and the Black Rivers are coming in a roundabout fashion and are a result of the Central Arizona Project (CAP). The CAP consists of several pumping stations and a long aqueduct (mostly uncovered) that will bring Colorado River water from Lake Havasu to the interior of Arizona, mainly Phoenix and Tucson. The CAP was developed to provide the means by which Arizonans could fully utilize their Colorado River water allocations. During the development of the CAP, municipalities, mining interests, Indian reservations, etc. requested that certain numbers of acre feet (AF) be allotted to them from the CAP waters. These municipalities are currently taking limited amounts of water from the watersheds closest to them and, in general, there is not sufficient supplies to meet their needs. The supply of water to municipal and other users is limited because of the water rights that the downstream water users have. For all intents and purposes the downstream water user that controls the removal of water from the East Verde and Black Rivers is the City of Phoenix and its suburbs. Under the current proposal those entities that asked for an allocation of CAP water will receive this water via water trades with downstream users. In other words, the Phoenix metropolitan area trades the Tonto Apache Reservation, E&R Water Company, and the City of Payson 6,436 AF of CAP allocations for current watershed allocations.

The long and short of these CAP water exchanges is the potential for 6,436 AF of water being drawn off at the headwaters of the East Verde River and 20,868 AF of water being drawn off of the Black River. These magnitudes of water removals will reduce the amount of water available for these important trout fisheries and seasonally dry portions of both the East Verde and Black Rivers.

DISCUSSION

In this section I would like to discuss the likelihood that the quality of the trout fisheries in each of the above areas will improve or decline. Of course, with minor exceptions, this discussion is conjectural on my part and, in fact, may not be very close to the eventual outcome at all.

It is my opinion that the trophy trout fishery at Lee's Ferry and within the Grand Canyon will not only remain but will improve due to the data being generated by the Glen Canyon Environmental Study. It is quite obvious to me that if the water temperature is increased to favor the endangered species exactly the opposite will happen. If the water temperatures are increased the Colorado River within the Grand Canyon will become a haven for the cool water walleye and possibly striped bass. If this happens there will be excessive predation on the currently endangered species and the likelihood of their recovery will be poorer than it is now. It is also my opinion that Glen Canyon Dam will always be used for hydroelectric power generation and that the Colorado River below the dam will continue to be scoured. This armouring will produce better trout habitat and poorer native fish habitat.

The trout fisheries of Lake Mead and Lake Mohave are another story. Unless the striped bass is eliminated from these waters the trout fishery will be eliminated in the lakes and limited to those areas just below Hoover and Davis Dams. State and Federal agencies may continue to stock trout into Lakes Mead and Mohave, but it will be a losing proposition and motivated by politics and not biological sense.

The trout fisheries in the East Verde and Black Rivers are literally up for grabs. If all entities accept the water that they were allocated then it is certain that the quality of these trout fisheries will decline. Natural reproduction will be inhibited or eliminated and the fisheries will become more of a put and take type. There are two lights at the end of this tunnel. First, indications are that not all entities will ask for the allocations that they were granted. Second, if the value of the trout fishery is decreased it will have to be mitigated for. Unfortunately, cold water suitable for mitigation is rare in Arizona.

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Carrying the Creel[1]

Pamela K. McClelland[2]

Abstract.--Trout Unlimited offers individual anglers education and organization for more effective wild trout conservation. Over the last 25 years, TU has done numerous local stream projects, and has been an advocate for wild trout at the state, regional, and national levels. The future portends challenges for the very existence of wild salmonids. There is, thus, a need to catalyze anglers and others to ensure the greatest productivity from local efforts and available funding. TU's approach can make a difference.

As individual anglers, we all have done at times our share of family chores for our favorite streams. We have pulled out a beaver dam, moved rocks to provide cover or contain erosion, and planted grass seed to stabilize banks after trees fall or after a spring freshet. Such instream and riparian chores are traditional angler activities.

And, as anglers, we all know that there is no Big Brother waiting in the wings to shoulder for us the responsibility for such activities. We accept that these individual efforts will need to continue.

Today, the pressure for these and other activities increases in step with the mounting problems that face wild salmonids. The challenge for Trout Unlimited (TU) is to make state-of-the-art fisheries management techniques available for individual angler initiatives. Faced with today's economic environment and general federal retrenchment in fisheries management, we cannot afford to get any less than the most bang from our limited bucks (both time and money) spent on instream and other activities.

To help meet this challenge, Trout Unlimited makes available to individual anglers the tools to provide the most effective results from their volunteer efforts. The basic tools are <u>education</u> and <u>organization</u>. With these, the individual angler can best assure that his instream and other efforts make the biggest contribution to wild trout for his and future generations' enjoyment.

To provide the tool of education, Trout Unlimited's local chapters acquaint the individual angler with wild trout requirements and appropriate management and conservation techniques. This is accomplished through seminars, speaker programs, publications, exposure to other anglers, and actual work on field projects.

To put the educational tool to work, Trout Unlimited chapters provide the means to organize and coordinate individual angler activities. Through local and national TU contacts with the private sector, universities, and state and federal fisheries agencies, specialists are brought in to provide technical assistance in reviewing local conservation priorities and designing local projects.

Trout Unlimited also provides money to spur the educational tool into action. TU's national grant program is called "Embrace-a-Stream." Funding through Embrace-a-Stream is available to TU chapters and councils as matching funds for actual project implementation, covering research, material purchasing, community awareness and support campaigns, etc. This exciting financial resource in support of TU chapter programs is a result of a project funding grant from the Richard K. Mellon Foundation in Pittsburgh. Over the last two years, TU has funded 91 projects under this program.

With the resources of local time and fund raising, supported by TU national staff and TU national project grants, local chapters pool the resources and skills of anglers, professional fishery managers, other conservation interests, and community groups in a team effort to carry out specific projects.

Once organized, such a team effort can tackle amazingly large projects, with positive impact on both the local and national levels with success--success that can far outstrip the sum of individual efforts.

The single idea, underpinning all TU activities, is: with the tools of education and organization used in a coordinated team approach, TU can provide individual anglers an exciting and effective means to enhance and protect local wild trout resources. This is the proven idea and the

[1]Paper presented at the Wild Trout III Symposium, Yellowstone National Park, Mammoth Hot Springs, WY, September 24-25, 1984.

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commitment of Trout Unlimited and its 40,000 members nationwide.

No one will do it for us. The pressures on our fisheries are increasing. It is only common sense that we accept the responsibility, and take the opportunity, to get the best results possible from the limited time and effort we can afford.

What then has been the evolution of this team approach? What are some of the results achieved? And what can be inferred for the impact of such activities in the future for the management of wild trout in the United States?

THE TROUT UNLIMITED CONCEPT

Since its founding 25 years ago, Trout Unlimited has been an important part of the national fisheries conservation effort.

Originally the idea of George Mason, TU's initial concept was signaled by George A. Griffith in July 1959, when he called the first organizing meeting at his home along the banks of Michigan's Au Sable River:

> "For some time I and several others have been considering ways and means to protect and preserve trout and trout fishing, and have come up with the idea of forming an organization to be known as Trout Unlimited.
>
> "We are convinced that to achieve that objective, a united, organized effort is necessary.
>
> "Such an organization could work with state and federal agencies now charged with that responsibility. Through bulletins, publications, and news releases, it would help educate the public on the dire need of sound, practical, scientific trout management and regulations to protect the trout as well as to satisfy fishermen."

TU was to be "a great step towards the preservation of our cherished sport." The founders saw, early on, the need and the opportunity for the twin roles of education and organization at the local level. As well, TU should be a representative group to stand up for local angler interests within larger political bodies and within the national conservation arena.

LOCAL FOCUS: PROJECTS AND INITIATIVES

Today, Trout Unlimited is fully committed to put the tools of education and organization to work with real projects which produce measurable results. The motto of TU is emblematic: we are "The Action Organization." The member anglers of TU know only too well that the health of wild trout and of wild trout fishing is measured by results, not by wishful thinking.

Today, Trout Unlimited has a growing, dynamic project portfolio responding to local needs for protection and enhancement of local wild trout fisheries.

These projects come in many shapes and sizes. But, generally, they are spurred by local TU anglers, just as those who met to save the Au Sable, when they realize the cruel blow that a favorite stream will apparently not support naturally reproducing salmonids. Upon examination, this is sometimes the case; the situation is not practically reversible. But often, this is not the diagnosis; and a TU chapter, with proper project planning and technical guidance, can work to successfully remedy the limiting factor(s).

Local action projects and initiatives which are being successfully managed by TU teams across the country can be categorized as follows:

-- instream, riparian, and watershed enhancement
-- instream flow protection
-- water quality assurance
-- fish passage
-- fish genetics protection
-- harvest regulations
-- community efforts and local fund raising

Instream, Riparian, and Watershed Enhancement

Many chapters have faced instream habitat problems as the limiting factor. TU's Southeastern Massachusetts Chapter, helped by other local chapters, set to work on a significantly degraded stream on Cape Cod, the Quashnet. The river in the nineteenth century was famous for its "salter" or searun brook trout fishing.

Tom Pero, in the Autumn 1979 issue of TU's *Trout* magazine, told of the evolution of the Quashnet's case. As he recounted, from 1860 to 1890 much of the Quashnet was a millpond, backed by a small sawmill dam that contained no fishway. Runs of anadromous fish were blocked from reaching their spawning grounds, and in a few short years the runs were slowed to a trickle. Beginning in 1895, the river underwent dramatic change as it was tapped to water the surrounding area's growing cranberry industry. By World War I, cranberry bogs lined almost the entire length of the Quashnet, with the attendant ravages of silting and primitive but indiscriminate use of pesticides taking their toll.

About 1955, many of the bogs were abandoned. The state bought up some abutting land and started limited stocking first of hatchery brook trout and then, in 1965, of hatchery brown trout. But fast-growing leatherleaf and blueberry quickly took hold on the abandoned bogs. Small trees sprang up. Vegetation began to choke the stream. In places the clogged channel became unrecognizable. Flow characteristics changed.

Over the years this caused the Quashnet to become broad and shallow, its banks to deteriorate, and the bottom to change from sand and gravel to mud. An electrofishing sample by the state in 1975 told the story: what had been one of the finest salter brook trout streams in New England was an unfishable, unwadable, brush-choked remnant of its former self--producing 40 pounds per acre of white suckers and only a half-pound per acre of trout.

The state biologist assigned to the sea-run trout project of the Division of Fisheries and Wildlife saw the potential for restoring the river. In the winter of 1975-76, he successfully enjoined the local TU chapter to pitch in to try and restore this special Massachusetts wild trout river. The ongoing project that resulted, planned in co-operation with DFW, has received funding--arranged through Trout Unlimited--from a number of national and local sources. The original catalytic funding came through Trout Unlimited's Embrace-a-Stream program.

Over 12,000 TU volunteer hours of clearing brush, building overhanging bank covers, and re-vegetating with grasses and shade trees, have been rewarded. The restored portion of the Quashnet has returned to its original channel, with its gravel being cleaned and used by breeding trout. Wild trout populations have responded with marked increases in both size and number.

The future of trout in the Quashnet is bright, with the local TU members continuing their work to rehabilitate new sections of the stream.

Other TU activities to save instream habitat around the country consist of totally different activities. For example, TU's work in Maine to save the native brook trout of the St. John River from extinction as a result of the Dickey-Lincoln School Lakes project has meant extensive volunteer time in presentation of angler conservationist viewpoints. Similarly, TU's Maine Council has presented public testimony and raised funds to collect scientific data in order to protect 21 miles of landlocked salmon and brook trout waters on the West Branch of the Penobscot from inundation by a newly proposed dam.

Many TU projects concern critical riparian and watershed management for suitable wild trout habitat. For example, TU's West Slope Chapter, in an effort to protect the pristine trout waters of Montana's Rock Creek, led a legal challenge that resulted in a $1.65 million settlement. With this money, the state is acquiring public conservation easements. The terms of the settlement will help minimize watershed damage from construction of a power line through the drainage.

Other TU projects have included many hours of building livestock exclosures to protect sensitive riparian areas. These exclosures range from solar-powered electric fences built by TU's Virginia Council along spring-fed Mossy Creek, to large wooden fences built in Wisconsin.

Instream Flow Protection

Maintaining instream flows is easily recognized by anglers as the key to protecting a healthy trout stream. A true success story, which TU helped shape, is the protection of Montana's Yellowstone River. TU led a campaign in support of Montana's Department of Fish, Wildlife and Parks in its fight with coal and agricultural interests over the use of the Yellowstone. Enlisting the public relations assistance of Glenmore Distilleries, a farsighted proposal was formulated, and finally adopted, which creates a Yellowstone water reservation. The river has been saved, keeping the free-flowing trout waters of the mighty Yellowstone undammed, while at the same time providing for the long-term interests of alternate water users.

The increasing and omnipresent demands for water continue to threaten water quality and quantity across the country. To maintain the wild salmonids of Washington's Green-Dumamish River basin, TU's South King County Chapter has challenged the city of Tacoma's efforts to divert this river's already diminished instream flow. Similar protection is also being sought by TU's Montana Bitterroot Chapter on the river of the same name. And in Wyoming, TU members--along with other conservationists--are working towards a state-wide vote to declare instream flow as a beneficial use of water. To date there is no such protection; the only legally recognized "beneficial use of water" from streams is diversion. These three water projects exemplify TU activism in areas that, long term, assure the very existence of important wild trout populations, as well as instream flow for all user groups.

Water Quality Assurance

Good water quality conditions are givens for trout survival. TU's water quality projects range from TU volunteers, under the guidance of Georgia's state biologists, doing year-long water quality studies of individual trout streams -- to TU's disseminating to its chapters a Water Quality Program manual, written by skilled TU volunteers, to allow local monitoring programs, with assistance of state authorities -- to the Maryland Chapter working out a solution to a water quality problem with a local country club.

The Maryland Chapter wanted to eliminate elevated temperatures which limited trout abundance in Jones Falls. One element which exacerbated this problem was the local country club drawing water from Jones Falls during the day to water its golf course. After negotiations, the country club agreed to withdraw water at night, and temperature elevations were lessened.

Another cooperative water quality solution was reached between TU's Valley Forge Chapter and General Crushed Stone, a quarry operator adjacent to West Valley Creek. The TU chapter determined there was little natural trout reproduction downstream of where the water used to wash the stone reentered the creek. By readjusting flow rates in the settling basins, quarry management was able to both continue their business and return silt-free waters to the creek.

Fish Passage

Providing fish passage is part of many TU projects. On Corte Madera Creek in Marin County, California, TU's North Bay Chapter installed fish passages to let remnant populations of steelhead trout and reintroduced coho salmon reach upstream spawning grounds. The chapter's first effort proved so successful that the State augmented the chapter's $2,000 Embrace-a-Stream grant and the estimated $30,000 of donated labor and materials, with another $15,000 to complete the project. Now, with physical barriers removed, the chapter is concentrating on increasing flows to support steelhead and salmon in the dry months.

TU's New England membership has been particularly concerned with providing up- and downstream passage to Atlantic salmon. TU volunteers assist the U.S. Fish and Wildlife Service in stocking salmon fry. The chairman of TU's Atlantic Salmon Task Force is a Commissioner of the Connecticut River Atlantic Salmon Compact Commission. Other TU members work at the local planning committee level on keeping the mainstem and tributaries of the Connecticut River as viable salmon habitat. In addition, TU has been active in working with both the Federal Energy Regulatory Commission and dam owners and operators on passage issues in the Connecticut River watershed.

Fish Genetics Protection

Maintaining genetic diversity and uniqueness of populations is crucial to preserving wild trout. TU efforts in this field take many forms. Often conservationists and anglers have overlooked opportunities to protect native salmonids. TU has found many such opportunities. In general, the many pressures on wild stocks mean that more scientific research and directed management is needed.

Three examples in Washington State, all concerning steelhead, serve to highlight TU's approach.

TU has supported research by the Department of Game's Snow Creek Research Station. There, important studies are being undertaken on steelhead life histories and the implications for management for wild fish vs. hatchery populations. Applying Snow Creek findings, TU has been able to catalyze other native steelhead programs in Washington State and throughout the Columbia River basin.

Special management was called for on the Sol Duc River, where anglers feared the native strain of steelhead was dying out. TU's enhancement project collected spawning stock by hook and line, had the eggs hatched by the state Department of Game at a local hatchery, and reintroduced the progeny as smolts, thus assuring survival of these unique steelhead.

A dam completed in 1970 on the Wynoochee meant a radical falloff in numbers of the large (20 to 30 lb.) steelhead traditionally found in this river. With the same measures used on the Sol Duc, the Grays Harbor Chapter of TU was able to preserve this magnificent strain.

TU efforts with genetic protection across the country concern many strains of trout. In Utah, TU's Salt Lake City Chapter has successfully protected the Snake Valley strain of the Bonneville cutthroat trout (Salmo clarki utah) in the small streams of the Deep Creek Mountain area. There, road and other development for a mining venture, and resultant stream disturbance from extraction, would have seriously endangered the few remnant populations. Our persistent oversight and petitions to Federal authorities resulted in denial of a permit for this economically marginal mining venture.

In Maine, Flood Pond is the last extant habitat for the once plentiful Sunapee trout (Salvelinus alpinus oquassa). The pond is the primary water source for Bangor. As such, Flood Pond and its unusual char population are particularly vulnerable. During any drought conditions, the city of Bangor would pump alternative water supplies through Flood Pond, thus introducing competitor fish which could spell extinction for the delicate Sunapee.

Alerted to this danger, the Sunkhaze Chapter in Maine sponsored a state biologist to visit Idaho to study a transplanted, thriving pure strain Sunapee trout population. Based on his findings, the state, with TU chapter support, set up a biological reserve for the strain, putting eggs of Flood Pond Sunapee into remote Johnson Pond, where it is believed the Sunapee can prosper.

Harvest Regulations

TU has often supported special regulations to limit fish killed by anglers when a critical population of trout is at stake. On both coasts last year, TU chapters exerted their leadership and offered to forego angling in rivers where stocks were in jeopardy.

In Washington, the TU council offered to forego fishing a severely diminished steelhead run. In Massachusetts and New Hampshire, TU sought a ban on fishing for Atlantic salmon in the Merrimack River, until such time as the Fish and Wildlife Service could assure adequate seeding.

At the national level, TU has cooperated with numerous groups to protect wild fish. An example is the joint effort, along with The Nature Conservancy and others, to put in place a management plan and angling regulations for preservation of the fish of the McCloud River in California. The regulations limit the number of anglers and require that all fish be returned to the river.

As a means of harvest regulation, many chapters have espoused catch-and-release regulations. Two examples are: the Icicle Valley Chapter's (WA) wild steelhead restoration program on the Wenatchee River; and the Upper Snake River Chapter's (ID) support of a similar program on the Henry's Fork of the Snake.

In other states, TU has supported variable catch, harvest, and management studies. Frequently, TU chapters have supported no-stocking programs. An example is the TU Colorado Council, which in 1981 gave its full support to the Colorado Wildlife Commission's plan to designate 26 segments of stream to be managed for wild trout only.

Community Efforts and Local Fund Raising

TU's chapters and councils don't live or work in a vacuum. Their effectiveness is often a function of their success in hooking up with otherwise unconnected community groups. Many chapter projects have gone forward because of the goodwill, participation, and volunteer work of local community groups. TU's Catskill Mountains Chapter, in the face of concerted adverse political activism, was able to raise some $180,000 from a wide spectrum of civic and business groups. The result was saving the wild brown and rainbow trout of Esopus Creek from the ravages of the Prattsville pumped storage project.

The California Council of Trout Unlimited, in concert with local and national conservationists, was able to save 83 miles of the Tuolumne River and tributaries as one of the longest, free-flowing stretches of wild trout waters in the state. There are too many examples to list; suffice it to say that TU has found that its effectiveness can be greatly enhanced by carefully enlisting support of similarly interested local and national constituencies.

NATIONAL FOCUS: EDUCATION AND POLICY

It is important to recognize that all these local efforts--positive as they are--can go for naught without due attention to national issues which often overshadow or compromise the best of local project efforts.

As a result, Trout Unlimited actively participates in research, planning and legislative undertakings at the state and national levels.

In Washington, DC, TU supports nationwide research and planning which, many times, only indirectly supports local projects. But more often than not, our work in Washington comes home to roost by allowing TU the critical expert scientific contacts and leverage to materially impact the effectiveness of chapter activities.

And, in a very real sense, our national lobbying efforts and the work of the local chapters reinforce each other. On the one hand, at the project level, national legislative efforts benefit local projects with key political input. On the other hand, our local projects and proven success in the field provide the Washington office with a credibility and recognition that many organizations lack. This interrelationship is dynamic--TU's most effective lobbyists are its grassroots members.

On the national level, then, TU's activities combine education and communication with legislation and policy action.

Education and Communication

These efforts take many forms. For example, TU has--over the past 5 years--been very active in the national debate about, and sponsored numerous regional and national seminars, on acid rain, water use and allocation, and Atlantic salmon, as well as wild trout.

TU not only shares published information amongst its chapters and the environmental constituency at large--it also actively disseminates new research findings and field methods to the professional and university communities.

In this vein, TU has sponsored professional workshops on trout stream habitat in Asheville, NC, Jackson Hole, WY, and (upcoming) in Humboldt, CA. These workshops spur interregional and national transfer of practical fisheries management information and techniques which can have direct bearing on local TU projects.

In addition to sponsoring workshops for professionals, TU has, with Embrace-a-Stream funding, held national workshops for nonprofessionals (for example in June 1984, in Stevens Point, Wisconsin) to help them be more effective in project implementation.

TU's widely respected magazine, <u>Trout</u>, is published quarterly as a national education and communications tool. Other special publications include resource fact sheets, which are distributed to councils, on the effects of acid rain, hydropower development, and chlorinated sewage effluent on trout habitat and management.

Legislation and Policy Action

All of us, TU and anglers included, are to a larger degree than we might choose, servants of so many government bureaucracies. If we accept this as a fact, and opt to look not askance but positively upon the governmental font, then state, regional and national organizations and funding become our very best of "friends to be."

To date, by group-sharing key resources, almost all TU projects have gained much through cooperation with governmental bodies. TU has participated in state initiatives, i.e., with the U.S. Forest Service and Colorado's Division of Wildlife, on that state's fisheries issues. TU faces greater promise for accomplishing more resource work, in a more efficient way, by working through this channel than through the resources of (albeit well-connected or -intentioned) individuals.

Where wild trout issues involve different states, TU takes a regional approach. For example, for efforts to protect wild trout habitat in the tri-state area around the Delaware River, TU leaders have had to coordinate chapter and council interaction of three states with the Delaware River Basin Commission.

In New England, TU chapters and councils in the four states abutting the Connecticut River worked to set up a joint Atlantic Salmon Compact Commission to provide a concerted support for Atlantic salmon throughout its riverine habitat period.

On the West Coast, such coordinating activities by TU have involved spearheading U.S. private sector efforts to obtain a bilateral treaty between Canada and the United States on Pacific salmon interception. The point is to manage stocks so that individual stocks will be better protected.

At the national level, fisheries conservation is, sadly, all too often the stepchild of a potpourri of different political interests and diverse laws. TU's vigilance on the national level needs to cover, as a result, an eclectic range of issues.

Trout Unlimited's work includes monitoring and substantial participation in such national policy issues as: acid rain, the Clean Water Act, non-point pollution, Dingell-Johnson funding, fisheries enhancement on public lands, federal fisheries budgets, U.S. participation in the North Atlantic Salmon Conservation Organization, the U.S.-Canada Pacific salmon treaty, hydropower laws, riparian and habitat programs for unique salmonids--to name a few.

CONCLUSION - AND THE BEGINNING

We can safely predict that the immediate future will bring an increasing demand for more trout and salmon by commercial and sport users. We also can expect that relatively fewer federal and state dollars will be available for coldwater fisheries. We can also predict that wild trout habitat will face pressures for reduction or elimination from alternative users and stressful pollutants.

In the face of these pressures, Trout Unlimited's team approach is both responsive and necessary. Our focus on both local projects and state and national policy, allows representation of angler interests at all levels--from rehabilitation of local streams, to passage of effective legislation and treaties in the halls of Congress.

In the next year, TU has the opportunity to meet challenges ranging from increased funding for the Forest Service anadromous fisheries program, which has the potential to increase the production of salmonids 72 million pounds--to greater seeding of the available Atlantic salmon habitat in the Connecticut River basin.

It will not be easy to successfully meet these and other important fisheries challenges. But, TU's crystal ball shows--each year less and less dimly--a promising future, with growing, and real results from practical, cooperative efforts amongst interested anglers and other private citizens, government officials, and professional fisheries managers.

As we know, the long term future for the great coldwater fishery of this country will depend on how successful we can adapt now to the twin pressures of greater demand for these fisheries and less government monies. We must shoulder our creels and accept the proper responsibility and opportunity to protect our wild trout heritage. Later might spell never.

Implications of Economics as Applied to Wild Trout Fisheries Management in Idaho[1]

Cindy F. Sorg[2]
Dennis M. Donnelly[3]
John B. Loomis[4]
George L. Peterson[5]

Abstract.--The economics of resource allocation is explored especially as it applied to the wild trout fisheries in Idaho. Values associated with wild trout fishing are identified and explained, as well as methods to derive these values. These concepts and methods are then applied to a case study based on data collected in Idaho in 1983. A hypothetical management situation is developed to show appropriate use of the values derived.

INTRODUCTION

A total of 404,805 anglers fished in Idaho waters during 1977 (Mallet 1980). These anglers fished a total of 3,741,200 days. Seventy nine percent of them listed trout fishing as their preferred fishing activity; of these, 47% preferred trout fishing in rivers and streams, which make up only 20% of the total water surface acreage in Idaho (Idaho Department of Fish and Game 1981). Thus 20% of the fisheries habitat is supporting 50% of the angling pressure. Additionally, Mallet (1980) reports 69% of all anglers questioned expressed the opinion that more emphasis should be placed on protection and enhancement of wild trout populations; they ranked it as the second most important fish management program. Such additional emphasis would add further angler pressure on the rivers and streams of Idaho by increasing the quality, and consequently, the attractiveness of wild trout fishing.

In evaluating the economic impact of fishing as a producer of economic activity and as a source of income for Idaho, local officials and businessmen are strongly motivated to seek opportunities and ways that competitively attract and concentrate economic activity into their jurisdiction.

From a broader perspective, however, increased activity in one locale may simply be a competitive diversion of activity from some other locale with no net gain, or perhaps with net loss in aggregate wealth or welfare. Or, there may be ways to allocate and manage resources within a local area so as to increase the aggregate net inflow of wealth. Economic efficiency is concerned with evaluation of overall net benefit. Are the resources being allocated and managed to maximize the overall welfare of the "society" in question, whether that "society" be the county, state, nation, or the world? Whether the actual expenditure of funds locally is of interest to those concerned with economic impact, public fish and wildlife managers are more interested in the net economic value.

The above discussion emphasizes the significance of demand for Idaho's trout fisheries, and specifically the increasing demand for wild trout fisheries. Projected growth in the demand for coldwater and wild trout[6] fishing opportunities means that decisions about fisheries emphasis must be weighed against needs of other water users including municipalities, agriculture and logging. Since the water resources in Idaho will not be able to meet all future demands, decisions regarding which use (or mix of uses) will be met should be based at least in part on sound economic rationale.

The purpose of this paper is to explore the economics of resource allocation as it applies to water for wild trout production. This issue will be discussed in four sections: 1) values associated with wild trout, 2) methods to measure these values, 3) discussion of a case study designed to measure coldwater fishing values in Idaho, and 4) management implications of the case study.

THE ECONOMIC VALUE OF FISHING

The notion of economic value can be divided into two major concerns: local economic impact and economic efficiency. Economic impact is primarily concerned with the production of income and employment (i.e. economic activity) within a city, county, state, or region. Local government officials and business people have a strong interest in economic impact because of its close tie with votes, profits, and local standard of living. For example, information on expenditures by anglers in Idaho is useful to state officials

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[6] In this study, coldwater fishing included fishing in mountain streams, alpine lakes, lowland lakes, and reservoirs. Wild trout waters included catch and release areas and wild trout waters.

in evaluating the economic impact of fishing as a producer of economic activity and as a source of income for Idahoans. Local government officials are strongly motivated to manage resources in ways that competitively attract the maximum economic activity into their jurisdiction.

From a broader perspective, however, increased activity in one locale may simply be a competitive diversion of activity from some other locale with no net gain, or perhaps with net loss in aggregate wealth or welfare. Or, there may be ways to allocate and manage resources within the local area so as to produce an even greater inflow of wealth. Economic efficiency is concerned with evaluation of aggregate productivity. Are the resources being allocated so as to maximize the overall wealth of society? The "society" in question might be a family, city, county, state, nation, or the world. While the actual expenditure of funds locally is of interest to those concerned with economic impacts, knowledge of net willingness to pay is needed for efficiency analysis.

There seems to be much confusion about the use and abuse of information on expenditure and net willingness to pay, and the distinction between the two concepts. To avoid this confusion, the objectives of an analysis need to be clearly understood. Do we want to measure cash flow and economic activity, or do we want to make sure resources are being put to their most productive uses? The principal focus of this paper is efficiency, and hence, net willingness to pay.

Fishing trips have value to anglers, as evidenced by the fact that they spend substantial amounts of money. However, the money spent is not necessarily an indication of the total value of a fishing experience to an angler. Assume that the costs faced by a given angler could somehow be raised exactly to the point that the trip is not made. In this case, the costs have exceeded the total value of the trip to the angler, and there is no longer any incentive to make the trip. The costs exceed the benefits. If, however, the costs are less than total value, there is a residual benefit or net willingness to pay equal to the difference. It is this residual that is relevant to efficiency analysis. Clearly, it is a grave error to try to use expenditures to measure net benefit. Just as in any business, costs reduce profits, and you can't stay in business long by maximizing costs.

A simple example may help. If I am offered a car at a price of $3,000 and I would be willing to pay $5,000, my net willingness to pay is $2,000. Reducing my expenditure increases my profit and increasing my expenditure reduces it. An important source of confusion is that anglers do not turn around and sell the fishing trips they purchase through their expenditures. They consume them. Thus, it is their own willingness to pay that determines the amount of the profit, not the willingness to pay of someone else. We have no trouble accepting the existence of a real profit of $2,000 when John is willing to pay Cindy $5,000 for a car she can get from George for $3,000. When Cindy sells the car to John, she has $2,000 profit in hand. However, if John buys the car directly from George for $3,000 the $2,000 profit is in the form of "consumer's surplus." It is this kind of surplus which comprises the net benefit of fishing.

A timber harvesting example may help demonstrate that expenditures are not correct for valuation of wildlife recreation. The example proceeds at two levels. First, remember that costs are benefits foregone. The more it costs society to harvest a certain number of trees, the less the net gain to society. That is, the more we give up to get something, the less benefit there is to having it. In this respect, not only is it inappropriate to compare expenditures, it often works to the detriment of fishing which may have a relatively low cost. A grossly inefficient deficit timber sale that requires several miles of expensive road building will result in thousands of dollars of expenditures in the local community and dozens of jobs. However, if the value of the trees is less than the expenditures there has been a net loss to society. One must look beyond the stumpage values and consider the other values which are generated as a result of the sale. These may include increased water yield, wildlife forage, and access to recreations areas. Expenditures in excess of economic benefits means the cost of what was given up exceeded the benefits of what was received.

Figure 1 illustrates the inappropriateness of expenditures for valuing fisheries. Suppose an agency has the choice of restoring one of two streams for wild trout fishing.

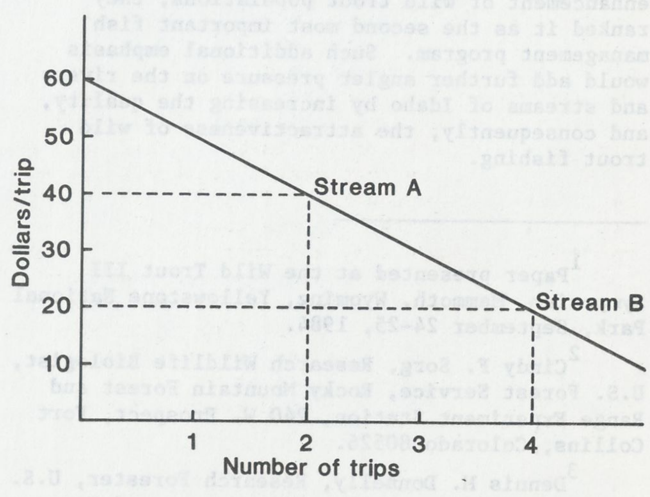

Figure 1. Demand for wild trout fishing used to compare economic benefits derived from stream restoration

Stream A is located at a distance which requires $40 of expenditures to visit the site. At this cost per trip only two trips are taken. The total angler expenditure associated with Stream A is thus $80 ($40 x 2). Alternatively, Stream B could be improved to support wild trout. Stream B is close enough that the expenditures associated with visiting it are only $20 per trip.

With our hypothetical demand, fishermen would take four trips to Stream B. At a cost of $20 per trip, this too results an expenditure of $80 ($20 x 4). The angler's expenditures will be the same whether one selects Stream A or Stream B for improvement. Does the equality of fishermen's expenditures mean there is equality of economic benefits? Clearly not! Anglers would prefer four trips to two trips for the same total cost of $80. Therefore, it would be more beneficial to improve Stream B.

What sort of measure or criteria would lead a decisionmaker to choose B over A? Expenditures would say provide either A or B. The efficiency, measure though, compares anglers' net willingness to pay (the area under the demand curve but above the travel cost) and leads to choosing Stream B over A. This result comes about because the consumer surplus associated with Stream B ($20 + $40 + $20) is larger than for Stream A ($20). Therefore, use of expenditures as a measure of benefits can lead to improvement of stream sites as far away from users as possible. With a higher cost to reach these distant stream sites, however, few trips will be taken. Thus measuring "benefits" by means of expenditure information can lead to serious inefficiency and waste. The USDA Forest Service's Resources Planning Act (RPA) values and U.S. Water Resources Council's unit day values for fishing are intended to reflect net willingness to pay, rather than expenditures.

There is an exception, however, where expenditure information is important to efficiency analysis. Assume wild trout fishing has a total value of $90 per trip, while the total value of warmwater fishing is $66 per trip. Assume also that because the wild trout sites are very remote, the per-trip expenditure is $80, giving a net willingness to pay of only $10. If the warm-water fishing sites are easily accessible and require a per-trip cost of only $30, the net willingness to pay is $36. This can be construed to imply that scarce resources should be invested in improvement of warmwater fishing sites. Let us further assume there is also a coldwater stream nearby suitable for a wild trout fishery. If it were managed as such, the per trip expenditure would be only $30, and because the total value of wild trout fishing is $90, the resulting net willingness to pay would be $60. In this case the more efficient investment is in the coldwater stream for wild trout water (ignoring development costs).

METHODS TO MEASURE CONSUMER SURPLUS

With the premise that consumer surplus is the appropriate measure for efficiency-related resource allocation decisions, let's consider two methods used to measure consumer surplus or net willingness to pay. A brief explanation of each follows.

The Travel Cost Method is based on the idea that travel cost can be used as a proxy for price in derivation of a recreation site demand curve. Broadly, the method involves dividing the area around the recreation site into zones of origin of recreationists. It is assumed that the costs from a particular zone to the recreation site are the same for all individuals in that zone. Statistical methods can be utilized to develop an equation for visitation rates based on travel cost and socio-economic data. From this analysis, we can plot the total number of observed visits for a given price (license fee) as one point on the demand curve. Additional points on the demand curve are obtained by successively adding alternative hypothetical fees to travel costs from each origin, then estimating visits from each origin at each fee using the per capita functional form. For a complete discussion, refer to Rosenthal et al. (1984), Dwyer et al. (1977) or Clawson and Knetsch (1966).

Contingent Value Methods are most commonly referred to as bidding games. Unlike the familiar market situation where people alter consumption in response to price changes, bidding-game scenarios revolve around individuals responding to hypothetical discrete changes in a nonmarket good. More often than not, the individual is responding to a quality rather than a quantity change. The term, contingent value, stems from asking individuals how their behavior would change contingent on a new hypothetical situation. Data are collected by directly asking individuals to provide estimates of their own consumer surplus or willingness to pay. Refer to Peterson and Randall (1984), Brookshire et al. (1980) or Schulze et al. (1981) for a complete discussion.

With this brief overview of values associated with wild trout and methods to measure consumer surplus, let's now apply these concepts and methods to a case study that measures net willingness to pay for coldwater and wild trout fishing in Idaho.

THE IDAHO CASE STUDY

The sample for this study was 1,952 anglers, both resident and non-resident, having an Idaho fishing license. The anglers were first mailed a letter of introduction from the University of Idaho's College of Forestry, Wildlife and Range Sciences. Included with the letter was a map identifying the fishing management units in Idaho. The map was included to assist the respondents in determining the sites they visited during 1982. The letter indicated that someone from the university would be calling to collect fishing information requested in the letter. Additional questions were asked during the telephone interview. The survey, performed during February and March 1983 achieved 99% response rate. Contingent Value Method questions were asked with regard to the last trip since it was felt respondents would have the best recall for that trip. Respondents were not asked specifically to identify whether or not they were fishing for wild trout. However, based on the 1982 fishing regulations, areas that are primarily wild trout or catch and release were identified and analyzed separately from general coldwater fishing. (These areas included portions of the St. Joe River, Kelley Creek, Lochsa River, Selway River, and the Middle Fork of the Salmon.)

Both Travel Cost and Contingent Value questions were asked; however, for the purpose of this paper, the focus will be on Contingent Value. Using an iterative bidding procedure, willingness to pay for current conditions was determined for the last trip, regardless of whether fishing was the primary or non-primary purpose. In addition, anglers were questioned about willingness to pay if they had caught twice as many fish, and if the fish they caught had been 50% larger.

Table 1 presents the results for wild trout areas and all other coldwater fishing. Both are presented to allow comparisons. Before asking willingness to pay questions, anglers were asked if their last trip was worth more than they paid. Eighty-four percent of wild trout fishermen indicated yes, while 79% of all other coldwater fishermen indicated yes. Net willingness to pay per trip for current conditions is $35.49 and $27.95 for wild trout and all other coldwater fishing, respectively (table 1).[8] Not only are wild trout fisherman willing to pay more per trip and per day, but they are also currently spending more as evidenced by trip expenditures of $54.08 versus $42.62 by coldwater fisherman. In total, a wild trout fishing trip is worth approximately $90.00 while a coldwater fishing trip is worth approximately $70.00.

Table 1: Contingent Value Method Values for Wild Trout Fishing and all other Coldwater Fishing (sample size)

	Wild trout	All other coldwater fishing
Yes, trip was worth more	84% (79)	79% (1154)
Net willingness to pay per trip	$35.49[1] (66)	$27.95[2] (911)
Net willingness to pay per trip for double number of fish caught	$5.65 (66)	$9.62 (908)
Net willingness to pay per trip for 50% increase in fish size	$10.17 (66)	$15.32 (907)
Expenditures per trip	$54.08 (79)	$42.62 (1159)
Number of fish caught per trip	7.40 (68)	5.35 (930)
Number of days fished	1.95 (79)	1.62 (1157)
Net willingness to pay per day for current conditions	$18.20	$17.25

[1] 95% Confidence Interval: $18.44 to $52.53

[2] 95% Confidence Interval: $24.16 to $31.75

Comparing wild trout to coldwater fishing for twice the number of fish caught and 50% increase in fish size shows some interesting results. In general, coldwater anglers are willing to pay more than wild trout anglers for more and bigger fish (Table 1). This is not surprising, since wild trout waters already provide higher catch rates and larger fish (Mallet, 1978). Our data indicate wild trout anglers are more satisfied with current conditions and therefore view an improvement in the resource as important, but less important than viewed by other coldwater anglers. Average number of fish caught per day is 5.35 for other coldwater fishing and 7.40 for wild trout, indicating a wild trout fishery has a higher quality as measured by catch rate. In addition, both wild trout anglers and other coldwater anglers indicate a greater preference for larger fish as compared to catching twice as many fish. Unfortunately, this survey did not collect information on the importance to anglers of keeping the fish caught or the type of bait used.

MANAGEMENT IMPLICATIONS

Now that we have expenditure and consumer surplus (willingness to pay) data for wild trout and other coldwater anglers, how can it be used in management decisions?

The information on angler expenditures is useful for evaluating the impact on communities dependent upon tourism, but it is not a measure of economic value. Much like the harvesting and transportation expenditures of logging contractors, angler expenditures can be used in Input-Output models to calculate the multiplier effects of expenditures on local income and employment.

To evaluate multiple-use trade-offs between natural resource products such as timber, cattle grazing, and fisheries, the net economic value (i.e., net willingness to pay) should be used. As a simple example, suppose the fisheries biologist estimates that fish populations could double in a river segment if cattle watering were controlled along a one mile stretch of the riparian zone. This doubling in fish populations

[7] For a more complete discussion of all results refer to Sorg, Cindy F., John B. Loomis, Dennis M. Donnelly, and George L. Peterson. 1984. The net economic value of cold and warm water fishing in Idaho. Draft report to the Idaho Department of Fish and Game. 62 p.

[8] Some anglers surveyed refused to place a dollar value on willingness to pay for the fishing resource. It was assumed nonrespondents were of the same population as respondents.

would be achieved through a wild trout or hatchery stocking program. Further suppose there is a demand for improved fishing in this segment of river. The biologist, recreation planner, and economist could then translate this doubling in wild or hatchery fish population into an increase in fish available for catch. The economic benefit of meeting the demand for added fishing trips that would result from increased fish available for harvest can be approximated by multiplying the increase in trips times the average net value per trip. In our data, this net willingness to pay per trip would be $35.00 for wild trout fishing or $28.00 per trip for hatchery reared trout fishing. Suppose, through this stream improvement, there is a demand for 200 additional fishing trips per year. This would yield long run annual benefits of $7,000 or $5,600 for either wild trout fishing or hatchery reared trout fishing from controlling cattle watering along a one-mile segment of a stream riparian zone.

Benefits of increased fish populations do not necessarily flow only from more angler-days. In the short run, an increase in harvestable fish may be captured only by current anglers. For example, it may take a couple of years before anglers believe this is a permanent change, and for word- of-mouth to spread that this area has improved fishing. As a result, the benefits of higher catch are obtained initially by current anglers only. In this study we found the value per trip would rise by approximately $6.00 for wild trout or $10.00 for other coldwater fishing if the number of fish caught doubled. If the size of the fish caught increased by 50%, the value per trip rose by about $10 and $15 for wild trout and other coldwater fishing, respectively. These values are then multiplied by the increase in days fished by current anglers to arrive at annual short- run benefits. Whether to use the wild trout values or other coldwater fishing values depends on which management option is chosen.

With the above information, the fisheries biologist can compare the benefits of the wild trout and the hatchery fisheries management plan to the costs of restricting cattle watering. These costs may take the form of enforcement costs, alternative water developments for cattle, fencing the one- mile stretch of riparian zone, or the net economic value of the water no longer available to cattle. Fisheries management costs would have to include costs associated with stream bank improvement for wild trout, or hatchery costs for coldwater stocking.

SUMMARY

The purpose of this paper was to explore the economics of resource allocation, especially as it applies to water for wild trout production. Using the demand for a wild trout fisheries as the focus, values associated with fishing were identified and explained. Expenditure information is used by local merchants, while net willingness to pay (consumer surplus) is appropriate to evaluate resource trade-offs. Results of a 1983 study indicate wild trout anglers are willing to pay $35.49 more per trip than current expenditures for the existing wild trout fishing resource. Other coldwater anglers are willing to pay $27.95 more per trip. The results of this study were then applied to a hypothetical example which looked at trade-offs between cattle watering in a riparian zone, wild trout management and hatchery released fishing.

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Habitat Management for Native Southwestern Trout[1]

Jerome A. Stefferud[2]

The Rio Grande cutthroat trout (Salmo clarki virginalis), the Gila trout (S. gilae), and the Apache trout (S. apache) are native to streams of the southwestern United States. Historically, the Rio Grande cutthroat was found in the Rio Grande, and the Pecos and Canadian River drainages in northern New Mexico, and southern Colorado. The Gila trout occurred in the upper Gila River basin in southwest New Mexico, and the Apache trout was located in streams in the White Mountains of east central Arizona. Today these trout can still be found in these areas, but in much reduced numbers and distribution.

Popular written accounts from the turn of the century indicated that these species were all widespread and plentiful in their habitats, and angling for them was a popular sport. Easily caught by hook and line, catches of 100 or more in only a few hours of angling were common. But introduction of brook trout, brown trout and especially rainbow trout into the streams of Arizona and New Mexico resulted in the disappearance of the native trouts from much of their waters. While brown trout and brook trout compete with the native trout for food and space and prey on their young, the greatest reason for the decline of the native trout populations is the hybridization of the native stocks with the introduced rainbow trout. Interbreeding through successive generations results in the loss of the genetic integrity of the native species and their eventual extinction as unique forms.

Other of Man's activities have also caused native stocks of trout to decline. Alteration and overuse of the water resources in southwestern aquatic ecosystems has reduced the capability of the habitat to support trout. Water quality problems resulting from road building, logging, livestock grazing, and mining have eliminated native trout populations in some streams.

Currently, the Gila trout occurs in only eight headwater streams in the Gila National Forest, and is listed by the U. S. Fish and Wildlife Service as Endangered.

The Apache trout is located in about two dozen streams on the Fort Apache Indian Reservation and the Apache-Sitgreaves National Forests and is listed as Threatened. The Rio Grande cutthroat has fared somewhat better than the other two species, probably because of its more extensive range, and can be found in more than thirty streams on the Carson and Santa Fe National Forests and some private lands. It is not currently listed.

During the past decade, considerable progress has been made towards reversing the downward trend of the populations of these native trout. The U.S. Forest Service, the U.S. Fish and Wildlife Service, the Arizona and New Mexico Game and Fish Departments, and the White Mountain Apache Tribe have cooperated in developing recovery goals, defining research needs, and prescribing management activities for these species.

Recovery goals have been stated in terms of numbers of genetically pure populations and/or miles of stream isolated from other non-native trout by fish barriers. Other goals have provided for the assessment of the native trout as sport species, for hatchery rearing, and for dissemination of public information regarding these species.

Research has been directed at determining genetic makeup and relationships of these trout, at investigating their life histories and use of the habitat, and at monitoring the effects of chemical treatment on the stream ecosystem during restoration activities. Current studies are assessing the value of Gila trout as a sport species. There are some indications that native trout may be able to provide a better, more dependable, fishery under harsh environmental conditions than do non-native trout. In the southwest, water is often in short supply, and many streams regularly recede to isolated pools. But the Rio Grande cutthroat, Gila and Apache trouts have apparently adapted to this fact of life and can do quite well in these marginal habitats.

Restoration efforts have concentrated on protecting existing native populations and reclaiming new stream habitats through construction of fish barriers, removal of non-native trout and subsquent stocking of the native species. Additional restoration efforts are being planned for other streams. Instream habitat improvement devices and fencing to protect stream and riparian ecosystems are being accomplished on streams that can benefit from habitat enhancement. In addition, policies that will protect native trout fisheries from detrimental effects of other land use activities have been drafted and are in effect.

The future looks promising for the Rio Grande cutthroat, Gila, Apache trouts. Passage of the Endangered Species Act 1973 was a result of the American public's refusal to willingly accept species' extinction. And the ever increasing demands for "wild trout" waters and increased diversity of fishing opportunities provide added inducement to management agencies to restore these native species to viable populations that can provide unique receational fisheries. The native trout of the southwest can fulfill this role.

[1]Poster display presented at Wild Trout III Symposium Yellowstone National Park, Wyoming, September 24 – 25, 1984.

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