Yellowstone Fisheries & Aquatic Sciences

Annual Report

2003

Thorofare Creek, October 2003.

Yellowstone National Park's Yellowstone Lake is home to the premier surviving inland cutthroat trout fishery in North America. Two significant threats to the native Yellowstone cutthroat trout, discovered over a five-year period during the 1990s, irreversibly altered the future of this thriving and diverse ecosystem. Without swift, continuing action, negative effects on this trout population—a keystone energy source for numerous mammal and bird species and a recreational focus for visitors—have the potential to produce ecosystemwide consequences.

Predatory, non-native lake trout were likely illegally introduced to the lake in 1988 and not discovered until 1994. They can consume 50–90 Yellowstone cutthroat trout per capita annually. Without heightened and maintained management efforts, they have the potential to decimate the Yellowstone Lake fishery in our lifetime. Lake trout also occupy an ecological niche unavailable to cutthroat-eating predators, imperiling the many species, such as grizzly bears, bald eagles, and river otters, that depend on the cutthroat for survival.

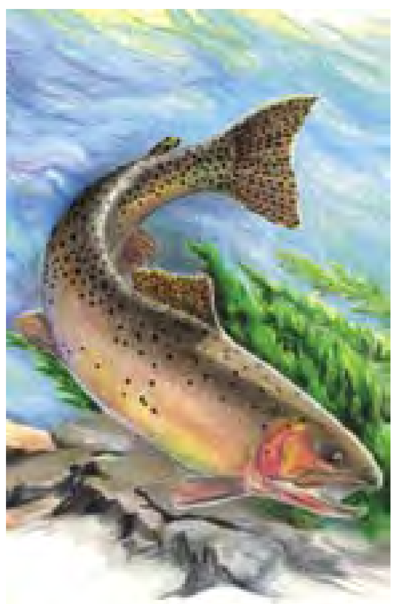
Whirling disease, a parasite that attacks the developing cartilage of young fish resulting in skeletal deformity, whirling behavior, abnormal feeding, and increased vulnerability to predation, was first detected in Yellowstone Lake in 1998, and in the Firehole River in 2000. This devastating disease further threatens already declining Yellowstone cutthroat trout populations. Although whirling disease is currently believed to be concentrated in the northern regions of the Yellowstone Lake watershed, several other tributaries have already been identified as at high risk.

In addition to native trout preservation, aquatics program goals include restoration of isolated but genetically pure westslope cutthroat trout, monitoring to track aquatic ecosystem health and expedite early warnings for other invasive exotic species, and encouragement of public involvement in various fisheries programs.

The stakes are high, raising the bar for innovative management and fundraising. The increased magnitude of the problems faced by the park's fisheries and the accelerated rate at which they are occurring are straining Yellowstone's resources. This annual report describes historic and continuing park aquatics programs as well as specific initiatives during 2003. It is a scientific call for action—action urgently needed to assure cutthroat trout survival and overall fishery health in Yellowstone National Park.

Yellowstone Fisheries & Aquatic Sciences

Annual Report 2003



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Yellowstone cutthroat trout

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Yellowstone Center for Resources
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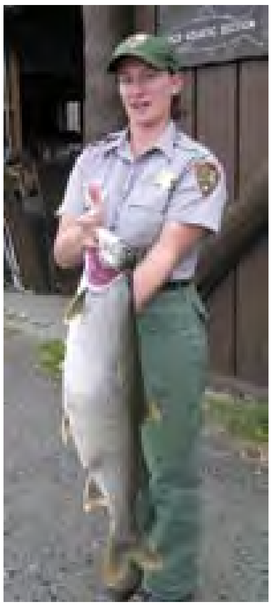
Front cover photo captions (left to right): NPS Aquatic Ecologist Jeffrey Arnold collecting aquatic macroinvertebrates; Arctic grayling from Grebe Lake, upper Gibbon River system (photo by Timothy Bywater); NPS volunteer Phillip Hurst radio tracking cutthroat trout on the upper Yellowstone River. Back cover photo captions (left to right): NPS stream fisheries crew conducting a survey of Slough Creek; native dragonfly flame skimmer along the Firehole River (photo by Jeffrey Arnold); non-native lake trout removed by gillnetting on Yellowstone Lake (photo by Patricia Bigelow). Facing page photo caption: NPS Fisheries Technician Barbara Rowdon with a lake trout removed from Breeze Channel, Yellowstone Lake (photo by Patricia Bigelow).

All photos in this report not otherwise marked are by Todd Koel.

Contents



Background 2
Map of Major Surface Waters of Yellowstone National Park 4
Summary 4
Yellowstone Cutthroat Trout Preservation 6
Maintaining long-term monitoring programs 7
Removal of non-native lake trout from Yellowstone Lake 8
Understanding the effects of whirling disease 10
Hydroacoustic surveys to document population change 11
Status of cutthroat trout in the upper Yellowstone River 11
Westslope Cutthroat Trout Restoration 12
Population surveys 12
Genetics surveys 12
Restoration potential 13
Stream Fishery Surveys and Fish Health 14
Population surveys 14
Monitoring associated with road reconstruction 14
Surveys for fish health 16
Genetics surveys 16
Aquatic Ecosystem Health 17
Invasive aquatic exotic species threaten the park 17
Long-term water quality monitoring 17
Limnology of Yellowstone Lake 19
Water quality associated with winter use 19
Macroinvertebrate monitoring 20
Impacts of the New Zealand Mudsnail in Waters of Yellowstone National Park 22
Angling in the Park 24
Trends from the volunteer angler report cards 24
Public Involvement 26
Yellowstone volunteer flyfishing program 26
Long-term volunteer assistance 26
Educational programs 26
Collaborative Research 27
Projects by graduate students 27
Other research and collaboration 27
Acknowledgments 28
Literature Cited 29
Appendices 30
i. Fish species list 30
ii. Long-term volunteers 30
iii. Seasonal staff 30

Background

Created in 1872, Yellowstone National Park was for several years the only wildland under active federal management. Early visitors fished and hunted for subsistence, as there were almost no visitor services. At the time, park fishes were viewed as resources to be used—by sport anglers and to provide park visitors with fresh meals. Fish-eating wildlife, such as bears, ospreys, otters, and pelicans, were regarded as nuisances, and many were destroyed as a result.[1]

To supplement fishing and counteract this "destructive" consumption by wildlife, a fish "planting" program was established in Yellowstone. Early park superintendents noted the vast fishless waters of the park, and immediately asked the U.S. Fish Commission to "see that all waters are stocked so that the pleasure seeker can enjoy fine fishing within a few rods of any hotel or camp."[2] The first fishes from outside the park were planted in 1889–1890, and included brook trout in the upper Firehole River; rainbow trout in the upper Gibbon River; and brown trout and lake trout in Lewis and Shoshone lakes.[3] During the park's early history, stocked fisheries were extremely important. The harvest-oriented fish management program accounted for the planting of over 310 million fish in Yellowstone between 1881 and 1955. In addition, from 1889 to 1956, some 818 million eggs were stripped from Yellowstone trout and shipped throughout the United States.[4]

Largely due to these activities in Yellowstone National Park and the popularity of its fisheries,

NPS PHOTO

U.S. Fish and Wildlife Service personnel removing fish from a Yellowstone Lake gillnet in 1981.

recreational angling became a long-term, accepted use of national parks throughout the country. In Yellowstone, fisheries management, as we understand the term today, began with the U.S. Army and was assumed by the National Park Service in 1916. Fish stocking, data gathering, and other monitoring activities began with the U.S. Fish Commission in 1889, were continued by the U.S. Fish and Wildlife Service until 1996, and have been the responsibility of the National Park Service since 1996.

Because 40% of Yellowstone's waters were once fishless, the stocking of non-native fishes has had profound ecological consequences.[5] The more serious of these include displacement of intolerant natives such as westslope cutthroat trout and grayling, hybridization of Yellowstone and westslope cutthroat trout with each other and with non-native rainbow trout, and, most recently, predation of Yellowstone cutthroat trout by non-native lake trout. Over the years, National Park Service management policies have drastically changed to reflect new ecological insights, as highlighted in the Leopold Report of 1963.[6] Subsistence use and harvest orientation once guided fisheries management. Now, maintenance of natural biotic associations or, where possible, restoration to pre-European conditions have emerged as primary goals.

A perceived conflict exists in the National Park Service mandate that states the people will "use and enjoy," and also "protect and preserve" our pristine, natural systems.[7] To date, we know of 18 fish species or subspecies in Yellowstone National Park; 13 of these are considered native (they were known to exist in

NPS PHOTO

Planting of hatchery fish in a Yellowstone National Park stream in 1922.

park waters prior to Euro-American settlement) and five were introduced (non-native or exotic; see Appendix i).[8] Fisheries management efforts in Yellowstone are currently focused on preserving native species, while allowing for use of fisheries by visiting anglers through catch-and-release regulations. As our primary mission is the preservation of natural ecosystems and ecosystem processes, we will not emphasize maintenance of established non-native fish stocks. Along with native fish preservation, our Fisheries and Aquatic Sciences Section (Aquatics Section) activities include native fish restoration, stream and lake inventory and monitoring, and an emphasis on aquatic ecosystem health including water quality and macroinvertebrate monitoring of lakes and streams to serve as an early warning for advancing invasive exotic species.

TOPOGRAPHY TAKEN FROM MAP PUBLISHED IN 1886 BY THE U.S. GEOLOGICAL SURVEY

Fisheries authority David Starr Jordan produced this map of Yellowstone waters in 1889, showing the large portion of the western side of the park as an AREA WITHOUT TROUT, *in anticipation of the extensive stocking program that followed. (From Baron W. Evermann, Report on the Establishment of Fish Cultural Stations in the Rocky Mountain Region and Gulf States, U.S. Government Printing Office, 1892).*

2003 Summary

The 2003 field season came to a close in early November, marking the end of the first decade of fieldwork since lake trout were discovered in Yellowstone Lake (Figure 1). This was a record year, as more than 18,000 of the non-native predators were killed to preserve our remaining native Yellowstone cutthroat trout of this system. Because each of the non-native lake trout would have consumed many cutthroat trout each year, the gillnetting effort has saved a tremendous number of cutthroat trout; 75,000 lake trout have been killed by gillnetting since they were first discovered in 1994. The angling community has also joined forces and has been contributing to a significant removal of lake trout from Yellowstone Lake each year. The result is a lake trout population that is suppressed and showing some signs of it. Catch per unit of effort for lake trout remains very low, and the average length of spawning adult lake trout continues to decline each year.

The number of Yellowstone cutthroat trout migrating upstream at Clear Creek, a major Yellowstone Lake spawning tributary, was only 3,432; the fewest to migrate upstream since 1959, just after loss of these fish due to overharvest of eggs by hatchery operations in the park. Similar results have been documented at many other, smaller spawning tributaries. Within Yellowstone Lake, cutthroat trout abundance, as indicated by the fall gillnetting program, suggested an increase in fish densities. The average number of cutthroat trout caught per net increased slightly from 6.1 to 7.4—the first encouraging signal in many years of sampling by this program.

Intensive research on whirling disease continues, with efforts focused on the Yellowstone River near Fishing Bridge, Pelican Creek (where the disease is most severe), and Clear Creek. Monitoring for spread of this exotic parasite also continues on streams with

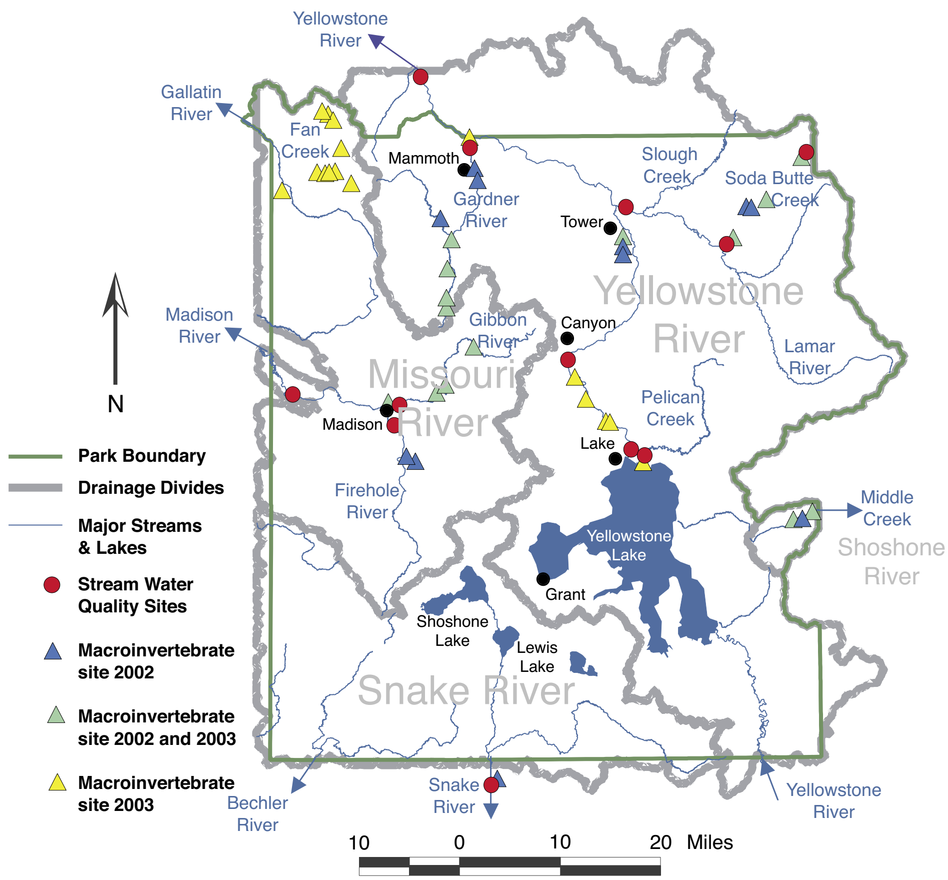


Figure 1. Major surface waters of Yellowstone National Park with 12 stream sites established for long-term monitoring of water quality and all sites sampled for macroinvertebrates 2002–2003. Labels for Fan Creek and Soda Butte Creek indicate locations, but streams are not shown.

similar drainage morphology to Pelican Creek, such as Beaverdam, Trail, Chipmunk, and Grouse creeks, and the upper Yellowstone River. Intensive searches for upstream-migrating adults and wild-reared fry over the past two years indicate that the Yellowstone cutthroat trout spawning population of Pelican Creek has been completely lost. Once numbering in the tens of thousands of fish, this loss has certainly contributed to the overall decline of cutthroat trout of the Yellowstone Lake ecosystem.

New research focusing on the status and life history strategies of cutthroat trout in the Yellowstone River and its tributaries upstream of Yellowstone Lake was initiated in 2003. This was the first survey of fishes in this region of the park, even though fisheries investigations have been occurring in Yellowstone since the late 1800s. The waters of this region likely support significant numbers of spawning cutthroat trout from Yellowstone Lake. Results will help managers understand the status and dynamics of cutthroat trout in this remote wilderness, and the contribution of this system to the overall cutthroat trout population of Yellowstone Lake.

Results in 2003 suggested that westslope cutthroat trout of North Fork Fan Creek are now hybridized with non-native rainbow trout. Intensive field investigations were completed to acquire additional samples for genetic testing. Work was also completed on amphibian occurrence, macroinvertebrate communities, habitat characteristics, and geology at the location of a potential barrier to additional invasion by harmful non-native fish species.

Native Yellowstone cutthroat trout population abundance and structure at Slough Creek remains excellent following several years of intense pressure on this stream by visiting anglers. Recent 2001–2003 survey data, when compared to information collected in 1987–1989, suggests that there has been no real change in densities or sizes of fish over this period. Of major significance was the documentation of non-native and potentially hybridizing rainbow trout in the first and second meadows of Slough Creek this year. It is unknown how these fishes moved above the barrier of Slough Creek near the campground, although rainbow trout are abundant in lower Slough Creek and in the Buffalo Fork.

The ecological health of aquatic systems in Yellowstone National Park continues to be monitored intensively. The quality of the park's surface waters are monitored biweekly at 12 fixed sites located near the confluences of major streams and rivers (Figure 1). The physical and chemical characteristics of Yellowstone Lake are monitored seasonally to assist the targeting of non-native lake trout. Macroinvertebrates continue to be sampled using regionally standardized methods to allow for easy comparison of data among agencies. Results are being used to assist with the development of Vital Signs Monitoring protocols for the Greater Yellowstone Network. A study was also completed which provided some of the first information on the effects of snowmobile emissions on the quality of snowmelt runoff in the park.

Over 54,000 special use fishing permits were issued in 2003. Anglers fished 2.75 hours per day during typical fishing trips in the park. Single-day anglers reported catching at least one fish 78% of the time, and on average landed almost one (0.89) fish per each hour of fishing. Native cutthroat trout remained the most sought-after and caught fish species, making up 59% of the total catch, followed distantly by rainbow trout 15%, brown trout 9%, brook trout 8%, whitefish and lake trout each 4%, and grayling 1%. Yellowstone Lake remains the most popular destination for anglers that come to the park.

Public involvement with the Aquatics Section continues to greatly increase, primarily through the incorporation of many volunteers. In 2003 alone, 98 volunteers dedicated 4,041 hours of their time to our projects. A highlight of the year was the continuation of the Yellowstone Volunteer Flyfishing Program, in which volunteer anglers from across the United States participated in several specific fisheries projects throughout the park. Information acquired by volunteers is being used to assess the status of fisheries in many waters of Yellowstone.

Brian Ertel, NPS fisheries technician, listening for a radio-tagged cutthroat trout in the upper Yellowstone River.

Yellowstone Cutthroat Trout Preservation

Yellowstone Lake and its tributaries represent the majority of undisturbed natural habitat and the home to the last stronghold of remaining genetically pure Yellowstone cutthroat trout (*Onchorhynchus clarki bouvieri*).[9] Now faced with pressure by non-native and exotic invaders and effects of three continuous drought years, the Yellowstone Center for Resources and Aquatics Section consider the preservation of this subspecies a top management and research priority. Ecosystem-level degradation is a possibility if the cutthroat trout population of Yellowstone Lake is allowed to decline.[10]

Data collected in 2003 provided some of the first evidence in several years that the Yellowstone cutthroat trout population may be responding positively to efforts to remove non-native lake trout.

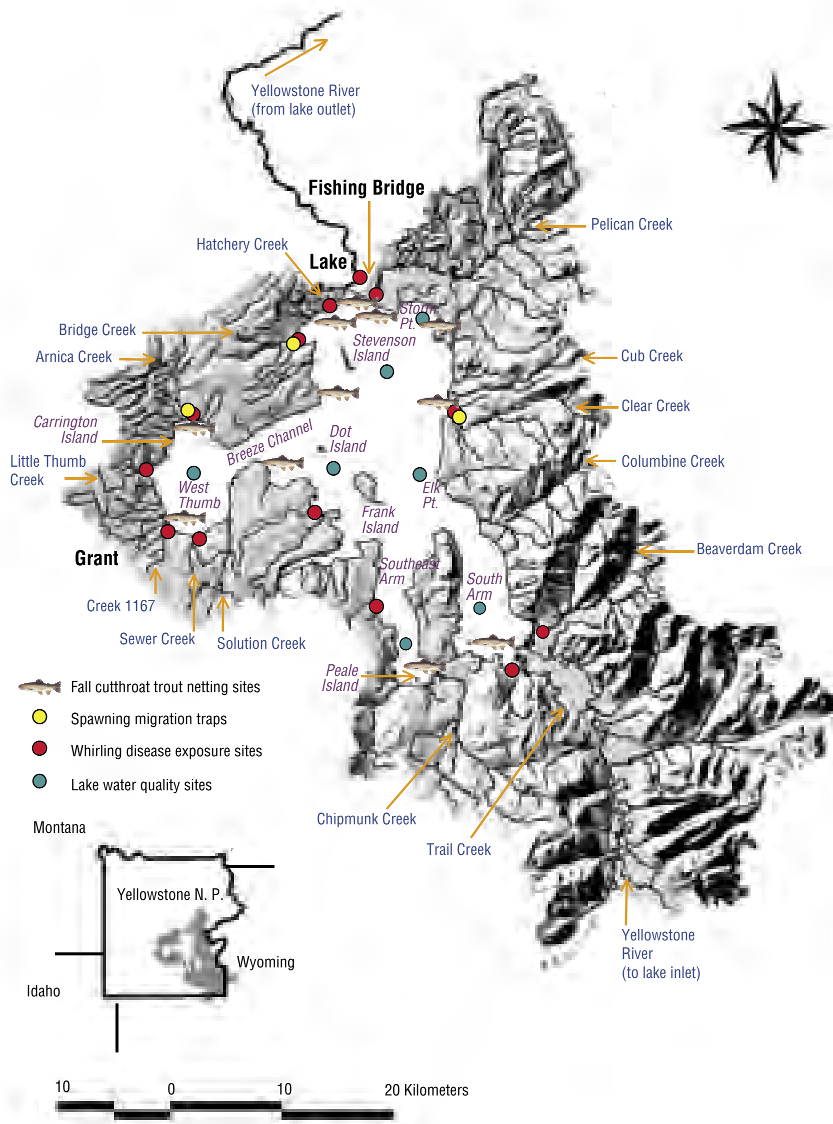


Figure 2. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

Maintaining Long-term Monitoring Programs

Annual assessment of the Yellowstone cutthroat trout population of Yellowstone Lake has been conducted by counts of upstream-migrating spawners at Clear Creek, Bridge Creek, and Arnica Creek; by dipnetting adult spawners at LeHardys Rapids; and by a netting program on the lake conducted during September each year.

Using multi-mesh-size gillnets set in shallow water at 11 sites throughout Yellowstone Lake, the Aquatics Section has been able to collect valuable cutthroat trout population information over time (Figure 2). Data collected in 2003 provided some of the first evidence in several years that the Yellowstone cutthroat trout population may be responding positively to efforts to remove non-native lake trout (*Salvelinus namaycush*) from Yellowstone Lake. An average of 7.4 fish were collected per net in 2003, up from 6.1 fish per net in 2002 (which was the lowest point recorded since the lake netting program began in 1969; Figure 3).[11] Prior to 2003, the reduction in catch had been 0–21% each year (averaging 11% per year) since 1994, the year lake trout were first discovered in Yellowstone Lake.[12]

Examination of length-frequency data from the fall netting survey has indicated an annual, continuous loss of adult cutthroat trout numbers in Yellowstone Lake (Figure 4). Entire age classes are virtually missing from the lake population. In 2003, few fish between the lengths of 300 and 430 mm were caught. Historically, most cutthroat trout noted in spawning tributaries such as Clear Creek and at LeHardys Rapids of the Yellowstone River have fallen in this size range.[13] Despite this, we see an apparent increase in juvenile cutthroat trout in recent years (2001–2003) as encouraging, and an additional signal that the lake trout removal program's effects may be significant, making a major contribution to the preservation of Yellowstone cutthroat trout. The South Arms of Yellowstone Lake may continue to act as refuges for cutthroat trout due to the low numbers of lake trout found there.[14]

The recent Yellowstone cutthroat trout population decline also remains evident in total numbers of upstream-migrating cutthroat trout at Clear Creek, a major spawning tributary on the lake's eastern side (Figure 3). A total of only 3,432 upstream and 1,576 (46%) downstream migrating cutthroat trout were counted at Clear Creek during May–July 2003. The upstream count was down from 6,613 in 2002, and was the lowest count since 1959, when only 3,353 cutthroat trout migrated upstream at Clear Creek (a year that closely followed the discontinuation of egg-taking operations on Yellowstone Lake). A fish counting station was also operated on Bridge Creek, a small northwestern tributary, where a total of 86 fish were counted migrating upstream and 46 (53%) were counted migrating downstream from late April through mid-June 2003. The number of spawning cutthroat trout continues to decline by more than 50% annually in Bridge Creek, and has decreased by over 97% since counts began in 1999.

Dan Mahony, NPS fisheries biologist, preparing the Clear Creek spawning migration trap.

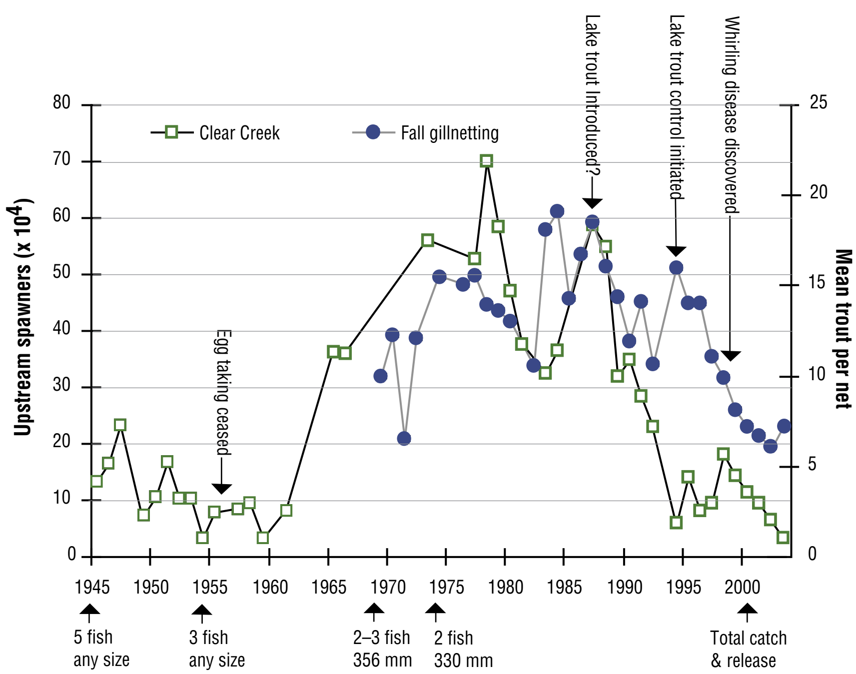


Figure 3. Total annual number of upstream-migrating Yellowstone cutthroat trout at Clear Creek and mean number of cutthroat trout collected per net by fall gillnetting on Yellowstone Lake. Arrows indicate dates of changes in sportfishing restrictions and other significant events, including the likely year for lake trout introduction as indicated by otolith microchemistry.

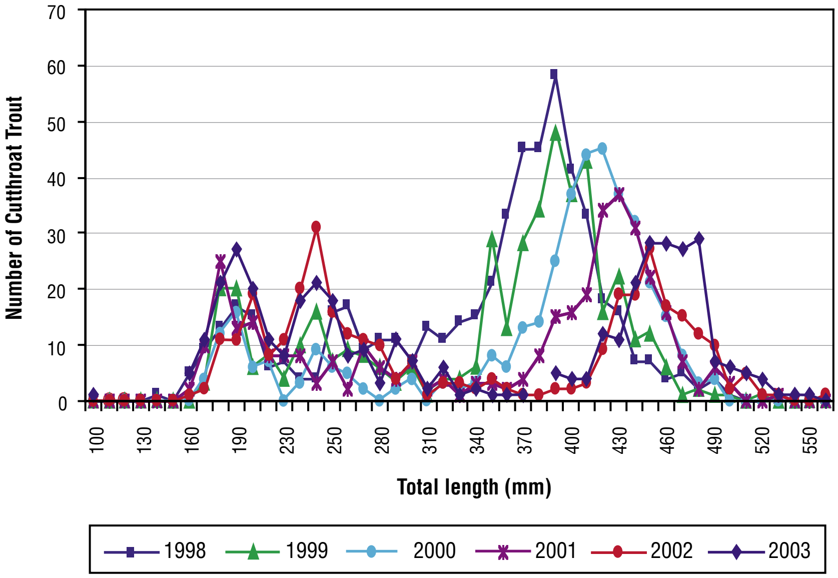


Figure 4. Length-frequency data collected from Yellowstone cutthroat trout, Yellowstone Lake, during fall netting assessments, 1998–2003. Note the severe decline in adults greater than 300 mm over time. Also note an increase in juveniles in 2002–2003.

The cumulative effect of the 2001–2003 drought in the intermountain west, and impacts by non-native/ exotic species have brought this precious population to its knees.

Yellowstone cutthroat trout population decline in recent times began during the years of drought and great fires of the late 1980s (Figure 3). The cumulative effect of the 2001–2003 drought in the intermountain west (resulting in extremely low stream flows and elevated water temperatures in Yellowstone National Park), and impacts by non-native/ exotic species have brought this precious population to its knees. Hope for sustaining the Yellowstone cutthroat trout population has come in the form of a large, dedicated crew of National Park Service and volunteer staff, with efforts aimed at suppressing the prolific and aggressive non-native lake trout population.

Removal of Non-native Lake Trout from Yellowstone Lake

Following the discovery of lake trout in Yellowstone Lake in 1994, efforts have continued to intensify to counteract this non-native threat.[15] Each year, gillnet operations staff have improved their knowledge of lake trout seasonal distribution patterns and their ability to target lake trout while avoiding bycatch of native Yellowstone cutthroat trout. In 2003, the ratio of lake trout killed to cutthroat trout sacrificed was very acceptable (0.11 cutthroat trout lost for every lake trout killed).

Over 18,000 lake trout from Yellowstone Lake were terminated in 2003, using 20,657 net units (one net unit = 100 m of net set over one night). Small mesh (19–44 mm mesh size) gillnets were placed on the lake bottom in water typically 50–75 m deep. As in past years, lake trout carcasses were returned to the lake to avoid removing nutrients from this relatively nutrient-poor system. On a typical day during the open water season on Yellowstone Lake, over 10 miles of gillnet were in place fishing for lake trout. Using the efficient National Park Service gillnetting boat, the *Freedom*, and at least one other vessel on most days, the gillnetting effort has increased to greater than twelve-fold over the 1999 level (Figure 5). Catch rate (catch per unit of effort) in 2003 remained very low (0.87), and was similar to that of 2002; catch rate has declined dramatically since 1998, when an average of 5.51 lake trout per net unit were caught each night.

In 2003, gillnetting crews identified a significant lake trout spawning location near the West Thumb Geyser Basin. This spawning location, along with areas near Carrington Island, Solution Creek, and Breeze Channel, is heavily gillnetted from late August through September using shallow-set (5–15 m depth), large mesh gillnet (51–70 mm mesh size) sets of short duration to avoid cutthroat trout bycatch and mortality. The average total length of lake trout caught near the spawning areas continued to indicate an overall decrease in the length of sexually mature lake trout (Figure 6). However, the total number of spawning lake trout caught in 2003 was much higher than in previous

BRIAN ERTEL

Large spawning female lake trout collected using gillnets set for short duration at night in the West Thumb of Yellowstone Lake.

years due to the discovery of the new spawning location.

Since 1994, more than 75,000 lake trout have been terminated in Yellowstone Lake by our gillnetting program. The majority of these fish have been in the West Thumb and Breeze Channel, where most of the gillnetting effort is concentrated. Bioenergetics modeling (estimates of how many cutthroat trout a lake trout potentially consumes) suggests that an average mature lake trout will consume 41 cutthroat trout per year.[16] Thus, the control project has saved a large number of cutthroat trout from lake trout predation. The recent decline in catch rate of lake trout throughout the season and overall reduction in average length of spawning fish are positive indications that gillnetting operations are exerting significant lake trout mortality in this system.

Although recent numbers from the lake trout removal program are encouraging, the effort must continue to keep this non-native predatory population in check. Lake trout densities in the West Thumb remain high and a serious threat to the Yellowstone cutthroat trout. Model simulations indicate that a 60% or greater decline in the cutthroat population could be expected within 100 years if the lake trout population were permitted to grow uncontrolled.[17] We remain unsuccessful at developing a technique to remove lake trout in the mid-size range (400–600 mm total length). This component of the population coexists spatially with our cutthroat trout population, making it impossible to effectively gillnet them without also incurring an unacceptable mortality rate in cutthroat trout. In 2003, fisheries staff deployed large fyke nets at lake trout spawning locations. Fyke nets are generally a non-lethal collection method and, if effective, would allow live release of any cutthroat trout also caught. Unfortunately, few lake trout were taken using

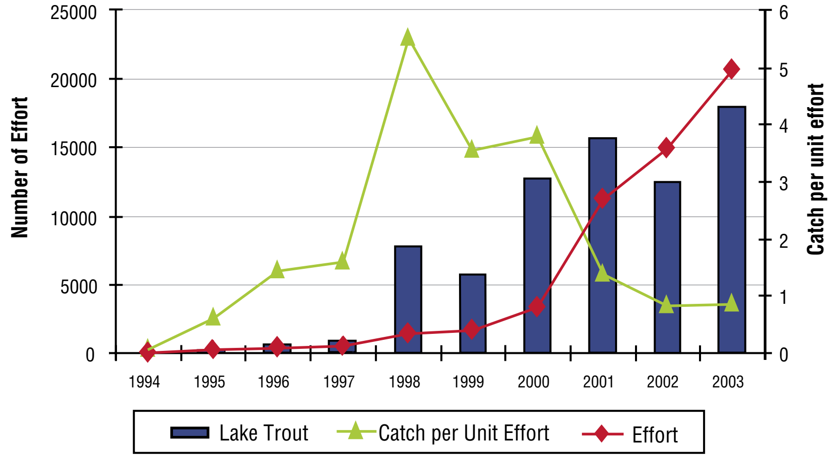


Figure 5. Total number of lake trout removed by gillnetting in Yellowstone Lake with total gillnetting effort and catch per unit of effort, 1994–2003. Each unit of effort represents 100 meters of gillnet set over one night.

More than 75,000 lake trout have been killed by gillnetting since they were first discovered in 1994.


BRIAN ERTEL

The reproductive potential of spawning lake trout is very high.

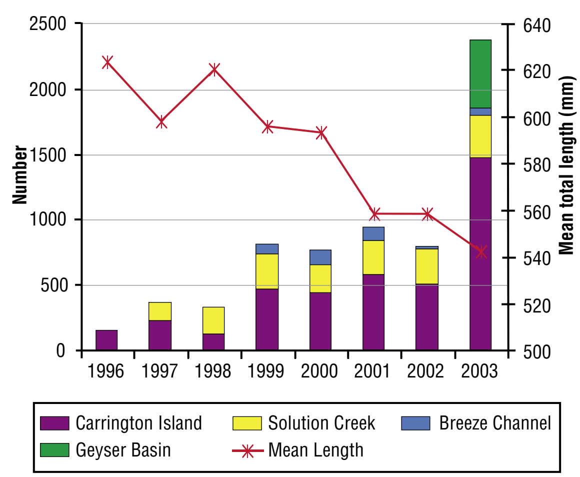


Figure 6. Total number and overall mean total length of lake trout gillnetted from or near spawning areas, Yellowstone Lake, 1994–2003.

this method. We will continue to investigate new methods to target this segment of the population before the fish reach full maturity, and perhaps pioneer new spawning sites.

Understanding the Effects of Whirling Disease

KENDRA KINNIN

The microscopic worm Tubifex tubifex *is the alternate host for the whirling disease life cycle and a focus of study for understanding this disease in Yellowstone.*

Recent work on *Myxobolus cerebralis*, the parasite that causes whirling disease, has shifted to intensive research on the apparent origin and potential source of infection in the Yellowstone River near Fishing Bridge, Pelican Creek (where infection is most severe), and Clear Creek. Infection risk of native Yellowstone cutthroat trout is being related to *Tubifex tubifex* (the alternate host for *M. cerebralis*) presence, abundance, and infection, and the environmental characteristics of tributary basins. Severe infection has been documented through exposure of Yellowstone cutthroat trout fry to the trail crossing (near the old bridge site) far upstream on Pelican Creek; the parasite likely extends upstream from there.

Disease spread is being evaluated through monitoring of tributaries with similar basin morphology to Pelican Creek, as recent survey results indicate that the spawning cutthroat trout population of this stream (which once numbered in the tens of thousands of migrating fish) has been completely lost. Rigorous netting for migrating adult cutthroat trout in this stream in 2002 and 2003 turned up only a handful of fish. In addition, intensive searches for wild-reared cutthroat trout fry resulted in none found in 2002, and only 9 in 2003. Establishment of *M. cerebralis* in Pelican Creek has contributed to the recent severe decline in the total Yellowstone Lake population of native Yellowstone cutthroat trout.

NPS fisheries crew checking nets set for upstream migrating cutthroat trout in Pelican Creek.

There have been significant differences among annual and within-season variation in infection prevalence and severity of exposed fry at Pelican Creek and other infected streams. The host–parasite and ecological interactions in this system have been unclear. The *T. tubifex* genetic strain has been considered moderate in its potential to produce triactinomyxons, and other myxozoans exist in the lake basin and are also infecting *T. tubifex* and (unknown) fish host(s) there.[18] *M. cerebralis* apparently tolerates, and has been highly successful in significantly higher mean water temperatures than those documented for most other systems. Many areas of Pelican Creek are thermally heated and remain without ice cover throughout the winter; these unique geothermal influences may have concentrated tubificids and *M. cerebralis* infection. If additional information regarding locations of infected tubificids in Pelican Creek were known, management action could potentially be taken (especially if the distribution were highly clumped) to reduce *M. cerebralis* infection risk in this stream.

Although laboratory challenges and previous field studies elsewhere have suggested that Yellowstone cutthroat trout are only moderately susceptible to *M. cerebralis* infection, results of our research indicate that this subspecies/strain may be very susceptible.[19] Additional work should be done to compare the *M. cerebralis* resistance among potentially unique cutthroat trout from isolated populations. Perhaps inherent resistance to this parasite exists, and could be used to support ongoing broodstock development programs for conservation efforts in Yellowstone National Park and the neighboring states.

Hydroacoustic Surveys to Document Population Change

Surveys using state of the art hydroacoustic equipment, for estimating fish densities, were conducted throughout Yellowstone Lake twice during the 2003 field season. Partial surveys were completed three additional times to compare seasonal distribution of lake trout. Thorough analysis of hydroacoustic data collected this past field season will allow us to determine areas of high density, size ranges of fish in given areas, and depths at which fish reside. New graduate-level research has been initiated to relate these data with detailed bathymetry data produced by the U.S. Geological Survey.[20] This research will allow us to identify specific lake areas where we need to either increase or decrease our lake trout gillnetting effort and will improve program efficiency. This technology will also allow for evaluation of the effectiveness of our removal efforts by estimating lake trout and cutthroat trout population densities annually.

Status of Cutthroat Trout in the Upper Yellowstone River

Although fisheries investigations have been occurring in Yellowstone National Park since just after its creation in the late 1800s, there has never been a survey of the Yellowstone River and its vast array of remote tributaries upstream of Yellowstone Lake. With the recent threats of lake trout and whirling disease to cutthroat trout in Yellowstone Lake, determination of cutthroat trout status in this region became crucial for purposes of making future management recommendations regarding this system. In 2003, the Aquatics Section and staff from the Wyoming Game and Fish Department initiated a fisheries assessment of the upper Yellowstone River. The study will determine movements of adult Yellowstone cutthroat trout during their spawning migration in the Yellowstone River and several of its tributaries. We also will determine if any resident populations exist in the drainage.

Radio transmitters were implanted in 62 adult Yellowstone cutthroat trout in the

Phillip Hurst, NPS volunteer, assisting with radio telemetry on the upper Yellowstone River.

Yellowstone River and several of its tributaries. Tag life is expected to be two years, with the tags operating for six months of the year (May–November). Tagged fish were monitored with weekly tracking flights and several trips to groundtruth what we were learning from the air. Surveys to locate fish that moved into Yellowstone Lake were conducted via boat.

Tagged Yellowstone cutthroat trout moved substantial distances through the summer of 2003. Fish as far upstream as Thorofare Creek, south of the park boundary, were found in the mouth of the Yellowstone River at Yellowstone Lake just a few weeks later, a distance of 31.5 stream miles. Signals were also received in Yellowstone Lake at Clear Creek and the Molly Islands, and one fish was captured by an angler at Breeze Point. The majority of fish tagged moved into Yellowstone Lake as the season passed. A few of the fish tagged in the upper reaches of the drainage stayed in the river, but all fish moved downstream from the initial tagging position. There were five known mortalities of tagged fish, including one angler-caused (outside the park boundary), two consumed by white pelicans (tags were recovered on the Molly Islands), and two with cause of mortality unknown. The study is planned to continue for several more years. The final tagging operations will take place this summer, with monitoring continuing for a minimum of two field seasons.

There has never been a survey of the Yellowstone River and its vast array of remote tributaries upstream of Yellowstone Lake.

Westslope Cutthroat Trout Restoration

Population Surveys

Since 1983, park fishery personnel have been collecting information about the westslope cutthroat trout (*Onchorhynchus clarki lewisi)* residing in Fan Creek, a tributary of the Gallatin River (Figure 1). This native trout was historically abundant in both the Gallatin and Madison river basins, but recent genetic surveys indicated that the most likely concentrations of genetically pure westslope cutthroat trout were located only in the headwater sections of Fan Creek. Although five genetically pure westslope cutthroat trout were collected near the confluence of Fan Creek and the Gallatin River in 1997, subsequent samplings upstream suggest that the population has hybridized with Yellowstone cutthroat trout, rainbow trout (*Onchorhynchus mykissi)*, or both, in most of the Fan Creek mainstem.

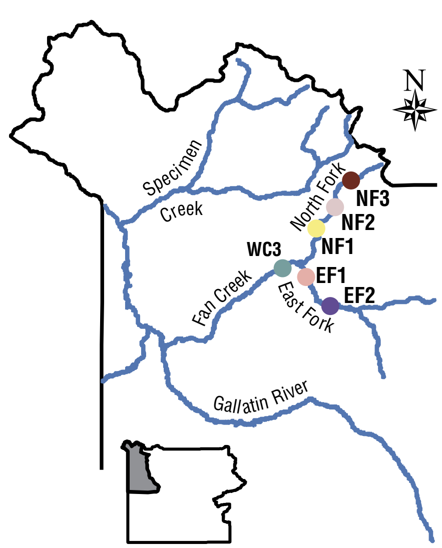


Figure 7. Reaches on Fan Creek sampled by electrofishing for westslope cutthroat trout, 1998–2003.

In order to obtain more detailed information about the remaining westslope cutthroat trout populations in the park, population estimates have been conducted annually since 1998 at several 100-m sections in the mainstem and each of the two forks of Fan Creek (Figure 7). Several years of sampling have shown that despite considerable annual variability, abundance of westslope cutthroat trout in much of the Fan Creek watershed is relatively low (<500 individuals per kilometer). At the low gradient sites (North Fork 1 and both of the East Fork sections), estimated density of cutthroat declined by about 50% from the maximum observed in 2001 (Figure 8). In contrast, estimated westslope cutthroat trout abundance in the upper two North Fork sections containing large amounts of woody debris was consistently higher than that observed in the downstream areas.

Westslope cutthroat trout captured from the North Fork in 2003 were mostly small fish (<200 mm total length), but two caught near the confluence of the North and East forks were 381 mm long. Preliminary length frequency analyses suggested that at least three, and possibly four, distinct year classes of cutthroat trout were present in the North Fork Fan Creek in 2003. As in previous years, mottled sculpin (*Cottus bairdi*), another native species, were collected at all sites except the two upstream sections of the North Fork Fan Creek. Where they occurred, sculpins were typically so abundant that their estimated biomass was higher than that of the westslope cutthroat trout in most years, even though most of the sculpins were quite small (<75 mm in length).

Genetics Surveys

Based on results from 1997 and 1998, the Aquatics Section has concentrated more recent genetic inventories on Fan Creek populations. The apparent verification of a genetically pure population in the North Fork Fan Creek encouraged NPS managers to proceed with development of a broodstock in cooperation with Montana and Wyoming state fishery agencies for eventual restoration projects throughout the upper Missouri River watershed.

To be considered a donor population, secondary verification of genetic status was recommended. To meet these requirements, tissue samples from 60 cutthroat trout each from 2001 and 2002 were analyzed in May 2003. Preliminary analyses suggested that the previously pure population in North Fork Fan Creek had recently become hybridized with rainbow trout. With this new information, plans for collecting gametes on site in Fan Creek were temporarily cancelled. Additional samples (>150 fish) were obtained in 2003, but they have yet to be analyzed. Because these samples were collected from a variety of locations in the watershed, it is hoped that these additional analyses will not only detail the amount of recent hybridization in the population, but also provide an accurate account of the spatial distribution of the hybridized (and remaining pure) cutthroat trout.

Restoration Potential

Unlike many other areas within its historical range, habitat degradation and excessive harvest rates by anglers do not appear to be the primary reason for the decline of westslope cutthroat in Yellowstone National Park. Rather, the extensive stocking and subsequent establishment of populations of non-native competing species (brown trout [*Salmo trutta*], and interbreeding rainbow trout and Yellowstone cutthroat trout) during the first half of the twentieth century have led to a serious reduction in the park's resident westslope cutthroat trout. Our electrofishing, genetic, and radiotagging surveys of the past five years have demonstrated that the once abundant westslope cutthroat trout is now confined to a single, small tributary in the northwest corner of the park.

A recent determination by the U.S. Fish and Wildlife Service that westslope cutthroat trout do not currently warrant classification as a "listed" species suggests that this native fish will only be protected if federal and state agencies continue to pursue strong conservation measures.[21] Despite results of recent genetics analyses, the North Fork Fan Creek population has high genetic integrity and should be considered an "at risk" population. Although these fish are protected from habitat and angler impacts, evidence from our surveys reveals that these fish could be affected by non-native fish species. The capture of non-native brown trout each year indicates that there are no barriers to prevent upstream migration of non-native species into the headwater cutthroat trout populations. Complete protection of the North Fork Fan Creek westslope cutthroat trout population requires that they be permanently isolated from invading species.

North Fork Fan Creek.

To meet our restoration goals, additional information needed for preparation of an environmental assessment was collected in 2003. Aquatics Section staff completed habitat assessments, water quality sampling, and macroinvertebrate collections of the Fan Creek system this year. With the assistance of the park's geology staff, an onsite survey was conducted to ensure that the preferred site for the migration barrier on the mainstem of Fan Creek was the most appropriate hydrological site. In addition to our annual population surveys, Aquatics Section staff provided logistical support for Idaho State University researchers conducting amphibian surveys at several headwater lakes in the Gallatin River basin that could potentially be used for broodstock development of verified pure westslope cutthroat trout.

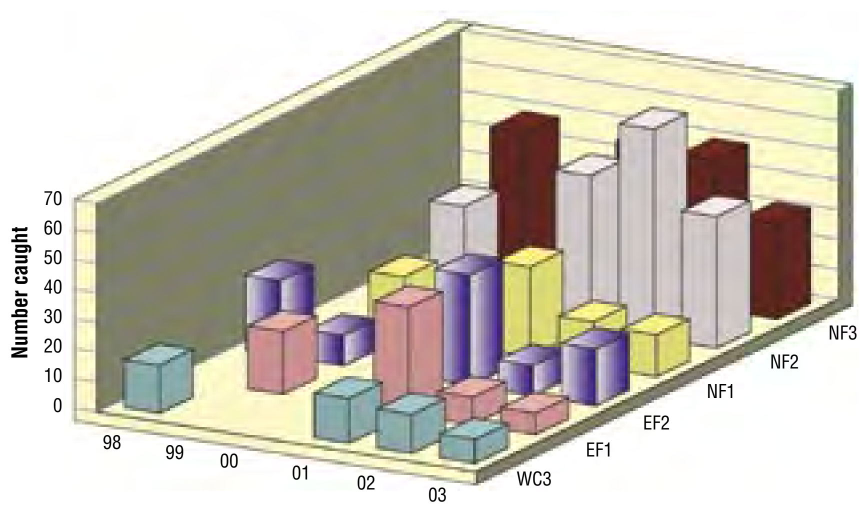


Figure 8. Number of westslope cutthroat trout collected by electrofishing from reaches on the Fan Creek mainstem (WC3), East Fork (EF1 and EF2), and North Fork (NF1, NF2, and NF3; see figure 7).

Stream Fishery Surveys and Fish Health

Population Surveys

This year we completed a multi-year population assessment of Yellowstone cutthroat trout in Slough Creek, prompted by concerns of perceived damage to riparian areas or the fish population arising from increased angler use. In the mid-1990s, annual angler use occasionally exceeded 25,000 angler days per year as Slough Creek became one of the most popular angling areas in the park, particularly in the meadow areas upstream from the campground, even though hourly catch rates were often below one fish per hour. During the drought periods of the past several years, anecdotal information indicated that additional anglers were fishing at Slough Creek as a substitute for other streams that were temporarily closed due to high instream water temperatures. With this information as background, we sampled some of the more heavily used portions of Slough Creek. Our electrofishing results indicated that there is little evidence that the abundance or size structure of the Yellowstone cutthroat trout population has changed since the stream was last sampled in 1989 (Figure 9). Although high levels of angler use continued in this popular catch-and-release fishery, estimated abundance of adult cutthroat trout longer than 330 mm remains at several hundred fish per kilometer. The recent capture of several potentially hybridizing rainbow trout of spawning size in areas of pure Yellowstone cutthroat trout appears to represent a much more serious threat to the long-term persistence of this population than are the current levels of angler use.

The abundance and size structure of the Yellowstone cutthroat trout population of Slough Creek have not changed since the stream was last sampled in 1989.

Monitoring Associated with Road Reconstruction

Reconstruction of the primary park roads is a major management objective in Yellowstone National Park. Because many of these roads parallel streams to enhance the scenic quality of the visitor experience, road construction projects can potentially impact fish populations if excessive sediment is generated or improper design impedes fish passage through road culverts. In 2003, road reconstruction was initiated between Fishing Bridge and Canyon Junction, and on the Dunraven Pass road. Several streams used by spawning and resident Yellowstone cutthroat trout are located within these construction areas. Cutthroat trout

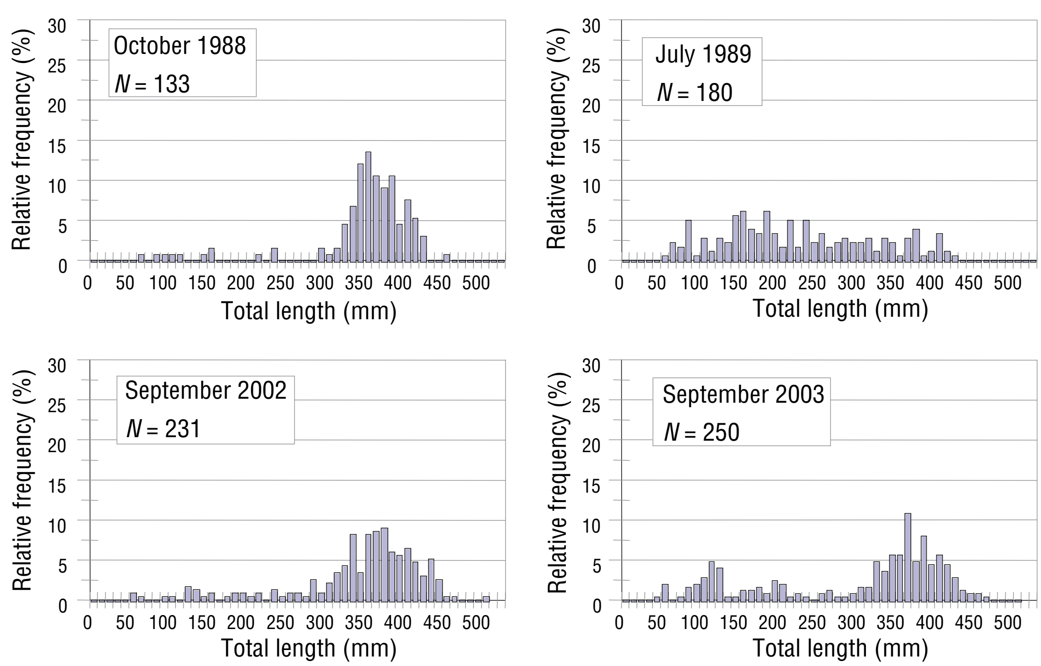


Figure 9. Relative length-frequency distributions (sample size = N*) of Yellowstone cutthroat trout collected by boom-mounted electrofishing in the first meadow of Slough Creek, 1988–89, compared to 2002–03.*

captured from Hayden Valley sites exhibited growth rate characteristics similar to those found in the Yellowstone River, but fish from Antelope Creek had lengths expected from a small headwater population (Figure 10).

For the fourth consecutive year, we sampled four locations in the Gibbon River between Gibbon Meadows and Madison Junction. The principal objective of this study was to monitor construction impacts to the stream during the Madison-to-Norris road reconstruction project. In addition to widening the existing road to meet current standards, several road kilometers are to be removed, and a new reroute and bridge over the Gibbon River built. Thus, the potential for increased sediment input into the stream and associated habitat degradation is very high. More importantly, this road removal portion of the project represents one of the first attempts by the park to restore a section of stream channel that has previously been altered by historic road building. Although most of the Gibbon River was originally barren of fish, the sections downstream from Gibbon Falls (Tuff Cliffs and Canyon Creek sample areas) historically contained westslope cutthroat trout and the riverine form of grayling. Westslope cutthroat trout have apparently been eliminated from

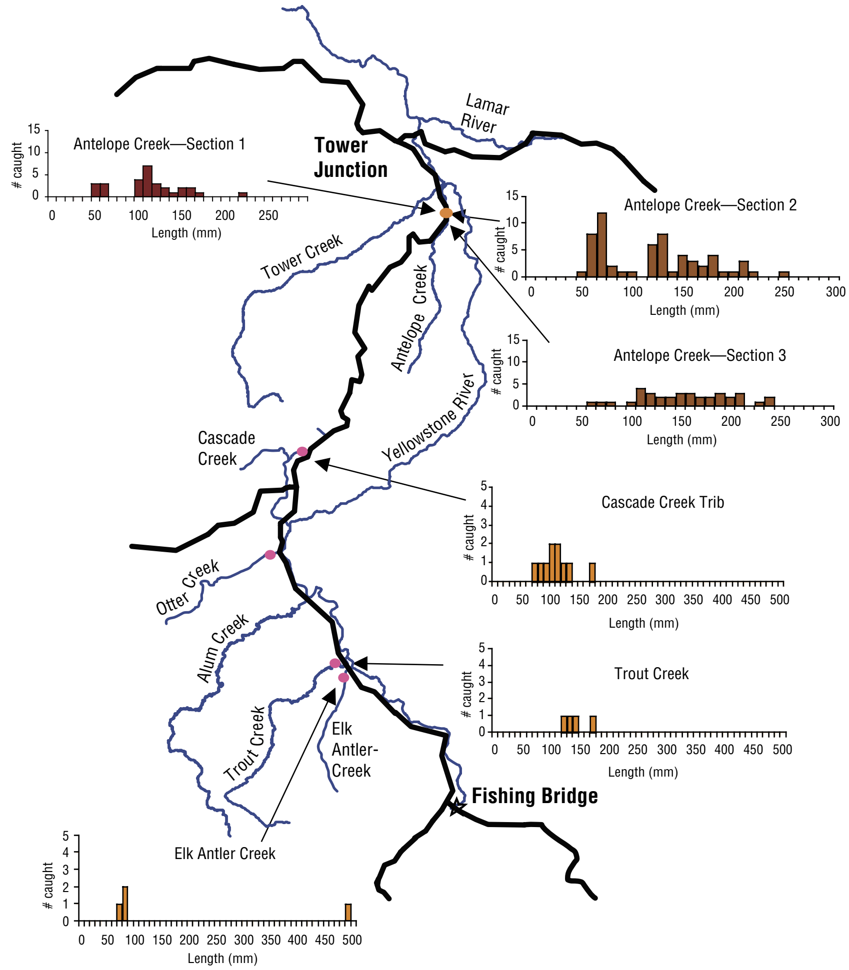


Figure 10. Length-frequencies distributions of Yellowstone cutthroat trout at sampling sites associated with road reconstruction activities along the Yellowstone River and several of its tributaries in 2003.

NPS fisheries crew, led by Dan Mahony, conducting an electrofishing survey of Slough Creek.

Yellowstone cutthroat trout from LeHardys Rapids, Yellowstone River.

the Gibbon River, but grayling are occasionally captured. Therefore, a secondary objective of our study was to document the responses of the few grayling that may reside in the lower sections of the stream to construction activities. Each year, brown trout were the most common fish collected at each sample area and the only species captured in the Tanker Curve section. During the past several low water years, estimated brown trout abundance averaged from 400 to 800 fish per kilometer. Rainbow trout were only captured downstream from Gibbon Falls; several dozen individuals sampled in 2003 were longer than 450 mm. Although no grayling were captured during 2002, the four individuals caught in 2003 represented the highest number captured in three years. Although this represents an encouraging trend, the widespread high density of brown trout probably contributes to the rarity of native grayling in its historical range in the Gibbon River watershed.

With the non-lethal analysis techniques now available, extensive genetic testing of small or other at-risk fish populations is now possible.

Surveys for Fish Health

In 2003, the Aquatics Section continued to participate in the U.S. Fish and Wildlife Service National Fish Health Survey to monitor the physical health of sampled fish populations that had not yet had a population level health diagnosis. According to the established survey protocols, a subsample of fish collected by fishery personnel were lethally sampled and examined for a variety of parasitic infections and bacterial and viral diseases. In 2003, 40 brook trout and 8 rainbow–cutthroat trout hybrids from Middle Creek (Shoshone River) were submitted for analyses. The fish health survey in Middle Creek is of interest not only as baseline information, but also because this stream is located in the headwaters of a large river basin that flows out of the park into Wyoming. Our sample sites are adjacent to a proposed construction area on the east side of the Sylvan Pass road reconstruction project, where the potential for spread of fish pathogens through construction activities is an important management consideration. Additionally in 2003, 35 cutthroat trout from the First Meadow area of Slough Creek were collected to complete the fish health survey of that basin, which was initiated in 2001. Final results about the health status of these populations are pending.

Genetics Surveys

With the non-lethal analysis techniques now available, extensive genetic testing of small or other at-risk fish populations is now possible. As described above for Fan Creek westslope cutthroat trout, continued genetic analyses are necessary to detect changes in a population that may prevent preservation of native trout genes. In addition to the new samples collected from 135 suspected westslope cutthroats in the Fan Creek watershed, fishery personnel also obtained fin tissue samples from Slough Creek ($N = 62$) and Bacon Rind Creek ($N = 25$). There is a high probability that non-native rainbow trout have interbred with native cutthroat at these sites.

Fin clips for genetic analyses were also obtained from Arctic grayling caught during the Gibbon River surveys. Although local grayling populations have low genetic variability, we are attempting to collect enough samples to examine whether there is a genetic difference between Grebe Lake grayling and those fish collected in downstream areas that are presumed to be fluvial grayling. Also, the Volunteer Flyfishing Program collected more than 100 additional genetic samples. Cutthroat trout were sampled in Lamar River, lower Pebble Creek, and Beula Lake, which are waters with known or suspected areas of hybridization. Individual genetic analyses of these fish will assist in determining the distribution of hybridization in these native fish populations.

Invasive Aquatic Exotic Species Threaten the Park

In addition to the parasite that causes whirling disease, Yellowstone National Park aquatic systems have been invaded by the New Zealand mudsnail (*Potamopyrgus antipodarum*). Mudsnails are extremely small (about 4–5 mm long) and highly prolific.[22] First found in the park in 1994, mudsnails now occupy the Firehole, Gibbon, Madison, and Gardner rivers, Polecat Creek, and likely others. Recent research indicates that these animals have been outcompeting and displacing native invertebrates. Dr. Billie Kerans at Montana State University reported that mudsnails comprised 25–50% of macroinvertebrates in the Gibbon and Madison rivers, and that fewer native mayflies, stoneflies, and caddisflies occurred in areas occupied by mudsnails.[23] The effect of these invaders on fish is unknown, but recent research indicates that mudsnails can pass completely through the gut of a fish unharmed while offering no nutritional value.

It would be nice to think that the waters of Yellowstone National Park could remain in a relatively pristine condition for future generations to enjoy, but this will not be the case without changes to the way we manage the movement of equipment, boats, and other gear among waters in our region. Presently, invasive exotic aquatic species occur in streams, rivers, and lakes (both near the coasts and inland) all across the United States.[24] While we may never know exactly how the parasite that causes whirling disease and the New Zealand mudsnail were introduced to the park, anglers can help prevent the additional spread of these animals, or of the many other invasive exotic species approaching our boundaries (e.g., zebra mussels, Eurasian watermilfoil, round goby).

Anglers should thoroughly clean all mud, plants, and debris from fishing equipment, and inspect footwear before leaving the angling site. We also recommend treating waders and boots with a 10% bleach solution. Boaters entering the park must completely remove plant material or any other debris from trailers and boat hulls; bilge areas and livewells must be thoroughly drained and likewise cleared of debris. The entire boat should be cleaned with hot (higher than 140°F) water and allowed to dry for several days. Boat transport is a primary method by which harmful animals are moving among waters in our country. Only through actions like these will we be able to stop the additional spread of invasive exotics.

Long-term Water Quality Monitoring

Water quality monitoring continued through 2003 at our 12 established stations on major river basins throughout Yellowstone National Park (Figure 1). Each site was visited once every two weeks, with sampling days being randomly selected. A multiparameter probe was used to collect water temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. Water samples were also collected at each location for total suspended solids (TSS) and volatile suspended solids analysis.

During 2003, most parameters varied considerably within and between sites

Anglers should thoroughly clean all mud, plants, and debris from fishing equipment, and inspect footwear before leaving the angling site.

Jeff Arnold, NPS aquatic ecologist, collecting macroinvertebrates from Bacon Rind Creek.

Highest mean temperatures of 15.9ºC and 15.4ºC occurred on the Firehole and Gardner rivers respectively, both of which are thermally influenced streams.

(Figure 11). Variations among water quality parameters were primarily due to diurnal cycles, high flows during spring snowmelt, rain events, seasonal temperature changes, altitude differences, and thermal influences that affected many streams. Highest mean temperatures of 15.9ºC and 15.4ºC occurred on the Firehole and Gardner rivers respectively, both of which are thermally influenced streams. Lowest mean temperature of 4.3ºC occurred on upper Soda Butte Creek (range -0.2ºC to 13.5ºC). Highest mean DO concentration of 9.2 mg L^{-1} was recorded for both the Gibbon and Snake rivers with ranges of 7.7–12.8 mg L^{-1} and 7.5–10.7 mg L^{-1} respectively. The Firehole River exhibited the lowest average DO concentration of 8.0 mg L^{-1} (range 6.8–9.1 mg L^{-1}). Pelican Creek, a tributary to Yellowstone Lake with low velocity, exhibited the lowest recorded DO concentration of 6.3 mg/L on July 1.

Within-site variation in pH was quite low; variation was higher between sites (Figure 11). This was best illustrated in the Madison River drainage, which receives water from the Firehole and Gibbon rivers. Mean pH for the Firehole River was 8.3 (range 8.0–8.7). This was the highest mean value for all sites sampled with the exception of Gardner River, which also had a mean pH of 8.3. Conversely, the Gibbon River had the lowest mean pH at 6.8 (range 6.5–7.2). Values for specific conductance, turbidity, and TSS were highly seasonal and seemed to be directly related to river discharge. On average, specific conductance tended to be lowest during spring runoff when water was more plentiful, thus diluting the ionic concentration of the water. Spatial and temporal differences of specific conductance are best illustrated with three sites on the Yellowstone River (Figure 12). Specific conductance on the Yellowstone River at Fishing Bridge was least variable among all sites, and had the lowest mean value of 90.1 µS cm^{-1} (µS) (range 84–93 µS). By comparison, specific conductance at Corwin Springs was quite variable, with a mean of 216 µS (range 88–354 µS). The Gardner River exhibited the highest

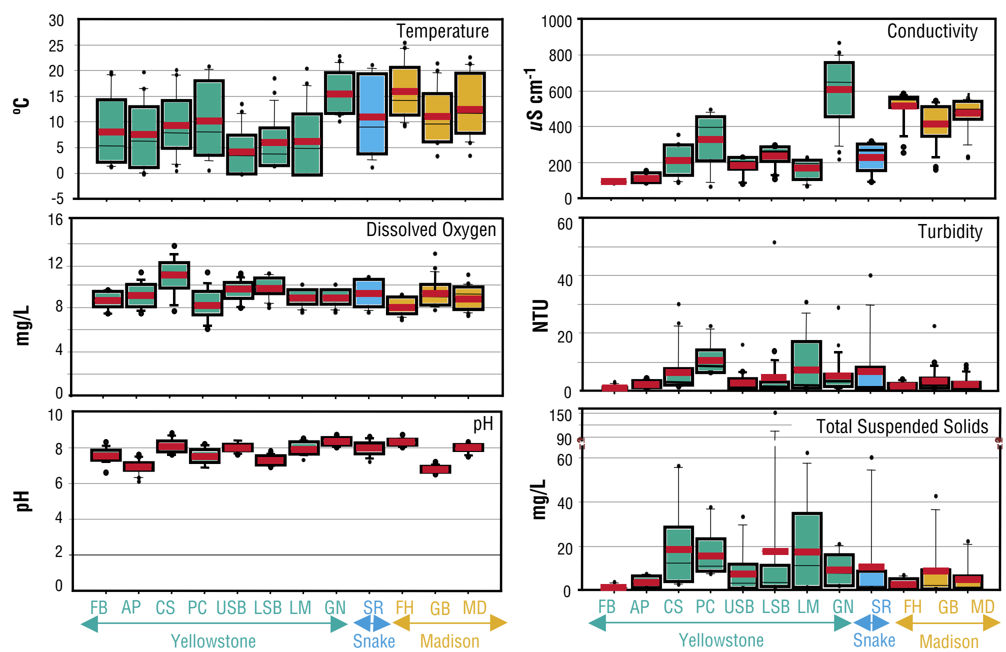


Figure 11. Box and whisker plot illustrating annual variation for selected parameters at each water quality location. Lower and upper portion of boxes represent the 25th and 75th percentile respectively; lower and upper black horizontal bars represent 10th and 90th percentile respectively. Outlying values are represented by black dots; means are indicated by solid red lines. Green, blue, and orange represent the Yellowstone, Snake, and Madison river basins, respectively (FB = Fishing Bridge, AP = Artist Point, CS = Corwin Springs, PC = Pelican Creek, USB = upper Soda Butte, LSB = lower Soda Butte, LM = Lamar River, GN= Gardner River, SR = Snake River, FH = Firehole River, GB = Gibbon River, and MD = Madison River).

mean value and was the most variable of all sites sampled for specific conductance, with a mean of 603 µS (range 217–866 µS). Overall, streams having high specific conductance were associated with drainages that had considerable thermal contributions, with Gardner, Firehole, Gibbon, and Madison rivers having the highest specific conductance of all sites sampled.

Turbidity and total suspended solids (TSS) were closely linked parameters (Figure 11). Higher turbidity values usually corresponded to spring runoff or localized precipitation events during summer months. Most sites had mean turbidity measurements below 10 nephlometric turbidity units (NTU), with the exception of Pelican Creek, which had a mean turbidity measurement of 10.8 NTU (range 6.4–22.4 NTU). The higher turbidity readings of Pelican Creek are most likely explained by higher phytoplankton concentrations in this slow moving stream. The Yellowstone River at Fishing Bridge had the lowest mean turbidity measurement of 1.0 NTUs (range 0.3–3.0 NTU). Not surprisingly, this site also had the lowest mean TSS concentration of 1.2 mg L^{-1} (range 0.5–3.5 mg/L). Lamar River exhibited the highest mean TSS of 21.2 mg L^{-1} (range 1.1–67.1 mg L^{-1}).

Limnology of Yellowstone Lake

A total of seven sites are now sampled periodically on Yellowstone Lake to document changes in basic limnological characteristics (two water quality sites were added in 2003 in the South Arm and Southeast Arm; Figure 2). The two new sites, sampled by the U.S. Fish and Wildlife Service from the mid-1970s through the early 1990s, were added to obtain a more comprehensive understanding of the limnology of Yellowstone Lake. Water quality data was collected every two weeks beginning in late May and continuing until mid-October. Water temperature, dissolved oxygen, pH, specific conductance, and turbidity measurements were recorded using a multiparameter probe. Water samples were also collected at each location for total suspended solids (TSS) and volatile suspended solids analysis.

SCOTT FAVROT

Jeff Arnold, NPS aquatic ecologist, collecting water quality information in Soda Butte Creek.

Water Quality Associated with Winter Use

During spring 2003, snowmelt runoff was sampled for concentrations of volatile organic compounds (VOC). VOCs in snowpack are most likely produced by incomplete combustion of gasoline from two-stroke snowmobiles. This study was initiated to determine if VOCs were present in snowmelt and, if so, whether there

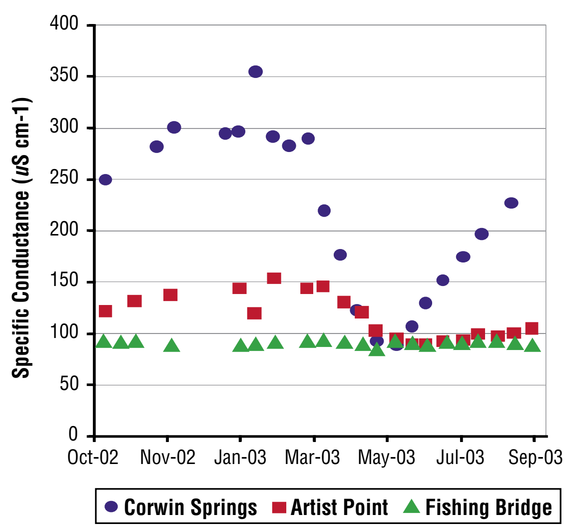


Figure 12. Specific conductance at three sites on the Yellowstone River illustrating temporal and spatial variation among sites. Note the low annual variability at the Fishing Bridge site versus high variability at the Corwin Springs site.

was a possible link to snowmobile use within Yellowstone National Park. Sampling began after the 2002–2003 winter season, and went from March 15 through April 15. The study area was located within the road corridor between the West Entrance and Old Faithful. Three test sites were established within this area, with one site each in the vicinity of the West Entrance, Madison Junction, and Old Faithful. Selection of sample locations was based on the assumption that snowmelt was derived from snow that had originated from groomed roads. A fourth site was used as a control located in the Madison Junction vicinity on a small, intermittent stream. This sample location was approximately 100 yards from the road and flowed through an area that had been burned during the 1988 fires. Each site was visited nine times during the sampling period.

Sample analysis was conducted by the U.S. Geological Survey's laboratory in Denver, Colorado. Nine compounds within the VOC category were analyzed, including benzene, ethylbenzene, ethyl tert-butyl ether, isopropyl ether, m-xylene/p-xylene, methyl tert-butyl ether, o-xylene, tert-pentyl methyl ether, and toluene. Of the nine compounds tested, only five were detectable within any given sample (benzene, ethylbenzene, toluene, o-xylene, and m-xylene/p-xylene). Samples collected from the vicinity of Old Faithful and the West Entrance contained all five compounds during at least one sampling event. Highest levels for each compound were recorded near Old Faithful during early April 2003. This sample location drains much of the parking area utilized by visitors in the Old Faithful vicinity. The maximum recorded concentration for these five compounds were (units are µg L-1): benzene, 0.031; ethylbenzene, 0.27; toluene, 0.61; o-xylene, 0.69; and m-xylene/p-xylene, 1.45. All VOC compounds for the Madison Junction site were below detection levels, likely due to large volumes of snow melting off adjacent hillsides and diluting VOC concentrations in snowmelt. The control site did contain trace levels of toluene during six of the nine site visits. These results are similar to those of previous investigators, where trace levels of toluene were found in snowpack from off-road locations.[25] The origin of this chemical remains unknown, and further studies are needed to evaluate its source. All VOC concentration levels were well below the Environmental Protection Agency's level of toxicity to aquatic organisms.

JEFF ARNOLD

Stonefly from Soda Butte Creek.

Macroinvertebrate Monitoring

Aquatic macroinvertebrates were used as a bioassessment tool to evaluate the current condition of water resources. They are ideal organisms to use because they are long lived (one to three years), relatively immobile, and sensitive to environmental (i.e., chemical and physical) changes. Thus, by investigating the type of aquatic organisms living within a selected stream reach, we can measure the current water quality condition of that stream.

By investigating the type of aquatic organisms living within a selected stream reach, we can measure the current water quality condition of that stream.

During fall 2002, the Aquatics Section worked in conjunction with the Greater Yellowstone Network (GRYN) to conduct aquatic macroinvertebrate sampling from selected streams within the GRYN's three National Park Service units: Bighorn Canyon National Recreation Area (BICA), Grand Teton National Park (GRTE), and Yellowstone National Park. This was done to supplement ongoing water quality monitoring and establish current inventories and distributional patterns of aquatic macroinvertebrate species.

In Yellowstone National Park, sampling

locations were primarily selected based upon proximity to various road construction projects that were expected to begin within three years. Streams (and the number of sites) selected for sampling near proposed road construction projects were: Obsidian Creek (4), Antelope Creek (3), Middle Creek (3), and Gardner River (3) (Figure 1). The objective was to obtain baseline information regarding aquatic invertebrate communities prior to road construction. This, and subsequent data, will be used to determine impacts on water resources within areas of major road construction. Additional criteria for selection of invertebrate sample locations within the three GRYN parks included threats from mining waste, grazing activities, and proximity to campgrounds. Some sites were also selected in areas of thermal inputs to ascertain community composition of invertebrates living in waters with naturally occurring thermal and chemical stressors.

To account for spatial and temporal variability of benthic macroinvertebrate communities from each park, 40 sites from 19 streams were sampled using a 500-m surber net. A total of 232 taxa (species groups) were identified from the three parks—70 from BICA and 165 each from GRTE and Yellowstone National Park. The modified Hilsenhoff biotic index (HBI) was calculated for each site. This index evaluates tolerance levels of benthic macroinvertebrates to organic pollutants, thermal regimes, and dissolved oxygen concentrations. The HBI rates each sample based on a scale of 0–10, with the lowest values representing excellent water quality condition and successively higher values representing a more degraded condition. From the 40 sites sampled within the three parks, 31 ranked between good and excellent, 7 ranked poor to fair, and 2 ranked very poor (Figure 13). Because of the abundant thermal features affecting Yellowstone National Park's surface waters, using contemporary methods to evaluate these waters is particularly challenging. Thermally influenced surface waters have naturally high temperatures, low dissolved oxygen concentrations, and higher dissolved solutes than streams lacking thermal inputs. The HBI ranked five sample locations within Yellowstone as being fair to very poor.

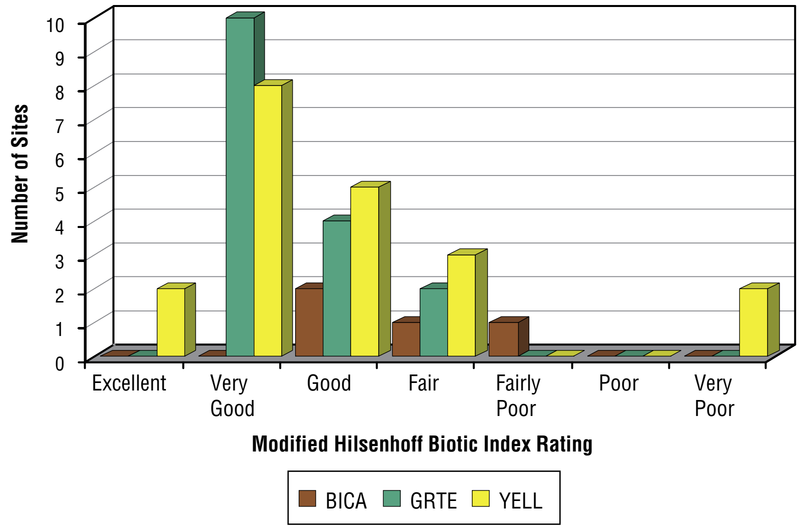


Figure 13. Stream ranking using the modified Hilsenhoff biotic index based on macroinvertebrate communities of streams in Greater Yellowstone Network parks, including Bighorn Canyon National Recreation Area (BICA), Grand Teton National Park (GRTE), and Yellowstone National Park (YELL).

All of these sample locations were in areas that receive heavy to moderate thermal inputs, thus affecting the aquatic communities residing within those waters. More sampling is needed to evaluate aquatic communities that occur naturally within thermally influenced streams.

During 2003, benthic macroinvertebrate sampling continued for many streams in Yellowstone National Park. Sixteen stream segments were sampled in areas where major road construction is anticipated during the next two years (Figure 1). In addition, 11 sites were sampled in the northwestern portion of the park. Nine sites were sampled within the Fan and Specimen creek drainages, with six sites sampled on Fan Creek and one set of samples each collected from Crescent, Sedge, and Crag lakes. These samples were collected as part of the westslope cutthroat trout restoration project. Invertebrate samples will be used to evaluate the current condition of streams within the Fan and Specimen creek drainages, and to provide current inventory information and distribution patterns of aquatic invertebrates living within those drainages prior to any fish restoration attempt there. Also, two sites were sampled on Bacon Rind Creek in response to potential impacts from a fire retardant spill that occurred during September. These samples will be used to evaluate impacts to water quality as a result of that spill.

Impacts of the New Zealand Mudsnail in Waters of Yellowstone National Park

Adapted from publications
by B. L. Kerans, D. C. Richards, and R. O. Hall Jr.

The New Zealand mudsnail (*Potamopyrgus antipodarum)* was first discovered in the western United States in the Snake River, Idaho, during the 1980s. It is now rapidly spreading and has become established in rivers in seven western states and three national parks, including Yellowstone. It is a parthenogenic livebearer with high reproductive potential, meaning that when conditions are right, the adult mudsnails can produce many offspring throughout the year without a mate. In fact, with an average of 50 offspring produced per snail, through six generations in a year, a single snail could result in the production of over 300 million new snails![1] The New Zealand mudsnail often reaches densities greater than 100,000/m^2 in suitable habitat and has been reported to approach densities as high as 750,000/m^2 in sections of rivers in Yellowstone National Park. Especially favored by these invaders are the unique, geothermally influenced waters of the park. Frequently, the mudsnails will comprise over 95% of the invertebrate biomass in a river.

Research has documented decreases in native macroinvertebrate populations in several rivers where the New Zealand mudsnail has invaded. In the Gibbon and Madison rivers, about a quarter to over half the macroinvertebrate community has consisted of mudsnails.[2] Also, a negative correlation was found between the numbers of native mayflies, stoneflies, and caddisflies, species that are an important component of the diets of salmonids and several bird species in Yellowstone National Park. The negative interactions between mudsnails and the native macroinvertebrates could be propagated up the food web and negatively effect these important consumer populations.

DAN GUSTAFSON

Even if they are eaten, mudsnails are difficult to digest because they have a hard shell and protective cover (called an operculum) that seals them from their environment. Mudsnails have been known to pass completely through the gut of a fish unharmed! Certainly their lack of nutritional value and ability to outcompete and displace native aquatic insect communities makes them a serious threat to the waters of Yellowstone.

New Zealand mudsnails have also been shown to drastically alter primary production in some streams. Recent research has shown these invaders are consuming most of the primary production (the dominant food source) in the Firehole River and Polecat Creek.[3] The food resources are being taken up by the invasive snails rather than by the native macroinvertebrates.

In the Greater Yellowstone Ecosystem, the New Zealand mudsnail currently exists in the Firehole, Gardner, Gibbon,

DAVID RICHARDS

New Zealand mudsnails can outcompete native macroinvertebrates and consume most of the primary production of Yellowstone National Park streams.

Decreases in native macroinvertebrates have been noted in streams where New Zealand mudsnails have invaded.

With an average of 50 offspring produced per snail, through six generations in a year, a single snail could result in the production of over 300 million new snails!

Madison, and Yellowstone rivers and Polecat and Nez Perce creeks (Figure 14). The invasion of this exotic species has generated much concern about the potential impacts it may have on native species, fisheries, and aquatic ecosystems in the western United States. Its spread into new systems is considered to be primarily human caused. To prevent additional spread of this harmful exotic species, all of us that enjoy the waters of Yellowstone have the serious responsibility to make sure all gear, waders, and other equipment are free of mud and debris, and we are not transporting mudsnails among waters in this region.

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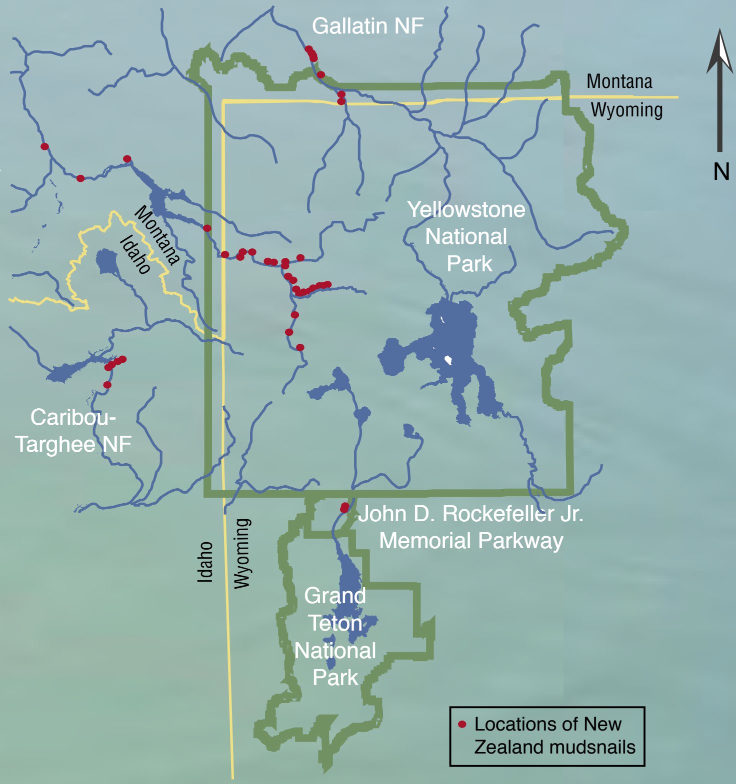

Figure 14. Locations of New Zealand mudsnails in the Greater Yellowstone Ecosystem.

Angling in the Park

Trends from the Volunteer Angler Report Cards

The more than three million visitors to Yellowstone National Park in 2003 represented another all-time high. Angling remains a popular visitor pastime; over 54,000 special use fishing permits were issued in 2003. A volunteer angler response (VAR) card is provided with each fishing permit, providing anglers the opportunity to report where they fish, the species and size of fish caught, and their satisfaction with the fishing experience. There has been a response rate of almost 4,000 angler outings per year in recent years from the VAR cards.

Native cutthroat trout remained the most sought-after and caught fish species, making up 59% of the total catch.

Park fisheries managers use the information provided by VAR cards to get an overview of fish population dynamics and angler attitudes toward the fisheries resource throughout the waters of Yellowstone National Park. Data from 2001 and 2002 indicate that anglers fished 2.75 hours per day during typical fishing trips in the park. Single-day anglers reported catching at least one fish 78% of the time, and on average landed almost one (0.89) fish per each hour of fishing.

TIMOTHY BYWATER

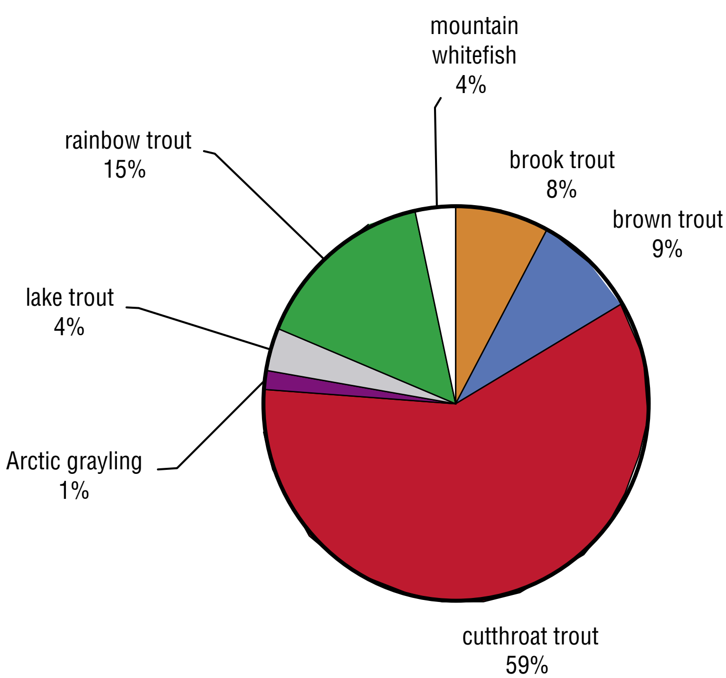

Figure 15. Total angler reported catch by percent of fish species in Yellowstone National Park in 2001–02.

Native cutthroat trout remained the most sought-after and caught fish species, making up 59% of the total catch, followed distantly by rainbow trout 15%, brown trout 9%, brook trout 8%, whitefish and lake trout each 4%, and grayling 1% (Figure 15). The majority of anglers were satisfied with their overall fishing experience (75%), the numbers of fish caught (62%), and the size of the fish caught (68%). Anglers typically reported on many fishable waters in the park; their observations can be the first line of information toward identifying potential fisheries related problems.

Yellowstone Lake remains the most popular destination for anglers that come to the park; an estimated 13,685 anglers fished Yellowstone Lake in 2002. The angler catch per effort for cutthroat trout in Yellowstone Lake has decreased for the past four years, and is now at its lowest level since summaries of VAR cards were compiled in 1979 (Figure 16). Average total length has increased annually for seven years and is also at an extreme, its highest level since 1979. These changes to the fishery coincide with the discovery and subsequent expansion of lake trout since the mid-1990s. Angler catch per effort of lake trout was at its all-time high in 2002; however, lake trout are still caught at a much lower rate than cutthroat trout.

Slough Creek has been a popular destination for anglers wishing to catch large numbers and sizes of the native Yellowstone cutthroat trout. Slough Creek can be divided into two distinct segments of meandering stream, separated by a narrow canyon and steep cascade that is

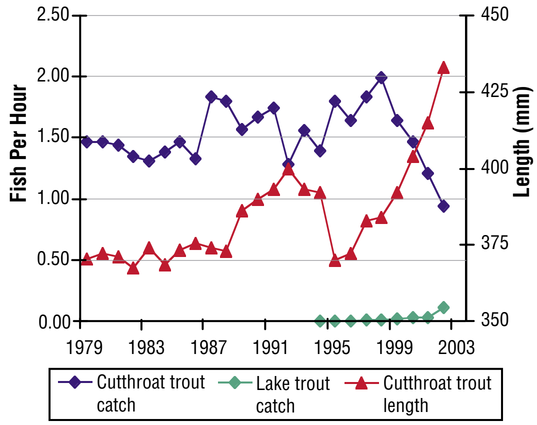

Figure 16. In Yellowstone Lake, angler-reported catch rate for Yellowstone cutthroat trout declined for the fourth year in a row during 2002. Average length of angler-caught cutthroat trout increased for the seventh year in a row, and is at its highest since 1979.

Opening day on the Yellowstone River.

impassable for fish. Anglers fishing the upstream section of Slough Creek catch cutthroat trout at twice the rate of those fishing the downstream section. However, the catch rate of fish in the upper section has been on a gradual downward trend (Figure 17). Anglers reported that rainbow trout are in both sections; however, they were more successful at catching rainbow trout in the downstream section. The length of trout caught in Slough Creek has not changed much in 35 years. Average length of a cutthroat trout caught in Slough Creek during 2002 was 315 mm (12.4 inches), while the average rainbow trout caught was 260 mm (10.3 inches).

Another noteworthy trend is the declining angler catch rate of Yellowstone cutthroat trout in Pelican Creek. Pelican Creek is a tributary to Yellowstone Lake and has historically been a destination for anglers seeking adfluvial "lake run" cutthroat trout. Angler catch rate of cutthroat trout in Pelican Creek is currently just a fraction ($^{1}/_{3}$) of what it was in the 1980s (Figure 18). The reduced catch rate in Pelican Creek is likely due to loss of cutthroat trout fry due to whirling disease and predation by lake trout in Yellowstone Lake.

Fisheries managers will continue to use the VAR cards as a tool to gauge fish population trends, use of waters, and visitor enjoyment of the tremendous fishing opportunities that remain in Yellowstone National Park.

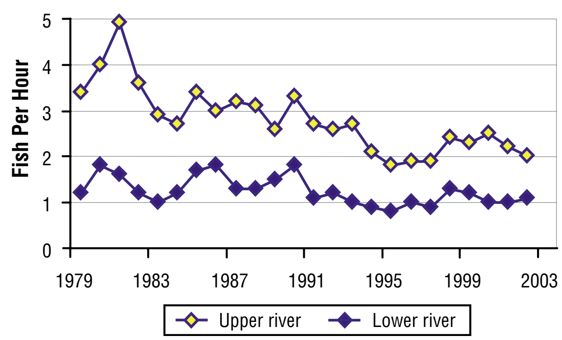

Figure 17. Angler-reported catch rates of Yellowstone cutthroat trout in Slough Creek upstream and downstream of the cascade near the campground. Catch rates of Yellowstone cutthroat trout are slowly declining in the upper river reach.

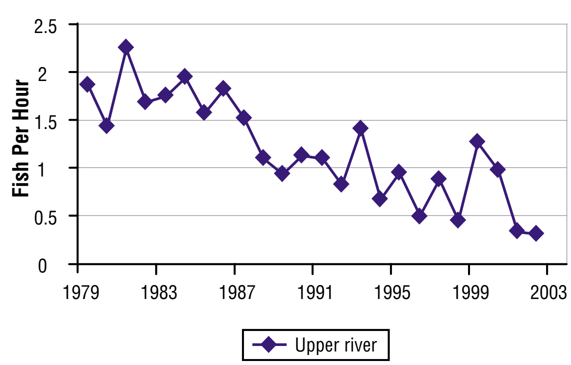

Figure 18. Declining trend of angler-reported success for Yellowstone cutthroat trout in Pelican Creek, a tributary to Yellowstone Lake.

Public Involvement

A program was established to incorporate flyfishing volunteers and use catch-and-release angling as a capture technique.

Yellowstone Volunteer Flyfishing Program

Much of the effort by Yellowstone's fisheries staff in recent years has been redirected at emerging crises such as lake trout removal and whirling disease, yet there are a multitude of other fisheries issues and questions to be addressed. There are an estimated 2,650 miles of streams and 150 lakes in the park, with surface waters covering 5% of Yellowstone's 2.2 million total acres. Realizing that NPS staff could not address many issues, a program was established to incorporate flyfishing volunteers and use catch-and-release angling as a capture technique to gather biological information on fish populations located throughout the park. In 2003, the Volunteer Flyfishing Program was coordinated by Dr. Timothy Bywater, an avid flyfisherman and long-time supporter and promoter of Yellowstone's fisheries. Projects addressed included:

- determination of the range of hybridized Yellowstone cutthroat trout in the Lamar River and its major tributaries;
- documentation of the Beula Lake fishery; and
- documentation of the status and movement patterns of grayling originating in Grebe and Wolf lakes of the Gibbon River system.

Under this incredibly successful program, 74 volunteer anglers from across the United States traveled to the park and participated as an active component of the Aquatics Section. Volunteers experienced many fisheries issues first hand. The biological data collected will assist in our understanding of the park's fisheries status.

TIM BYWATER

Long-term Volunteer Assistance

The Aquatics Section recruits long-term (more than 12-week) volunteers from the Student Conservation Association and other sources (see Appendix ii). Volunteers stay in park housing at Lake and work a full-time schedule similar to paid NPS seasonal staff. All aspects of the Aquatics Section are affected and greatly benefit from both long- and short-term volunteer support. In 2003, a total of 98 volunteers dedicated 4,041 hours to Aquatics Section activities.

Educational Programs

Aquatics Section staff continued to provide a variety of short-term educational programs for visiting schools and other interested groups. Of special note in 2003 was the incorporation of six high school scholars from St. Steven & St. Agnes School, Washington, D.C., and their leader, Mansir Petrie. This group spent over a week in the park's interior working closely with NPS fisheries biologists, primarily on tributary spawning migration trap operations.

Collaborative Research

The Yellowstone Center for Resources through the Aquatics Section has provided direct and indirect support for collaborative research with scientists at other institutions, primarily universities. The studies address some of the most pressing issues faced by NPS biologists and other regional managers of aquatic systems.

Projects by Graduate Students

Graduate Student: Silvia Murcia (Doctor of Philosophy candidate). *Committee Co-Chairs:* Dr. Todd Koel and Dr. Billie Kerans, Department of Ecology, Montana State University. *Title:* Relating *Myxobolus cerebralis* infection in native Yellowstone cutthroat trout (*Oncorhyncus clarki bouvieri)* with environmental gradients at three spawning tributaries to Yellowstone Lake in Yellowstone National Park.

Graduate Student: Lusha Tronstad (Doctor of Philosophy candidate). *Committee Chair:* Dr. Robert Hall, Department of Zoology and Physiology, University of Wyoming. *Title:* Decline in nitrogen transported by Yellowstone cutthroat trout spawning migrations.

Graduate Student: Carrie Brooke (Master of Science candidate). *Committee Chair:* Dr. Al Zale, U.S. Geological Survey Cooperative Fisheries Research Unit and Department of Ecology, Montana State University. *Title:* Life history strategies of native westslope cutthroat trout in Fan Creek, Yellowstone National Park.

Researchers Dave Lovalvo (left) and Jim Maki (center) prepare a remotely operated vehicle for deployment, with assistance from Erika Thompson.

The NPS Cutthroat *on the West Thumb of Yellowstone Lake.*

Other Research and Collaboration

The Aquatics Section continues to support a variety of other research projects in Yellowstone National Park. Of special mention is the research by the Great Lakes WATER Institute, University of Wisconsin at Milwaukee; Marquette University, Milwaukee; the U.S. Geological Survey, Denver; and Eastern Oceanics, Connecticut. Scientists from these institutions set up a laboratory at Lake and outfitted the NPS Aquatics Section's boat, the *Cutthroat,* with a submersible remotely operated vehicle, or ROV, to study the physical, chemical, and biological characteristics of Yellowstone Lake, especially associated with hydrothermal vent systems.

A limited number of Yellowstone cutthroat trout gametes were collected by Montana Department of Fish, Wildlife and Parks from McBride Lake (Slough Creek drainage) and by Wyoming Game and Fish Department from the Yellowstone River at LeHardys Rapids. In all cases, gametes were used for enhancement of native cutthroat broodstock and restoration activities in Montana and Wyoming. Each year, age-zero Yellowstone cutthroat trout from the broodstock (LeHardys Rapids origin) in Wyoming are returned to the park for whirling disease exposure studies.

Acknowledgments

Much-appreciated administrative support for the Aquatics Section was provided by Becky Anthony, Rene Farias, Melissa McAdam, Joy Perius, Beth Taylor, and Colleen Watson.

Many additional dedicated individuals from within Yellowstone National Park have contributed to the success of Aquatics Section activities; unfortunately we cannot mention them all here. However, we would like to especially thank Dave Hill, Earl McKinney, Susan Ross, Bruce Sefton, Melinda Sefton, Art Truman, Mark Vallie, Lynn Webb, and Dave Whaley from Lake Maintenance; Rick Fey and Kim West from Lake District Rangers; and Wally Wines from Ranger Corral Operations.

The Aquatics Section is supported through Yellowstone Center for Resources base funding and by anglers visiting Yellowstone National Park through a portion of the fees collected from the Fishing Special Use Permits each year. We have received additional funding (2002–2003) from the following sources:

- Federal Highway Administration, Park Roads and Parkways Program
- Greater Yellowstone Coordinating Committee
- National Park Service, Natural Resource Challenge, Natural Resource Preservation Program
- National Park Service, Recreational Fee Demonstration Program
- National Park Service, Inventory and Monitoring Program, Vital Signs Monitoring Program
- National Partnership for the Management of Wild and Native Coldwater Fisheries, Whirling Disease Initiative
- Whirling Disease Foundation
- Yellowstone Association
- Yellowstone Park Foundation

Special thanks to Dr. Charles Peterson, Idaho State University, for conducting amphibian surveys, and to Dr. Cheryl Jaworowski, Yellowstone Center for Resources, for conducting geological surveys associated with potential westslope cutthroat trout restoration efforts at Fan Creek.

We thank the many volunteers who have dedicated their time and also a great deal of other expense to our Aquatics Section, as without them, much of what we do in our programs would not be possible.

Flyfishing anglers from Trout Unlimited, Fly Fishing Federation, Henry's Fork Foundation, and many other organizations in the region and throughout the United States contributed hundreds of hours of time and costs associated with travel to our Volunteer Flyfishing Program; for that we are extremely grateful.

Through collaboration with the U.S. Fish and Wildlife Service's Bozeman Fish Health Laboratory, the U.S. Geological Survey's Western Fisheries Research Center in Seattle, Washington, the Department of Ecology at Montana State University, the Montana Department of Fish, Wildlife and Parks, and the Wyoming Game and Fish Department, we have been able to learn a great deal about whirling disease in the Yellowstone Lake basin. We thank all the individuals from these agencies for their kind support.

The printing of this publication was made possible by the Yellowstone Park Foundation.

BRIAN ERTEL

NPS Supervisory Fisheries Biologist Dr. Todd Koel with Sammy *and* Ethan, *packing into Thorofare Creek, October 2003.*

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Appendices

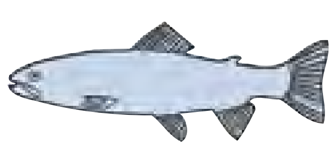
Appendix i. Fish Species List

Native (N) and introduced (non-native or exotic, I) fish species and subspecies known to exist in Yellowstone National Park waters including the upper Missouri (Missouri, Madison, and Gallatin rivers), Snake River (Snake), and Yellowstone River (Yell R.) drainages.

Family	Common Name	Scientific Name	Status	Missouri	Snake	Yell R.
Salmonidae	Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Native	I	I	N
	westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Native	N		
	finespotted Snake River cutthroat trout	*Oncorhynchus clarki behnkei*	Native		N	
	rainbow trout	*Oncorhynchus mykiss*	Non-native	I	I	I
	mountain whitefish	*Prosopium williamsoni*	Native	N	N	N
	brown trout	*Salmo trutta*	Exotic	I	I	I
	eastern brook trout	*Salvelinus fontinalis*	Non-native	I	I	I
	lake trout	*Salvelinus namaycush*	Non-native		I	I
	Montana grayling	*Thymallus arcticus montanus*	Native	N		I
Catostomidae	Utah sucker	*Catostomus ardens*	Native		N	
	longnose sucker	*Catostomus catostomus*	Native			N
	mountain sucker	*Catostomus platyrhynchus*	Native	N	N	N
Cyprinidae	lake chub	*Couesius plumbeus*	Non-native			I
	Utah chub	*Gila atraria*	Native	I	N	
	longnose dace	*Rhinichthys cataractae*	Native	N	N	N
	speckled dace	*Rhinichthys osculus*	Native		N	
	redside shiner	*Richardsonius balteatus*	Native		N	I
Cottidae	mottled sculpin	*Cottus bairdi*	Native	N	N	N

Appendix ii. Long-term Volunteers, 2003

Name	Period of Involvement	Hours
Christianson, Collin	08/10/2003–09/24/2003	240
Harris, Jessica	08/10/2003–11/01/2003	480
Hurst, Phillip	05/18/2003–08/09/2003	480
Metsky, Jeffrey	08/10/2003–11/01/2003	480
Reider, John	05/18/2003–08/09/2003	480
Schamberry, Nicole	05/18/2003–08/09/2003	480
Selvage, Nina	07/18/2003–08/21/2003	200



Appendix iii. Seasonal Staff, 2003

Name	Period of Involvement
Bywater, Timothy	05/18/2003–09/07/2003
Dixon, Chris	05/04/2003–11/01/2003
Facendola, Joseph	05/11/2003–11/01/2003
Farias, Rene	05/04/2003–09/20/2003
Favrot, Scott	05/04/2003–12/31/2003
Keep, Shane	05/04/2003–11/01/2003
Legere, Nicole	05/25/2003–08/26/2003
Mintkeski, Tyler	05/11/2003–09/12/2003
Olszewski, Brad	05/18/2003–08/29/2003
Rowdon, Barb	01/01/2003–12/31/2003
Ruhl, Mike	02/18/2003–05/16/2003
Slattery, Kelly	05/25/2003–08/22/2003
Sigler, Stacey	05/11/2003–11/01/2003
Steed, Amber	05/04/2003–10/10/2003
Vonderohe, Gary	05/04/2003–11/01/2003
Wethington, Don	05/04/2003–11/01/2003
White, Davina	05/04/2003–11/01/2003

Arctic grayling.