Yellowstone Fisheries & Aquatic Sciences

Annual Report 2005

NPS/JEFF ARNOLD

High Lake, at the headwaters of East Fork Specimen Creek, would provide a refuge for genetically pure westslope cutthroat trout.

Yellowstone National Park is home to the most ecologically and economically important inland cutthroat trout fisheries remaining in North America. However, threats to these native trout have, over the past decade, irreversibly altered and made future sustainability of this thriving and diverse ecosystem uncertain. Science has helped to develop our understanding of the consequences of status-quo management. In fact, without swift and continuing action, negative effects on the native trout populations of Yellowstone—keystone energy sources for numerous mammal and bird species, and a recreational focus for visitors—have the potential to produce impacts that will reverberate throughout the Greater Yellowstone Ecosystem.

For instance, each predatory, non-native lake trout—a species illegally introduced to Yellowstone Lake at least 20 years ago but not discovered until 1994—can annually consume at least 41 cutthroat trout each year. Lake trout have the potential to decimate the Yellowstone Lake cutthroat trout population in our lifetime without heightened and maintained management efforts. Lake trout are not an acceptable substitute for cutthroat trout in the ecosystem because they occupy an ecological niche unavailable to cutthroat-eating predators, threatening the many species, such as grizzly bears, bald eagles, and river otters, which depend on cutthroat trout for survival.

Albeit much more quietly, the brook, brown, and rainbow trout intentionally stocked by managers during the park's early history have also taken their toll on cutthroat trout populations across Yellowstone. The native westslope cutthroat trout of the Madison River, for example, a specialist species requiring pristine habitats, have been eliminated due to their inability to compete with aggressive, non-native trout. In addition, in many park waters the infusion of non-native-trout genetic material into stream-resident cutthroat populations by interbreeding among species has occurred and cannot easily be reversed. The loss to the cutthroat populations is permanent, and any recovery will be achieved only through direct intervention. The recent rainbow trout invasion of the upper Slough Creek meadows, and the resulting loss of that world-renowned fishery's genetic integrity, is an example of how serious this problem is.

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. Despite this, our hope and enthusiasm remain high. Within Yellowstone Lake, cutthroat are showing subtle signs of recovery, while lake trout are showing signs of suppression. Within the streams, momentum could not be greater as we near our first cutthroat restoration operation and the replication of a newly discovered, pure-strain westslope cutthroat trout population.

This annual report describes historic and continuing park aquatics programs with data and information obtained through 2005. In several instances, the report also outlines our vision for the program, with specific project goals and objectives for future years. This was done in an attempt to ensure program transparency; we want to make sure that everyone with an interest has a solid understanding of both our intent and the direction our efforts are taking to preserve and restore native fishes in the waters of this tremendous park.

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Yellowstone cutthroat trout

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Yellowstone Center for Resources
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YCR-2006-09

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Front cover photo captions (left to right): NPS fisheries technician Jeremy Erickson and NPS volunteer Matthew Christianson at Soda Butte Creek (photo by Jeffrey Arnold); westslope cutthroat trout from an unnamed Grayling Creek tributary; NPS fisheries staff on board the lake trout gillnetting boat *Freedom* (photo by Philip Doepke). Back cover photo captions (left to right): NPS aquatic ecologist Jeffrey Arnold with a Yellowstone cutthroat trout from the upper Yellowstone River (photo by Brian Ertel); NPS fisheries technicians and volunteers electrofishing Obsidian Creek (photo by Dan Mahony); NPS fisheries technicians Brad Olszewski and Brian Ertel processing a fish sample. Facing page photo caption: Elk Creek at road crossing is a barrier to non-native brook trout (photo by Michael Ruhl).

All photos in this report not otherwise marked are by Todd Koel. (*Note:* Native fishes shown out of water were not injured.)

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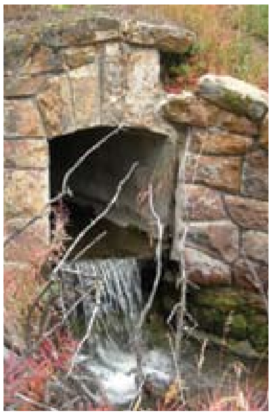


Background

Created in 1872, Yellowstone National Park (YNP) 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, fishes of the park were viewed as resources to be used by sport anglers and provide park visitors with fresh meals. Fish-eating wildlife, such as bears, ospreys, otters, and pelicans, were regarded as a nuisance, and many were destroyed as a result (Schullery 1997).

To supplement fisheries and to counteract "destructive" consumption by wildlife, a fish "planting" program was established in Yellowstone. Early park superintendents noted the vast fishless waters of the park and 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" (Boutelle 1889). The first fishes from outside the park were planted in 1889–1890, and included brook trout (*Salvelinus fontinalis*) in the upper Firehole River, rainbow trout (*Oncorhynchus mykiss*) in the upper Gibbon River, and brown trout (*Salmo trutta*) and lake trout (*Salvelinus namaycush*) in Lewis and Shoshone lakes (Varley 1981). The harvest-oriented fish management program accounted for the planting of more than 310 million native and non-native fish in Yellowstone between 1881 and 1955. In addition, from 1889 to 1956, some 818 million eggs were stripped from Yellowstone trout and shipped to locations throughout the United States (Varley 1979).

Largely due to these activities and the popularity of Yellowstone's fisheries, recreational

NPS PHOTO

The NPS boat Pelican *at Molly Island, July 1957.*

NPS PHOTO

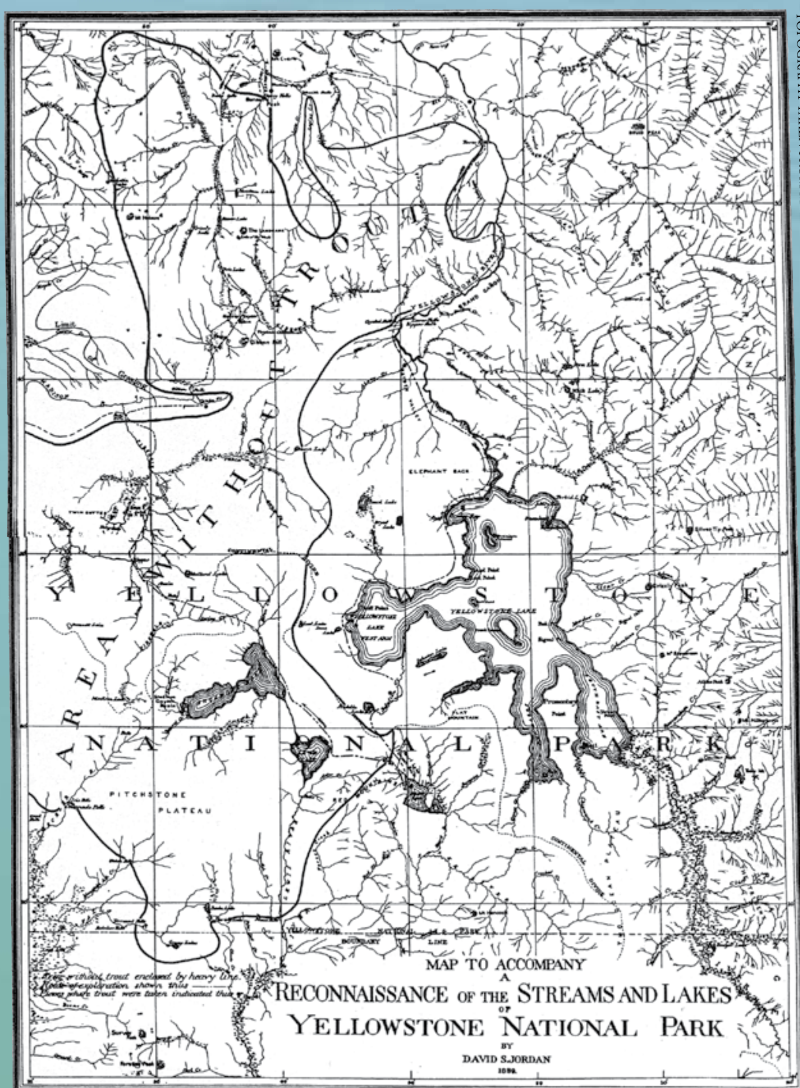
NPS personnel packing fish in the Mammoth Hot Springs area in 1938.

angling became a long-term, accepted use in national parks throughout the country. In Yellowstone, fisheries management, as the term is understood 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 begun 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 then.

Approximately 48% of Yellowstone's waters were once fishless (Jordan 1891), and the stocking of non-native fishes by park managers has had profound ecological consequences. The more serious of these include displacement of intolerant natives such as westslope cutthroat trout (*O. clarki lewisi*) and Arctic grayling (*Thymallus arcticus*), hybridization of Yellowstone (*O. c. bouvieri*) 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, management policies of the National Park Service have drastically changed to reflect new ecological insights (Leopold et al. 1963). Subsistence use and sport fishing harvest once guided fisheries management. Now, maintenance of natural biotic associations or, where possible, restoration to pre-Euro-American conditions have emerged as primary goals. Eighteen fish species or subspecies currently are known to exist in Yellowstone National Park; 13 of these are considered native (they were known to exist in park waters prior to Euro-American settlement), and five are introduced (non-native or exotic; see Appendix i) (Varley and Schullery 1998).

A perceived conflict exists in the National Park Service mandate to protect and preserve

pristine natural systems and also provide for use and enjoyment (NPS 2000). Fisheries management efforts in Yellowstone are currently focused on preservation of native species, while allowing for use of these fisheries by visiting anglers through a complete catch-and-release regulation. Because the primary mission of Yellowstone's Fisheries and Aquatic Sciences Section (Aquatics Section) is the preservation of natural ecosystems and ecosystem processes, the program's activities are not focused on maintenance of established non-native fish stocks. Beginning in 2006, harvest regulations will be liberalized, and anglers encouraged to keep non-native trout caught in waters where they co-exist and are causing harm to native cutthroat trout or Arctic grayling. Aquatics Section activities almost exclusively include the preservation of Yellowstone Lake cutthroat trout, the restoration of fluvial populations of native trout, and focused research and monitoring to support these critical activities.



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 Barton W. Evermann, Report on the Establishment of Fish Cultural Stations in the Rocky Mountain Region and Gulf States, U.S. Government Printing Office, 1892).*

Fisheries management efforts in Yellowstone are currently focused on preservation of native cutthroat trout.

2005 Summary

Preservation of Yellowstone Lake cutthroat trout continued to be one of the Aquatics Section's top priorities in 2005, as a total of 36,438 non-native lake trout were killed, bringing the overall total killed to more than 139,000 during the period 1994–2005. Because each of those lake trout could have consumed at least 41 cutthroat trout each year, the park's gillnetting effort has saved a tremendous number of cutthroat trout. The angling community has also joined the effort, and has been contributing to the removal of lake trout from Yellowstone Lake each year. The result is a lake trout population that is beginning to show signs of suppression. Catch per unit of effort for lake trout remains low, and the average length of the spawning adult lake trout continues to decline. However, the cutthroat trout population has yet to demonstrate a significant positive response. The number of upstream-migrating cutthroat trout counted at Clear Creek, one of the cutthroats' largest spawning tributaries, was only 917 during 2005. This count was down from 1,438 in 2004; 3,432 in 2003; and 6,613 in 2002, and was the lowest count made at Clear Creek since 1945, the first year when total annual counts were recorded there.

Yellowstone cutthroat trout abundance within Yellowstone Lake, as indicated by the fall netting assessment, has suggested a modest increase in the abundance of smaller juvenile fish within the population. During 2003–2005, this assessment has provided some of the first indications that the cutthroat trout may be responding positively to efforts to remove lake trout. An average of 7.4, 7.9, and 7.4 fish were caught per net in 2003, 2004, and 2005, respectively. Prior to 2003, there had been a reduction in catch by the fall netting program of 0–21% each year (averaging 11% per year) since 1994, the year lake trout were first discovered in Yellowstone Lake. Critical to the cutthroat now will be the ability of these juvenile fish to recruit to the spawning population and appear within the spawning tributaries of Yellowstone Lake; this is really the only means by which the population can be expected to rebound and return to the higher densities seen in the past.

Due to generous support by the Yellowstone Park Foundation and its Fisheries Fund Initiative, developed in 2005, the park's fisheries program is moving quickly forward with restoration of fluvial populations of native trout. Although an introgression of the North Fork Fan Creek westslope cutthroat trout was reported early in the year, in June a potentially pure population was found in a previously unsurveyed, unnamed tributary to Grayling Creek. Aquatics Section staff documented the extent of this population during July and August, and through collaboration with state of Idaho and Montana geneticists, determined that they are pure-strain westslope; the only pure westslope cutthroat trout known in the park, and one of only four pure populations remaining in the entire Gallatin and Madison river drainages of southwest Montana. It is estimated that more than 700 fish exist in this hidden stream, and Aquatics Section staff now intend to carefully replicate this population by moving small numbers of eggs into a much larger, more secure habitat each year. National Environmental Policy Act (NEPA) compliance was initiated in July specifically for this purpose. The focus for restoration is East Fork Specimen Creek, including the biologically productive High Lake, located at the headwaters of this watershed. Work was also completed to prioritize watersheds in the park's northern range based on probability of success for Yellowstone cutthroat trout restoration. Reese Creek, Rose

NPS/PHILIP DOEPKE

Due to the impacts of lake trout, whirling disease, and drought, Yellowstone Lake now harbors only a fraction of the estimated 3–4 million cutthroat trout that thrived here 20–30 years ago.

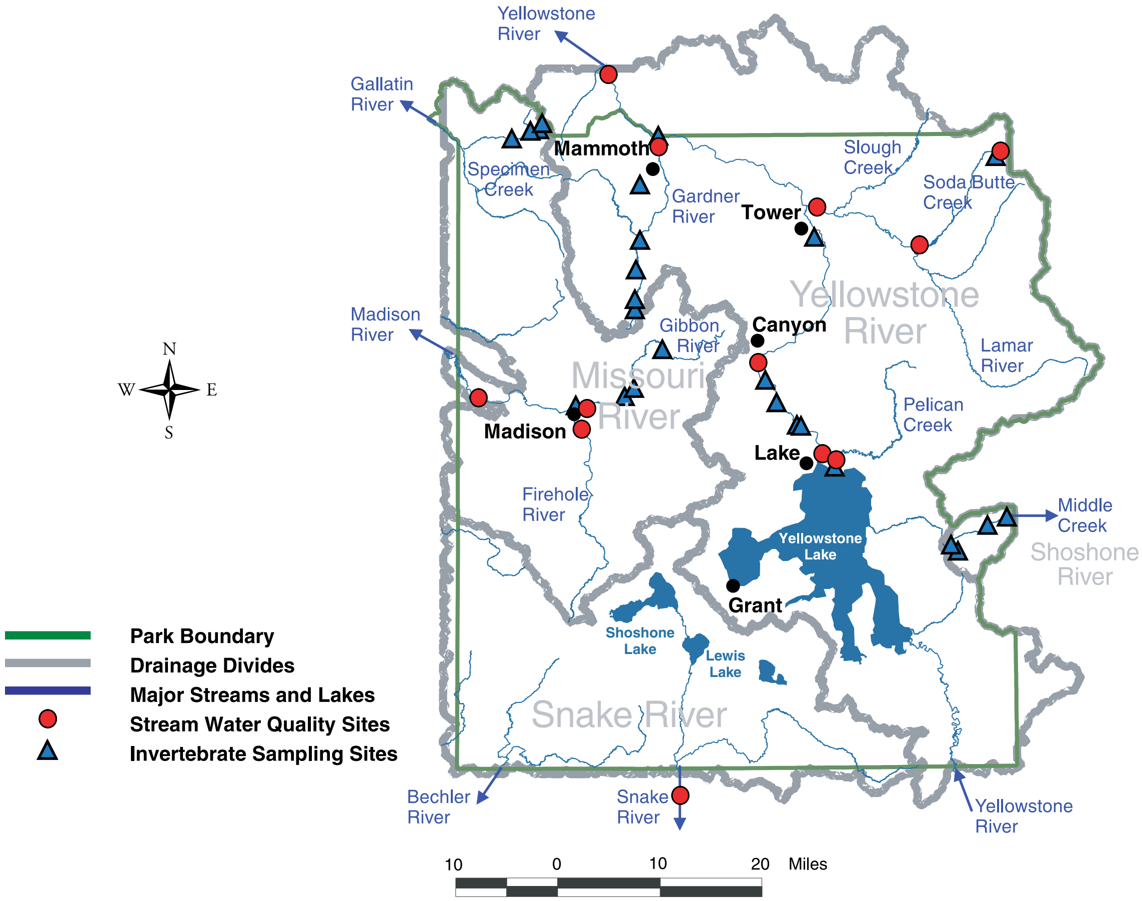


Figure 1. Major surface waters of Yellowstone National Park, with 12 stream sites established for long-term monitoring of water quality and sites sampled for macroinvertebrates in 2005.

Creek, the Elk Creek complex of streams, and Blacktail Deer Creek all provide excellent opportunities for re-establishment of genetically pure Yellowstone cutthroat trout populations. Rose Creek, in particular, given its proximity to the Lamar Buffalo Ranch, would also provide opportunities for public education and awareness activities regarding native trout issues in the park. The next step will be to finalize plans and initiate the NEPA process for restoration in the northern range.

Monitoring of fish communities occurred in many frontcountry and remote backcountry streams during 2005, including research focusing on the status and life history strategies of cutthroat trout in the Yellowstone River and its tributaries upstream of Yellowstone Lake. An inventory of fishes in the remote reaches of the Snake River and its tributaries also continued. These are among the first surveys of fishes in these regions of the park, even though fisheries investigations have been occurring in Yellowstone since the late 1800s. The waters of the upper Yellowstone River support significant numbers of spawning cutthroat trout from Yellowstone Lake. It is unknown to what extent the Snake River supports migrating cutthroat trout. Results will help managers understand the status and dynamics of cutthroat trout in these remote wilderness areas, and the contribution of these systems to the overall cutthroat trout populations of the Greater Yellowstone Ecosystem.

The ecological health of aquatic systems in Yellowstone National Park continues to be monitored intensively. The quality of the park's surface waters is monitored bi-weekly 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

Due to generous support by the Yellowstone Park Foundation and its Fisheries Fund Initiative, the park's fisheries program is moving quickly forward with restoration of fluvial populations of native trout.

JORDAN ALLISON

Remaining genetically pure cutthroat trout will be used to restore populations to streams which currently support hybridized and/or non-native trout.

for easy comparison of data among agencies. Results are being used to assist with the development of National Park Service (NPS) Vital Signs Monitoring protocols for the Greater Yellowstone Inventory and Monitoring Network. A study was also completed that provided information on the effects of road operations at Sylvan Pass on the water quality and macroinvertebrate communities of Mammoth Crystal Spring of the Middle Creek drainage.

Public scoping for proposed changes in fishing regulations occurred in 2005. The framework for the proposal was based on the presence or absence of native sportfish species, and contained just two management areas within the park: a Native Trout Conservation Area and a Wild Trout Enhancement Area. The proposal greatly simplified the regulations' structure compared to what has been used in the past. In addition, the park sought input on the idea of requiring the use of barbless hooks as a way to reduce injury to fishes, especially in popular, heavily fished waters such as the Yellowstone River, Soda Butte Creek, and others. Five public meetings were held in gateway communities. In addition, a period for written public comments remained open for more than five months. A total of 506 comments were received, of which 352 (70%) were in favor of the proposed regulation changes, and 18 (4%) were opposed. Three hundred seventy-six (74%) were in favor of a parkwide policy for barbless hooks and 10 (2%) were against it. Given the strong public support for the proposal, the park plans to implement the regulation changes in 2006.

A total of 506 comments were received, of which 352 (70%) were in favor of the proposed regulation changes.

Anglers caught an estimated 522,258 fish in the park during the 2005 fishing season. Native cutthroat trout remained the most sought-after and caught fish species, comprising 52% of the total catch, followed distantly by rainbow trout (20%), brown trout (13%), brook trout (6%), lake trout (4%), Arctic grayling (3%), and mountain whitefish (*Prosopium williamsoni*; 2%). Overall, native species comprised 57% of the total catch. Yellowstone Lake remained the most popular destination for anglers; an estimated 10,267 anglers fished the lake this year, representing one-quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching 0.71 cutthroat trout per hour of fishing. This catch rate is lower than that of recent years, and follows a six-year downward trend following a record high catch rate in 1998. The angler-reported catch rate for lake trout in Yellowstone Lake decreased for the second consecutive year, to 0.05 fish per hour. This is a positive sign that lake trout suppression efforts are having some success. The park encourages anglers to fish for lake trout on Yellowstone Lake and killing them is required by law; an estimated 5,529 lake trout were removed by anglers from Yellowstone Lake during the 2005 angling season.

Public involvement with the Aquatics Section continued to greatly increase, primarily through the incorporation of many volunteers. A highlight for the year was 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.

The Fisheries Program

Yellowstone National Park Core Mission Priorities

Cutthroat trout and Arctic grayling are considered "core" resources that are known to be at risk within Yellowstone National Park. Priorities developed during NPS Core Analysis exercises include efforts to reduce the threats to, and improve the condition of, these and other at-risk resources. Aquatics Section activities are almost entirely aimed at threat reduction and improvement of the overall condition of native aquatic communities in the park, with special focus on cutthroat trout subspecies. Yellowstone National Park lies at the heart of the present-day distribution of Yellowstone cutthroat trout (Figure 2), and the NPS recognizes the need to preserve existing populations and restore them where feasible.

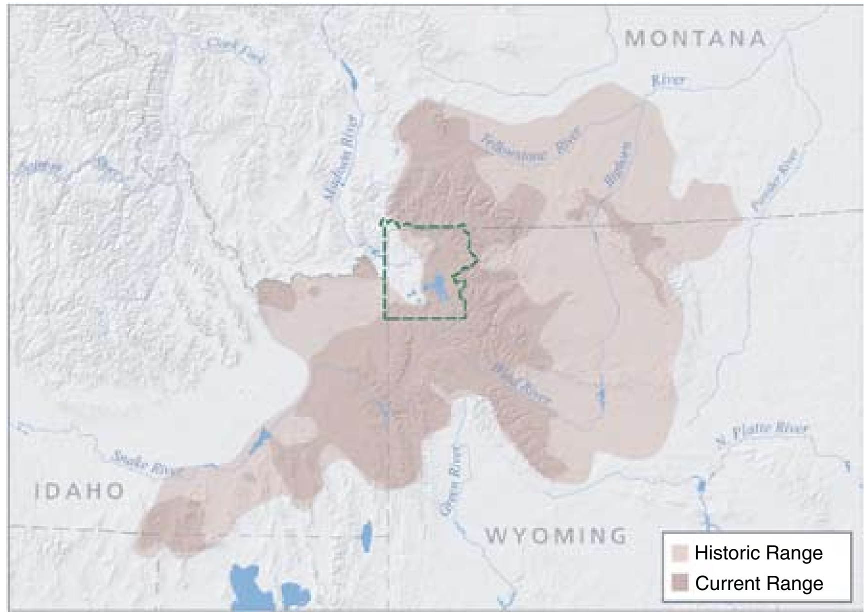


Figure 2. Yellowstone National Park lies at the center of the remaining range of Yellowstone cutthroat trout (adapted from May et al. 2006).

A Model for the YNP Fisheries Program

Over the past decade, the aquatic resources of Yellowstone National Park, and the ecosystems they support, have become seriously threatened by introductions of non-native (from elsewhere in North America) and exotic (from another continent) species. For the foreseeable future, the Aquatics Section will focus the greatest amount of effort possible on conducting activities aimed at supporting its two main priorities: (1) preservation of Yellowstone Lake cutthroat trout, which is the largest remaining concentration of genetically pure inland cutthroat trout in the world; and (2) restoration of fluvial populations of native trout (Figure 3).

The specific activity currently conducted to preserve Yellowstone Lake cutthroat trout is the lake trout suppression program, which is one of the largest non-native fish removal programs occurring in the United States. Activities related to the restoration of fluvial populations of native trout include the environmental compliance process underway for westslope cutthroat trout restoration in the East Fork Specimen Creek watershed. Also, prioritization of streams based on their potential for restoration success has been completed and will allow us to move forward with planning for restoration of Yellowstone

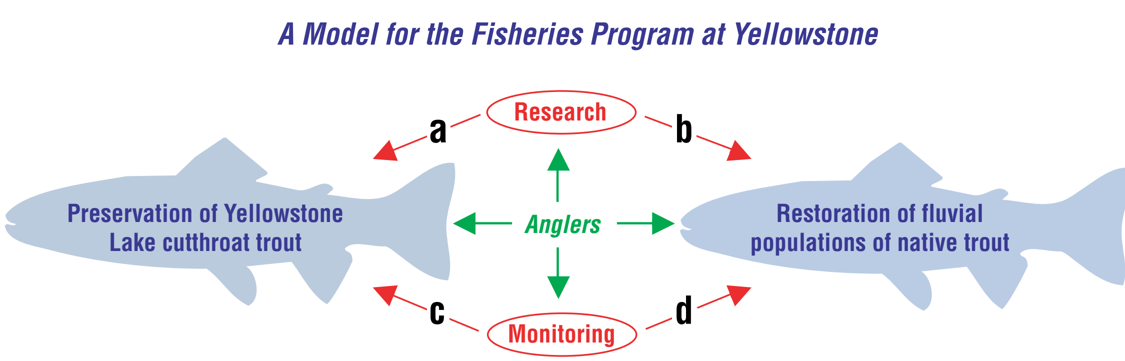


Figure 3. A model for the fisheries program at Yellowstone National Park.

Fisheries technicians Brian Ertel and Michael Ruhl electrofishing an unnamed Grayling Creek tributary.

Goals of the Aquatics Section's research program are to support cutthroat trout preservation and restoration activities.

cutthroat trout in streams of the park's northern range.

The goals of the Aquatics Section's research program are to support and enhance the two primary priorities listed above. Research to support the preservation of Yellowstone Lake cutthroat trout (Figure 3a) includes (1) improving lake trout suppression efficiency through the identification of spawning locations, (2) understanding the ecology of *Myxobolus cerebralis* (the cause of whirling disease) to potentially mitigate for its effects and/or slow its dispersal, and (3) understanding the trophic implications of a cutthroat trout decline in the Yellowstone Lake system. Research to support the restoration of fluvial populations of native trout (Figure 3b) is currently being conducted by partner agencies and universities in the greater Yellowstone region, and will be undertaken within the park when on-the-ground restoration activities begin. Current research to understand the status of fluvial Arctic grayling within the Gibbon River may lead to restoration, or at least preservation efforts for that species.

Monitoring and inventory activities that support the preservation of Yellowstone Lake cutthroat trout (Figure 3c) include the long-term, annual cutthroat trout spawning migration assessment at Clear Creek; the annual visual survey of spawning cutthroat trout at several frontcountry tributaries; and an overall cutthroat trout population assessment within Yellowstone Lake conducted by netting at 11 sites during September each year. Monitoring and inventory activities to support the restoration of fluvial populations of native trout (Figure 3d) include extensive surveys to determine the genetic integrity of cutthroat trout populations; surveys to quantify the geomorphology and habitat conditions of streams supporting existing cutthroat trout conservation populations, and of reaches with the potential to be restored in the future; and surveys of water quality, amphibian, and macroinvertebrate communities and other natural and cultural resources of watersheds, so any potential impacts of future cutthroat trout restorations are well understood.

Anglers are an integral component of the fisheries program model, as they assist with many aspects of native species conservation (Figure 3). For example, anglers contribute to the reduction of lake trout within Yellowstone Lake and they assist with removal of non-native species in streams where they co-exist with native trout. Anglers also provide research assistance; they have tagged Arctic grayling from Grebe and Wolf lakes to help collect information on the dynamics of those fish in that river system. Finally, anglers annually provide an incredible amount of inventory and monitoring information through the Volunteer Flyfishing Program, and through returns of the Volunteer Angler Report Cards provided to all anglers upon their purchase of special use permits required for fishing in park waters.

KIM WEST

Aquatics Section staff, May 2005.

Yellowstone Cutthroat Trout Preservation

Yellowstone Cutthroat Trout Long-term Monitoring

Impacts of historical egg-taking operations and liberal angler harvest regulations for Yellowstone Lake cutthroat trout have long been noted in counts of upstream-migrating fish at Clear Creek (Figure 4). Only 3,161 cutthroat trout ascended Clear Creek in 1954, just two years prior to the cessation of fish culture operations on Yellowstone Lake (Figure 5). With the end of culture operations and the implementation of restrictive angling regulations, the population rebounded during the 1960s and 1970s; 70,105 cutthroat trout were counted at Clear Creek in 1978 (Jones et al. 1979; Gresswell and Varley 1988). Although there was variation among years, the increasing trend in cutthroat trout abundance within Yellowstone Lake was also indicated by the fall netting assessment. An average of 10.0 fish were caught per net by this assessment in 1969; in 1984, 19.1 fish were caught per net.

Contemporary data suggest that a significant decline has occurred in the Yellowstone Lake cutthroat trout population. The number of upstream-migrating cutthroat trout counted at Clear Creek was 917 during 2005 (Figure 5). This count was down from 1,438 in 2004; 3,432 in 2003; and 6,613 in 2002, and was the lowest count made at Clear Creek since 1945, the first year total annual counts were recorded there. The fish-counting station that has been operated since 1999 on Bridge Creek, a small northwestern tributary, was not operated in 2005 because of the near-total absence of cutthroat trout observed there during 2004 (Koel et al. 2005a, 2005b).

During 2003–2005, however, the fall netting assessment (Figure 5) provided some of the first indications that the cutthroat trout population may be responding positively to efforts to remove non-native lake trout from Yellowstone Lake. An average of 7.4, 7.9, and 7.4 fish were caught per net in 2003, 2004, and 2005, respectively. Prior to 2003, there had been a reduction in catch by the fall netting program of 0–21% each year (averaging 11% per year) since 1994, the year lake trout were

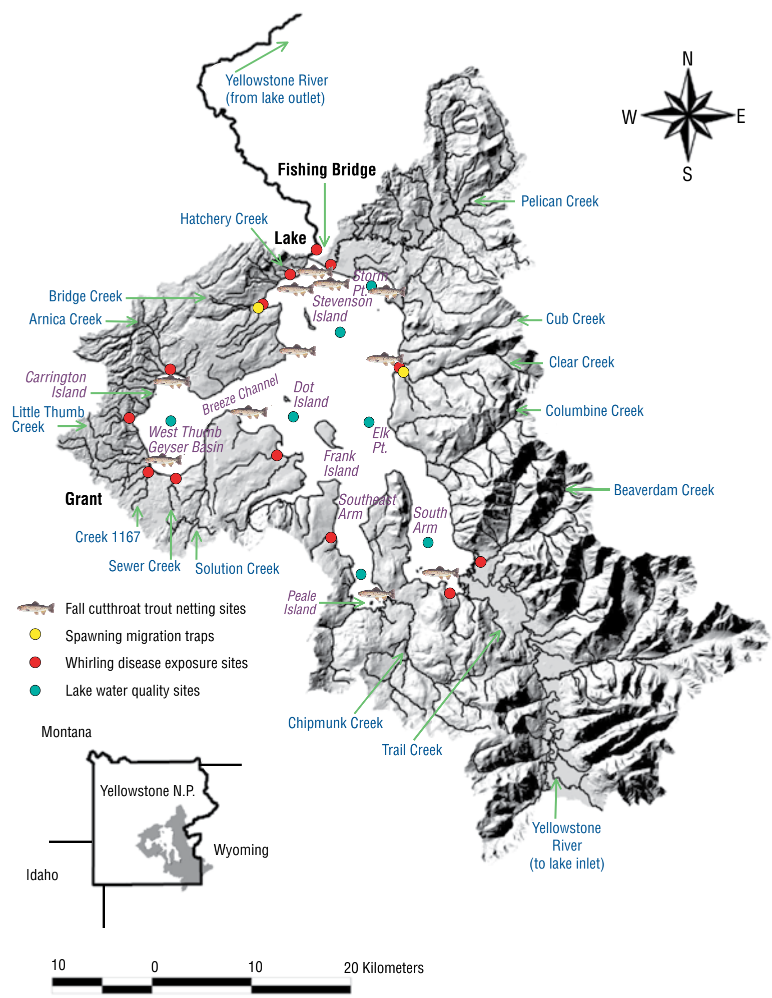


Figure 4. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

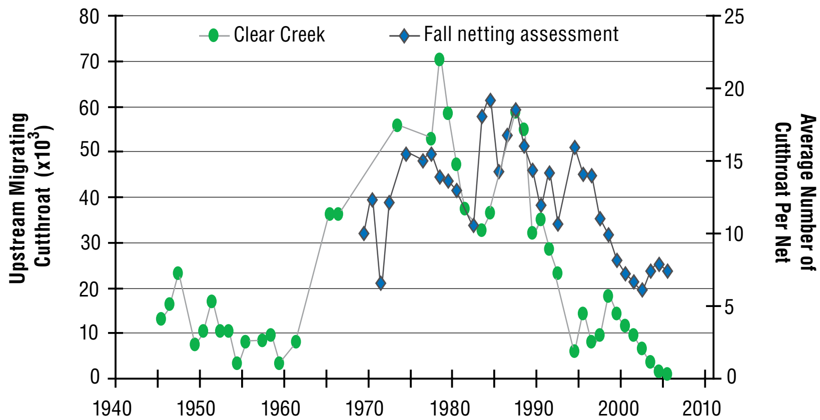


Figure 5. Number of upstream-migrating cutthroat trout counted at the Clear Creek spawning migration trap (1945–2005) and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake (1969–2005).

first discovered in Yellowstone Lake. Although dramatic increases in cutthroat trout within Yellowstone Lake are not yet being seen, the within-lake netting assessment suggests that cutthroat trout abundance has at least somewhat stabilized.

Length–frequency data from the fall netting program, 1997–2005, indicated an increase in length and reduction in numbers of adult cutthroat trout (>325 mm) in Yellowstone Lake (Figure 6). In 2004 and 2005, fewer fish between the lengths of 325 and 425 mm were collected compared to the number collected in earlier years. Historically, most cutthroat trout sampled in spawning tributaries such as Clear Creek were in this size range (Jones et al. 1993). However, an apparent increase in numbers of juvenile cutthroat trout (100–325 mm) has been noted in recent years (2002–2005). Many of these juveniles have been collected in the southern arms of Yellowstone Lake, which may act as refugia for cutthroat trout due to the low numbers of lake trout and low incidence of *M. cerebralis* in these areas (Koel et al. 2006). It is hoped that in the coming years, these juvenile cutthroat trout will recruit to the spawning population and appear in the lake's spawning streams, including Clear Creek. The cutthroat trout are an important component of the Yellowstone Lake ecosystem; impacts to bears and anglers have resulted from the population decline (Koel et al. 2005b).

NPS/BRIAN ERTEL

University of Wyoming graduate research assistant Lusha Tronstad with a Yellowstone cutthroat trout at Clear Creek.

Lake Trout Suppression Program

A total of 36,438 lake trout were removed from Yellowstone Lake in 2005, which is more than were removed during any previous year of the suppression program (Figure 7). Of these, 35,088 lake trout were removed via gillnetting and 1,338 were removed by electrofishing (described below). The ratio of lake trout killed to cutthroat trout sacrificed remained low (only 0.04 cutthroat trout was lost for every lake trout killed). The overall gillnetting effort was maintained at a high level in 2005—7% higher than in 2003, and more than 22% higher than in 2004. Despite these high levels of removal effort, catch per unit of effort rose slightly for the third year in a row, to an average of 1.81 lake trout removed for every 100 meters of net placed in the lake over a period of one night (unit of effort). This catch rate was higher than those of 2003 and 2004, but remained dramatically below levels seen during the early years of the suppression program; in 1998, an average of 5.16 lake trout were caught with each unit of effort.

The majority of gillnets were set to target young lake trout residing at depths greater than those occupied by cutthroat trout (these are termed "control sets"; Figure 8). Small mesh (25–38-mm bar mesh) gillnets were placed on the lake bottom in water typically 40–65 m deep. As in past years, lake trout carcasses were returned to the lake to avoid removing nutrients from the system. On a typical day during June through September, more than 10 miles of control sets were in place fishing for lake trout

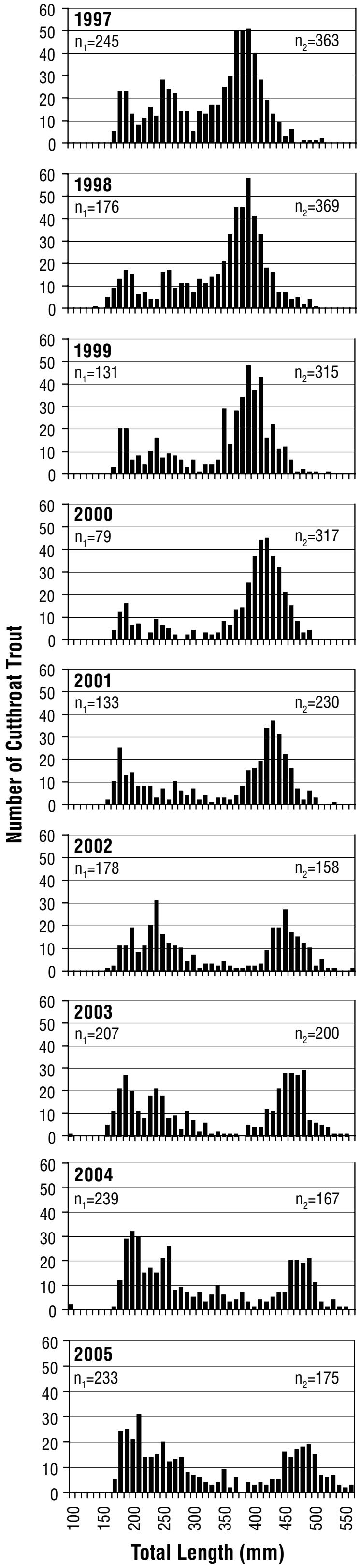


Figure 6. Length–frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake with total number of trout <325 mm (n_1) and >325 mm (n_2), 1997–2005.

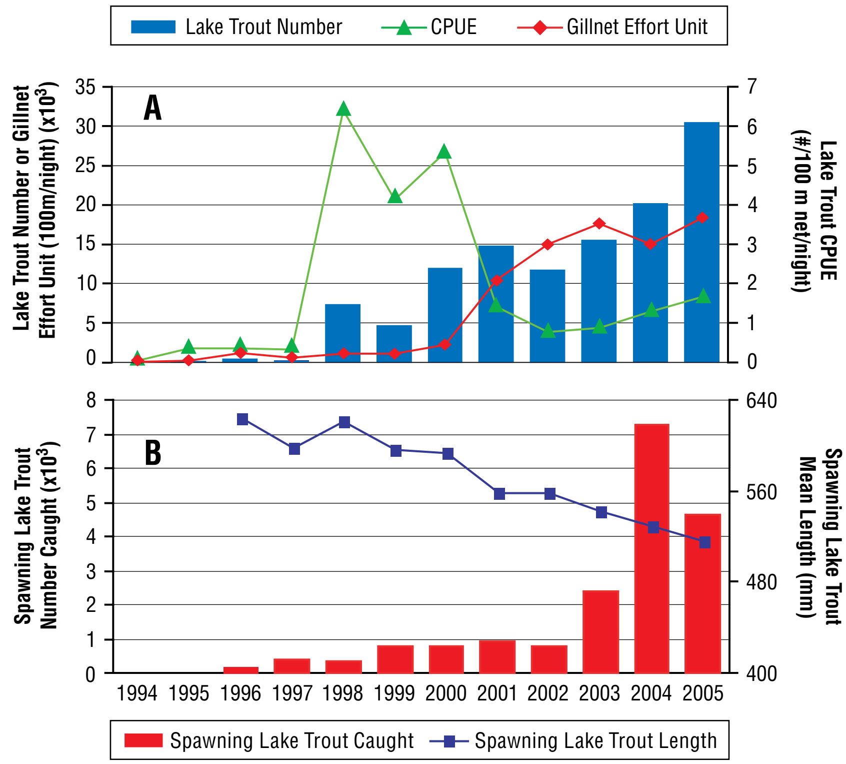


Figure 7. (A) Number of lake trout removed, gillnet units of effort (1 unit = 100 m of net/night) used, and lake trout catch per unit of effort obtained by the lake trout removal program on Yellowstone Lake during the entire gillnetting season, 1994–2005. (B) Number and mean length of mature lake trout removed near spawning locations (Breeze Channel, Carrington Island, Geyser Basin, and Solution Creek) on Yellowstone Lake during late August–early October, 1996–2005.

on Yellowstone Lake (Figure 9). These control sets removed 30,449 lake trout (87% of the total gillnet catch) from Yellowstone Lake. More than 53% of this catch occurred in 25-mm bar mesh gillnets, the smallest size used consistently; 20% of that occurred in October. Apparently, these fish had only recently grown to a size large enough to become entangled in our gear. These increases are likely results of strong year class production in 2003, when large numbers of spawning lake trout were observed.

Lake trout in Yellowstone Lake congregate from late August until early October for spawning. This has proved a prime time to target mature fish. Approximate locations of three spawning areas are known in Yellowstone Lake, and include areas near Carrington Island, west of the mouth of Solution Creek, and northeast of West Thumb Geyser Basin (Figure 4). These spawning areas were intensely gillnetted during the spawning season using net sizes ranging from 38- to 76-mm bar mesh. A fourth area south

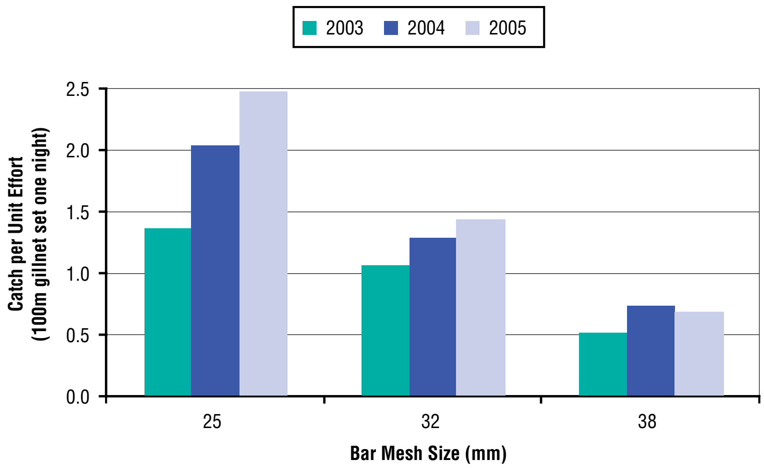


Figure 8. Catch per unit effort (1 unit = 100 m of net/night) by bar mesh size for control nets in Yellowstone Lake, 2005. The increase in catch for the smallest mesh used correlates well with recent increases in catch of mature lake trout during spawning season, indicating strong recruitment.

of Grant Village in West Thumb was targeted for mature fish in 2005. This area proved very productive and may indicate another spawning site in the vicinity. Nets were also deployed in Breeze Channel (a corridor into West Thumb from the lake's main basin) and sporadically throughout West Thumb. With these spawner gillnet sets, 4,568 lake trout were removed from Yellowstone Lake in 2005 (Figure 7). The size of lake trout caught near spawning areas continued to decrease from that observed in previous years. Mean total length (515.7 mm) was more than 12 mm less than that of 2004, and has shown a steady decline since the inception of the program. Also as observed in previous years, the females were larger than males (mean total lengths of 549.8 and 514.5 mm, respectively). The ratio of male-to-female spawning lake trout caught was 1.60:1 in 2005.

For the second consecutive year, electrofishing was used to remove mature lake trout congregated for spawning. The U.S. Fish and Wildlife Service (Ahsahka, Idaho) again allowed Yellowstone to use their electrofishing boat. With this assistance, the Carrington Island site was electrofished on eight nights during September and an additional 1,338 lake trout were removed from the population.

Despite high catches of both young and adult (spawning) lake trout, there is reason to be optimistic about the impacts the program is having. Overall catch rate of lake trout remains low, and nearly 139,000 lake trout in all have been eradicated from Yellowstone Lake. If left

NPS/PHILIP DOEPKE

Freedom skipper Don Wethington removes lake trout from a gillnet. (Freedom in roman)

NPS/PHILIP DOEPKE

Fisheries technician Brad Olszewski prepares gillnets on board the Freedom.

NPS/PHILIP DOEPKE

NPS Fisheries technician Nicole Schamberry with a gillnetted lake trout.

in the lake, each lake trout (and each surviving offspring) could have consumed at least 41 cutthroat trout each year (Ruzycki et al. 2003). Therefore, the suppression program has saved an incredibly large number of cutthroat trout. The mean size of mature lake trout continues to decline and there appear to be fewer older, larger, and therefore most detrimental, lake trout in the system each year. Another encouraging sign is the decline noted in angler catch-per-hour of lake trout for the second consecutive year. In past years, this index has been a good indication of the strength of the following year's spawning numbers. However, continued increases in overall catch rate by gillnetting underscore the importance of maintaining efforts to keep this predatory population controlled. Lake trout densities in the West Thumb remain high, and a serious threat to the Yellowstone cutthroat trout.

Lake Trout Growth Potential

To determine age and growth of lake trout, a sample of 404 fish was collected in July–early October 2005. Otoliths were collected for aging, maturity levels were assessed, and total length was measured for each fish. Immature lake trout comprised 34% (138) of fish collected, and females comprised 46% (184) of the sample. Ages ranged from 1 to 16 years old, and total length ranged from 190 to 902 mm. Using this information, an age-length key was applied to all lake trout collected from spawning areas in Yellowstone Lake (Figure 10).

The oldest lake trout sampled was a 16-year-old mature male captured in Breeze Channel on September 29, in 19 m of water. The heaviest lake trout removed from Yellowstone Lake in 2005 was also the heaviest ever recorded; this mature female was caught in Breeze Channel, weighed 22.5 lbs, and was just under one meter in total length (921 mm). This lake trout was caught in a gillnet set in 20 m of water on September 23. Neither of these two fish had spawned in 2005 when they were captured.

Lake trout are known to be a long-lived fish species; a specimen 65 years old was reported in Canada's Northwest Territories (Behnke 2002). However, less than 2% of the spawning

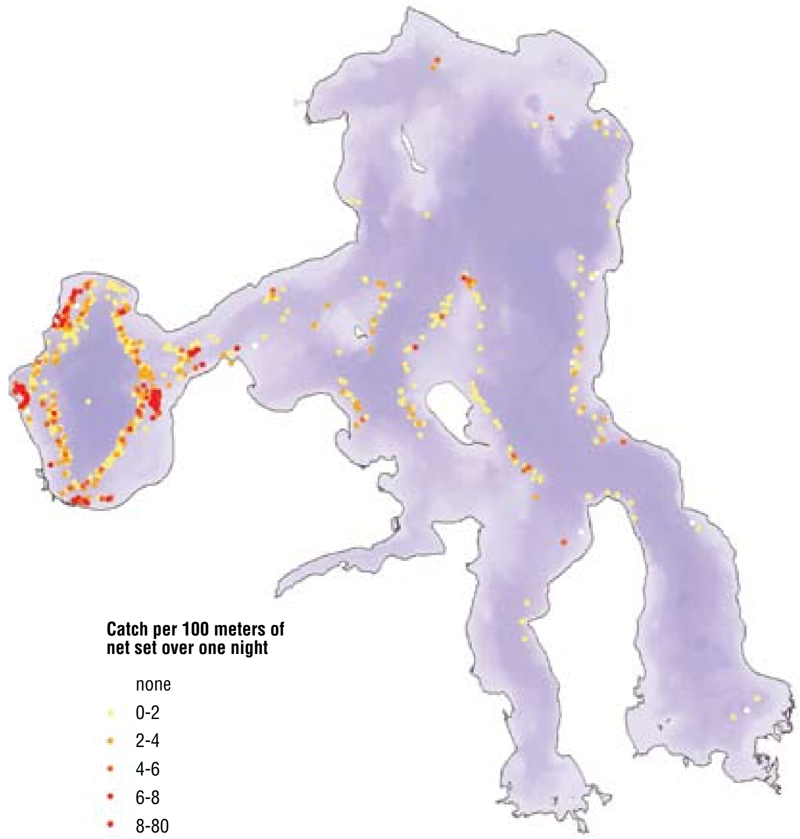


Figure 9. Locations of gillnets set to remove non-native lake trout from Yellowstone Lake in 2005.

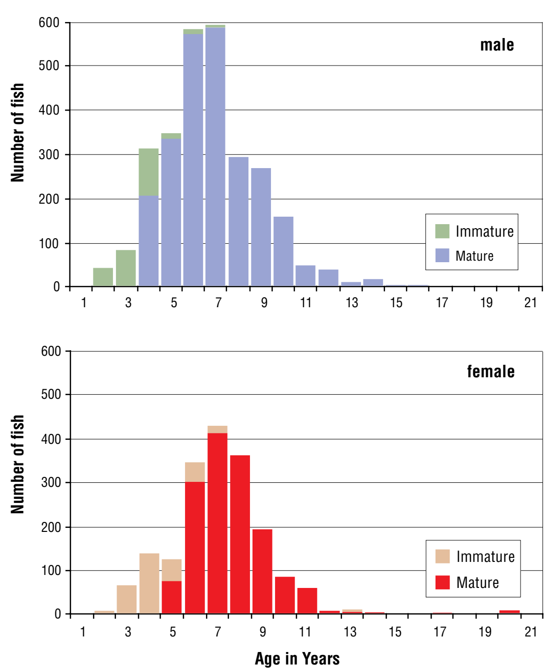


Figure 10. Relative abundance, by estimated age, of male and female lake trout caught on or near spawning areas late August through early October 2005.

NPS/PHILIP DOEPKE

The Yellowstone Center for Resources lake trout gillnetting boat Freedom *at Bridge Bay.*

Surveys using hydroacoustic (fish sonar) gear will be used to assess seasonal shifts among lake areas, and potentially, congregations near spawning sites in the fall.

lake trout population of Yellowstone Lake is more than 13 years old. Our aging information suggests that this is a relatively young, exploited population. Many of the adults being caught were likely attempting to spawn for the first time. Aging structures will continue to be collected in future years, and ratios of older lake trout to younger lake trout will continue to provide evidence of the effectiveness of the suppression program.

Goals to Improve Suppression Efficiency

Results of the lake trout suppression program clearly emphasize the importance of locating and targeting additional spawning areas in Yellowstone Lake, if they exist. Although approximately 5% of the total effort was expended on gillnet sets in spawning areas during 2004 and 2005, they accounted for 27% and 13% of the total catch for those years, respectively. (It should be noted, however, that spawner sets are checked daily, and require a much greater time commitment than do control sets, checked weekly or even bi-weekly.) Furthermore, the spawning lake trout, due to their size, are likely more detrimental to cutthroat trout than those caught in the smaller-mesh size control nets.

Given the importance of spawning areas for targeting lake trout, we have initiated research to identify other currently unknown or potentially new potential spawning areas throughout Yellowstone Lake. Substrate size and distribution data are being collected using an underwater video system in areas where computer models predict spawning habitat may exist. The video will also enable staff to obtain exact timing of lake trout spawning and delineate boundaries of known spawning sites. Surveys for lake trout using hydroacoustic (fish sonar) gear will be used to assess seasonal shifts among lake areas and, potentially, congregations near spawning sites in the fall. Areas that have a high potential for supporting spawning can be monitored in future years; if spawning lake trout are found at those sites, they can be included in the suppression program as key locations for gillnetting or electrofishing.

Restoration of Fluvial Populations of Native Trout

Westslope Cutthroat Trout Restoration Goals

The purpose of westslope cutthroat trout (WCT) restoration is to reverse the declining trend in WCT genetic integrity and ensure the persistence of native, genetically pure WCT within Yellowstone National Park. There is an urgent need to isolate remote headwater habitats, completely remove all non-native and hybridized fishes, and restore genetically pure WCT. Goals of the project are to (1) reduce long-term extinction risk for WCT within Yellowstone, and (2) provide a secure refugium for genetically pure WCT. It is proposed that genetically pure WCT be reintroduced in East Fork Specimen Creek (EFSC) and introduced into High Lake to secure this subspecies within additional waters of Yellowstone. Work planned for 2006–2007 includes (1) completing the NEPA process, (2) beginning the removal of non-native fish within High Lake and the introduction of WCT and development of a refugium there, (3) creating an artificial barrier of logs and other natural materials at the downstream reach of EFSC to prevent movement of non-native and hybridized trout into the restoration area, and (4) beginning the removal of non-native and hybridized fish within EFSC.

NPS/DAN MAHONY

Pool habitat of the East Fork Speciman Creek, the location for westslope cutthroat trout restoration.

Our long-term goals include the creation of a barrier to upstream movement of fish from the Gallatin River in the area of the Highway 191 road bridge, followed by a restoration of the North Fork and mainstem Specimen creeks. If this were possible, the result would be an entire watershed restored to native westslope cutthroat trout in the park. Grayling Creek, Duck Creek, and other watersheds within the natural, historic range of WCT are also being evaluated and seriously considered for restoration within the park.

Grayling Creek, Duck Creek, and other watersheds within the natural, historic range of WCT are also being evaluated and seriously considered for restoration within the park.

Westslope Cutthroat Trout Status

Unlike many other areas within the historical range of WCT, habitat degradation and excessive harvest rates by anglers were not responsible for the decline of this subspecies in park waters. Rather, the extensive stocking and subsequent establishment of populations of non-native competing species, including brook trout and brown trout, and interbreeding of rainbow trout and YCT during the first half of the twentieth century, led to a serious reduction in the park's resident WCT, and in their near extinction from most park streams by the 1930s (Varley and Schullery 1998). Survey efforts from 1994 to 2003 were directed toward obtaining additional information from

In 2005, a genetically pure WCT population was found in an isolated, unnamed tributary to Grayling Creek.

what was thought to be the only genetically pure WCT population remaining in the park, located in North Fork Fan Creek. Life history (radiotelemetry) studies (Zale 2003), habitat inventories, macroinvertebrate assessments, and water quality surveys were completed on this system, and the most appropriate site for an in-stream fish barrier was selected for stabilization and long-term protection of the WCT there. However, NPS plans to assist with a WCT broodstock development program at the Sun Ranch in the Madison River Valley were suspended in 2003, when additional genetic analyses by the Wild Trout and Salmon Genetics Laboratory, University of Montana, revealed previously undetected rainbow trout alleles in the North Fork Fan Creek donor population (Koel et al. 2004). Through collaboration with the Idaho Department of Fish and Game, Eagle Fish Health Laboratory, we obtained a "second doctor's opinion" in 2005 regarding the status of the North Fork Fan Creek WCT genetic status. Eleven markers (10 nuclear and 1 mitochondrial) were examined from 35 fish obtained in the upper reaches of North Fork Fan Creek in 2003. Only a single rainbow trout allele was detected among a total of 570 tested, yielding a result of 99.82% genetic purity among alleles and 97.1% genetic purity among individuals. The North Fork Fan Creek WCT are now considered a "conservation population," but not a "core population" as originally thought. Consequently, the NPS re-evaluated the park's WCT restoration program. Other watersheds originally supporting WCT but now containing highly-hybridized populations were assessed to determine which might provide the highest probability for successfully restoring a viable, genetically pure population of WCT in the park. The East Fork Specimen Creek has been chosen as the location for our first WCT restoration in the park (described below).

Genetically Pure Population Discovered within the Park

Following the confirmation of WCT hybridization in North Fork Fan Creek, it was thought that all genetically pure WCT populations had vanished from Yellowstone. However, in June 2005, fisheries biologists from the U.S. Forest Service (USFS) were informed by David Klatt, a West Yellowstone resident, and Chad Kashmier, a local USFS law enforcement ranger, of an isolated cutthroat trout population in an unnamed tributary of Grayling Creek

Headwater springs in the Gallatin National Forest (top) give rise to approximately 2 km of pristine stream habitat within Yellowstone (middle), supporting >700 WCT (bottom).

Table 1. Estimated extent of range and current genetic status of cutthroat trout in Yellowstone National Park.

	All cutthroat trout		Yellowstone cutthroat trout		Westslope cutthroat trout	
	km of stream	% of total stream lengths	km of stream	% of total occupied stream lengths	km of stream	% of total occupied stream lengths
Extent of range						
Historically fishless	5,044	48%	4,096	48%	948	48%
Cutthroat trout present	5,477	52%	4,446	52%	1,031	52%
Total	10,521		8,542		1,979	
	km of stream	% of total stream lengths where all cutthroat were present	km of stream	% of total stream lengths where YCT were present	km of stream	% of total stream lenths where WCT were present
Current genetic status						
Extirpated	371	7%	0	0%	371	36%
Pure	3,340	61%	3,338	75%	2	0%
Hybridized	1,766	32%	1,108	25%	659	64%

A roadbed placed prior to any stocking of rainbow trout has served to isolate and preserve WCT in the unnamed Grayling Creek tributary.

Abandoned roadbed along Grayling Creek.

(Madison River drainage). The USFS, in turn, informed Aquatics Section staff. Park biologists have subsequently determined that more than 700 trout reside there, and through collaboration with the Idaho Department of Fish and Game's Eagle Fish Genetics Lab, confirmed that the population is 100% genetically pure WCT, that is, a "core population" suitable for use as source fish for restoration projects in the upper Missouri River drainage (Ruhl and Koel 2005). The subterranean nature of the unnamed tributary and placement of a roadbed prior to any introductions of rainbow trout to Grayling Creek have served to isolate and preserve the genetic integrity of the WCT population there.

Recent analyses using geographic information systems (GIS) suggested that approximately 1,031 stream kilometers within the park originally supported genetically pure WCT (Table 1). They have been extirpated from an estimated 36% of stream (371 km) and exist in hybridized form in most of the remaining 64% of stream (659 km). At present, the only known genetically pure WCT population in the park exists in approximately 2 km of habitat in the unnamed tributary to Grayling Creek.

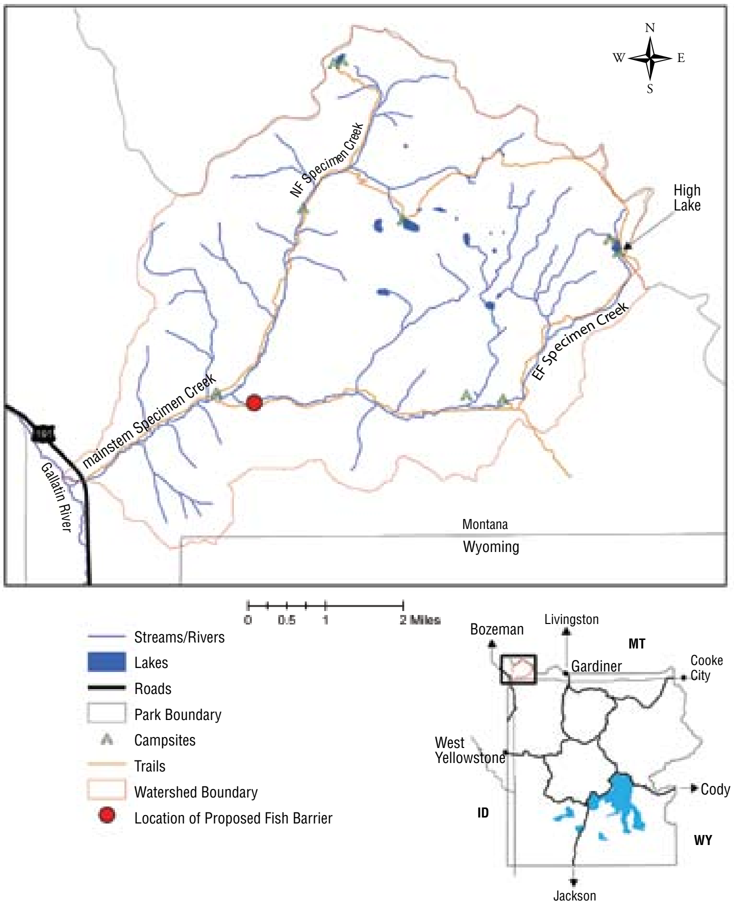


Figure 11. The Specimen Creek watershed in northwestern Yellowstone National Park.

East Fork Specimen Creek as a Focus for Restoration

A requirement for westslope cutthroat trout restoration is that the watershed be large enough to support a population that would remain resilient when faced with natural disturbance by drought, fire, and/or flood. The EFSC watershed meets these criteria. This watershed originates in the high, rugged Gallatin Mountain Range (Figure 11). Several small headwater lakes and spring seeps feed this fork as well as North Fork Specimen Creek (NFSC) and several smaller, unnamed tributaries. Due to natural barriers to fish movement upstream, these lakes were historically fishless. In 1937, however, the NPS stocked these lakes with YCT (which are not native to the upper Missouri River drainage) (USFWS 1971). These fish, over time, have migrated downstream, while rainbow trout from the Gallatin River have moved upstream into the watershed. Due to interbreeding among the species, genetic integrity of the native WCT has been severely compromised; the EFSC watershed currently supports a highly hybridized (<80% pure) WCT population (Koel et al. 2003). Because the EFSC watershed WCT are not considered a "conservation population" (which requires more than 90% genetic purity), the fish are prime candidates for complete removal and replacement with a genetically pure strain.

High Lake, situated at the subalpine headwaters of EFSC, comprises 7.1 surface acres, has a maximum depth of 19.4 feet, and rests at 8,500 feet (2,600 m). A single outlet stream on the south shore serves as a primary source of flows for the EFSC. A natural waterfall (15 feet height) approximately 200 yards downstream from the outlet of High Lake prevents fish from ascending the drainage, and is the reason High Lake was historically fishless. For introduced WCT, High Lake would serve as a significant buffer to many watershed-scale natural disturbances, such as wildfire, drought, and flood. Unlike EFSC or other similar stream systems, the lake environment is not prone to high and abrupt variation in flows, water temperatures, and other environmental conditions that have a strong influence on survival of cutthroat trout. High Lake, over time, would provide a secure refugium and a source of WCT for the EFSC through downstream emigration by fry and adults.

NPS/ANNA VARIAN

Fisheries technician Brian Ertel at the location for the East Fork Specimen Creek fish barrier.

Of all the lakes in the Specimen Creek watershed stocked with YCT in 1937, only High Lake continues to support YCT. The Bozeman Fish Hatchery was the source for these stocked YCT, and the current population within High Lake is not a unique form warranting preservation. They have resulted in the degradation of WCT within the EFSC watershed, and their removal is required as a part of any WCT restoration attempts there. Many other high mountain lakes in the Intermountain West presently contain stocked YCT populations, including lakes within protected national park or wilderness areas. Due to the significant productive potential of High Lake and its greater overall contribution of flow (habitat availability) and trout abundance, EFSC was chosen over the North Fork as the focus for WCT restoration within the park.

During July 2005, the environmental compliance process was initiated to lead toward potential restoration of WCT in Specimen Creek. An interdisciplinary team was assembled and resource issues were identified. Public scoping for the project occurred October 25–November 30, 2005, and included public meetings in Bozeman (November 16) and West Yellowstone, Montana (November 17). Writing of the draft environmental assessment was initiated in late 2005, with plans for NPS and public review by spring/early summer 2006 (Koel and York 2006).

Fisheries biologists Pat Bigelow (left) and Dan Mahony leaving the Specimen Creek trailhead for High Lake. Fisheries horses (left to right) are Ethan, Pat, Sammy, and Scotty.

NPS/MIKE RUHL

NPS Fisheries technician Kevin Olsen and Supervisory Fisheries Biologist Todd Koel prior to returning westslope cutthroat trout netted from the unnamed Grayling Creek tributary.

Sources for Genetically Pure Westslope Cutthroat Trout

The genetically pure WCT population in the unnamed Grayling Creek tributary provides an incredible opportunity for enhancement of this subspecies within Yellowstone National Park. This isolated WCT population has many aspects of an unexploited fishery, including a wide range in size structure (Ruhl and Koel 2005). Given the life history strategy of these fish, which must involve only a very limited amount of movement among habitats each year, the population would be an excellent choice for replication into similar, headwater systems elsewhere in the park, such as EFSC.

Additional potential sources of genetically pure WCT for the proposed project include recently developed broodstock at the Sun Ranch in the Madison River Valley, Montana; the MO12 WCT broodstock held at Washoe Park State Trout Hatchery (Anaconda, Montana), and, potentially, the WCT population that remains in North Fork Fan Creek within the park (Koel et al. 2004). Park staff will continue to monitor the North Fork Fan Creek WCT population to track any potential changes there in genetic purity. Analyses have indicated 99.8% genetic purity among alleles examined for rainbow trout introgression in North Fork Fan Creek.

For introduced WCT, High Lake would serve as a significant buffer to many watershed-scale natural disturbances, such as wildfire, drought, and flood.

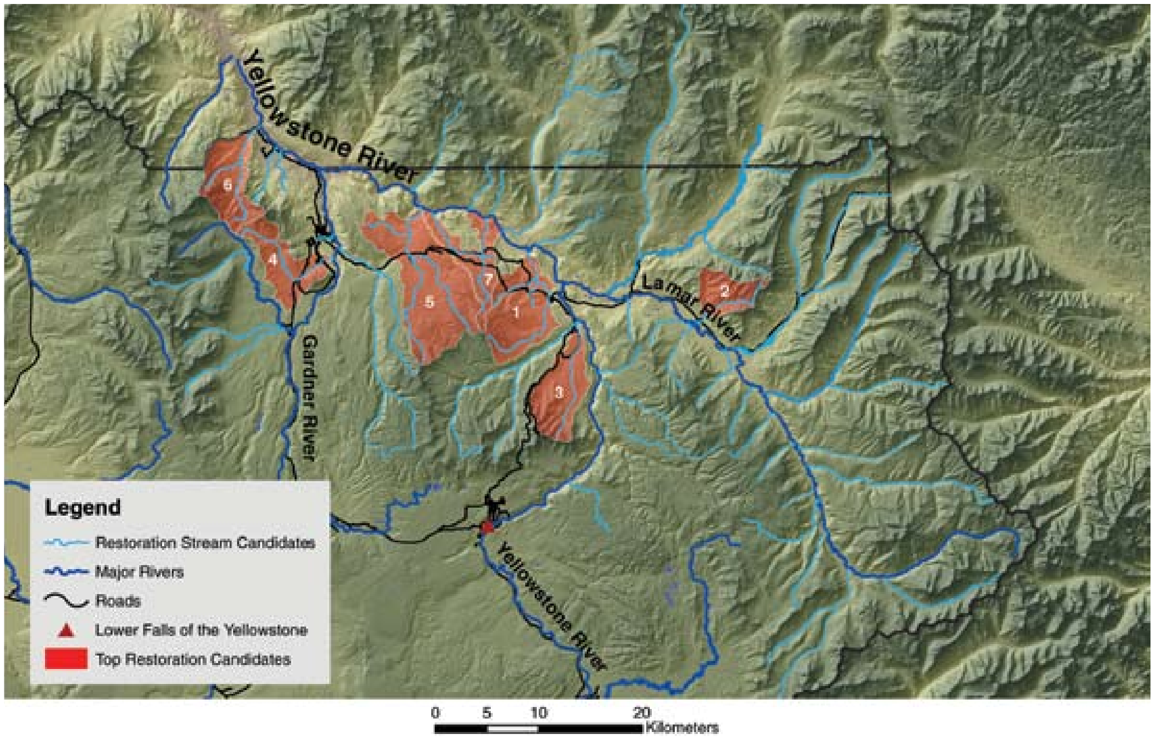


Figure 12. Yellowstone's northern range, including major rivers and tributary watersheds considered for potential cutthroat trout restoration. Watersheds receiving highest priority from prioritization ranking are highlighted in red and numbered by rank: 1) Elk Creek complex, 2) Rose Creek, 3) Antelope Creek, 4) Glen Creek, 5) Blacktail Deer Creek, 6) Reese Creek, 7) Oxbow/Geode Creek complex.

The overall goal for fluvial YCT restoration within Yellowstone National Park is to restore YCT to streams in the park's northern range watersheds.

Yellowstone Cutthroat Trout Restoration Goals

The Yellowstone Lake basin and the Yellowstone River upstream of the upper falls at Canyon have long stood as one of the last strongholds of Yellowstone cutthroat trout. Despite fluctuations in abundance attributed to early egg-taking operations and intensive angling, the cutthroat trout population in Yellowstone Lake remained relatively strong into the early 1980s. Problems that arose were addressed through changes in management policies, that is, cessation of egg-taking operations and implementation of restrictive angling regulations. Despite widespread introductions of non-native salmonids into many other park waters, the Yellowstone Lake basin largely avoided the establishment of species known to compete or hybridize with Yellowstone cutthroat trout. However, the discovery of lake trout in 1994, and the subsequent discovery of whirling disease four years later, have left the future of Yellowstone cutthroat trout in the Yellowstone Lake basin in question (Koel et al. 2005).

These developments have led managers to seek ways to increase the prevalence of genetically pure YCT within the park outside of the Yellowstone Lake basin. The overall goal for fluvial YCT restoration within Yellowstone National Park is to restore YCT to streams in the park's northern range, that is, the Gardner, Lamar, and lower Yellowstone river watersheds (downstream of the lower falls). The northern range is comprised of several major watersheds with more than 50 named streams and hundreds of unnamed tributaries (Figure 12). Streams of the northern range were chosen for restoration, in part, because of their accessibility; the logistics for completing stream restorations in this region are very good. In addition, Middle Creek, a tributary that enters the North Fork Shoshone River near the East Entrance, may provide an opportunity for YCT restoration. Specific objectives for 2006–2008 are to (1)

finalize the prioritization of watersheds and specifically identify those that provide the greatest likelihood of success for restoration; (2) complete amphibian, invertebrate, water quality, wetland/rare plants, and other resource surveys of watersheds chosen for YCT restoration; and (3) complete the required planning documents and NEPA process that will lead to on-the-ground YCT restoration. After restoration has begun, the newly created YCT populations will be available for future restoration efforts within Yellowstone National Park and elsewhere.

Yellowstone's Northern Range Restoration Initiative

The rivers and associated tributaries of the northern range once represented a vast amount of YCT habitat. However, with the exception of the upper Lamar River and a few isolated waters such as upper Soda Butte Creek and Pebble Creek, almost all of the medium and large streams in this region now support populations of non-native salmonids or rainbow-cutthroat trout hybrids. To date, a paucity of data has inhibited our complete understanding of the status of YCT on the northern range.

In order to identify streams where conservation action is necessary, or where restoration efforts would have a high probability of success, initial efforts in 2005 included the centralization of information regarding current and historic species composition; genetic integrity of cutthroat trout present; current fish distribution; presence and location of existing or potential barriers to upstream fish movement; road and trail accessibility or other logistical components; and length, flow, and physicochemical information for nearly all named streams on the northern range. The first step was a review of historical information held by the Aquatics Section. The parameters listed above were placed into a spreadsheet containing 58 streams from Yellowstone's northern range. From this spreadsheet, data gaps were identified and sampling priorities established. The remainder of the 2005 season was spent filling in the most important pieces of missing data through field investigations.

One focus of northern range restoration initiative activities is Rose Creek, a tributary of the Lamar River at the Lamar Buffalo Ranch.

NPS/MIKE RUHL

The falls on Amphitheater Creek create a natural fish barrier.

Field Surveys Document Remaining Populations

Field investigations sought to answer four basic questions: (1) What species, if any, are present in the stream? (2) What is the genetic status of any cutthroat trout found within the stream? (3) What is the upstream extent of fish distribution in the watershed? and (4) Are any existing or potential barriers to upstream fish movement present in the system? Staff walked streams, locating potential barriers and electrofishing to determine fish distributions. Fin clips were taken from all fish resembling cutthroat trout until a sufficient sample size (n = 30) to determine the genetic status of

NPS/MIKE RUHL

Cutthroat trout from the Oxbow/Geode Creek complex.

JORDAN ALLISON

Yellowstone cutthroat trout from Rose Creek.

each population was reached. The up- and downstream side of every suspected natural or human-created barrier to fish movement was sampled. This method identified barriers above which naturally or artificially established populations do not exist.

Amethyst Creek, Amphitheater Creek, Crystal Creek, Elk Creek, Geode/Oxbow Creek, Lost Creek, Lupine Creek, Pebble Creek, Reese Creek, Rose Creek, and Yancey Creek were sampled in 2005. Barriers not previously shown in Yellowstone's fish barrier database were identified on Amphitheater, Elk, Lost, and Yancey creeks, where upstream extent of fish distribution was limited to the portions of the streams below the barriers. Extent of fish distribution was also documented for Rose and Reese creeks. A previously undocumented and potentially pure cutthroat population was discovered in the Oxbow/Geode Creek complex. These fish are likely the result of stockings conducted in 1922–1924 (Varley 1981). It is not known if these waters were historically fishless or what the broodsource of the stockings was. However, it does appear that the portion of Geode Creek upstream of the Grand Loop Road is isolated by the existing road culvert. Because the road pre-dates the stocking record, it is likely that if the broodsource was genetically pure, then the population that currently occupies the stream has retained that status. What is uncertain is which subspecies is represented in the Oxbow/Geode Creek complex, as Dr. Robert Behnke has initially identified the trout, through images provided, as WCT. Sufficient genetic samples have been collected from locations above and below the Grand Loop Road to determine whether the fish are YCT or WCT, and if hybrids are present in the population; analysis is pending.

A second previously undocumented and potentially pure cutthroat population was discovered in the Oxbow/Geode Creek complex in 2005.

NPS/MIKE RUHL

Fin clips are taken to determine genetic status of trout populations. Fin clipping does not limit life quality or expectancy of the fish.

Prioritization of Northern Range Watersheds

All of the watersheds included in the Northern Range Restoration Initiative that do not already contain pure-strain YCT are being considered as candidates for restoration. Many of the parameters that influence the likelihood of successful restoration are considered in the database that is being compiled. Data collected through library research, GIS analysis, and field investigations were used to develop a prioritization matrix containing a set of 12 parameters, all given equal weight in the prioritization analysis. Several systems have already been identified as candidates providing a high probability of restoration success. These include Reese Creek, Rose Creek (watershed above the Lamar Ranger Station), Blacktail Deer

Creek, and Elk/Yancey/Lost creeks (Elk Creek complex). No waters that have retained their original, historically fishless condition will be considered as a candidate for YCT restoration.

Arctic Grayling Status within the Gibbon River

In Yellowstone National Park, fluvial (stream-resident, year-round) Arctic grayling originally existed in the Madison River, and in the Gibbon and Firehole rivers below the falls of these streams (Kaya 1992; 2000). Non-native brown trout introductions and the creation of Hebgen Lake quickly led to what appeared to be the complete loss of fluvial Arctic grayling within the park by the mid-1900s.

In recent years, both anglers and electrofishing surveys have consistently found Arctic grayling throughout the Gibbon River, leading to a re-evaluation of the status of fluvial Arctic grayling within Yellowstone National Park. In fact, anglers have reported catching grayling in the Gibbon River in all but one year since 1979. Determining whether or not a viable population of fluvial Arctic grayling exists, however, is somewhat complicated because in the 1920s, adfluvial (lake-dwelling) Arctic grayling were intentionally stocked into historically fishless Grebe and Wolf lakes, at the headwaters of the Gibbon River. Although grayling are now regularly found in the Gibbon River above and below all three of its barriers to upstream fish movement, including Gibbon Falls, it is not known if these fish are truly fluvial or if they are merely strays moving downstream from the headwater lake populations. The Aquatics Section has initiated research with the specific goal of determining whether there is a viable population of fluvial Arctic grayling within the Gibbon River system. Work planned for 2005–2006 includes (1) tagging grayling and tracking movements of juvenile and adult fish at Grebe and Wolf lakes and in the mainstem Gibbon River above and below Gibbon Falls; (2) conducting intensive surveys for spawning grayling during late May, June, and early July in the Gibbon River and suitable tributary streams; (3) conducting intensive surveys for young-of-the-year (YOY) grayling using fry traps from June to October in the Gibbon River; and (4) relating spatial dynamics and any observed variation of adult/juvenile/YOY grayling to thermal, flow, and other environmental characteristics of the Gibbon River system.

This work is being completed through a collaborative effort with the U.S. Geological Survey's Montana Cooperative Fisheries Research Unit. Results will have immediate relevance for the park's management and conservation of fluvial Arctic grayling, if indeed they are found to persist here.

One of 12 sites along the Gibbon River where fry traps were placed in 2005 to capture Arctic grayling.

NPS/BILL VOIGHT

Arctic grayling in Gibbon River.

Although grayling are now regularly found in the Gibbon River, it is not known if these fish are truly fluvial or if they are merely strays moving downstream from the headwater lake populations.

Frontcountry Fishery Inventories

NPS/DAN MAHONY

Yellowstone cutthroat trout from Soda Butte Creek.

Soda Butte Creek Long-term Monitoring

Soda Butte Creek has historically been sampled regularly in the park. Since the mid-1960s, park fishery personnel have collected information about the resident fish and macroinvertebrates there to monitor responses, if any, to reduction in water quality arising from ongoing inputs of mining-associated pollutants. With few exceptions, annual monitoring has occurred at a site near the park's northeast boundary since 1984.

Cutthroat trout abundance in Soda Butte Creek has varied considerably from year to year, and length-frequency data suggest that at least three size/age groups have consistently been caught. Average size of captured trout was typically between 160 and 175 mm; few individuals were longer than 300 mm (Figure 13). Although the cutthroat trout in Soda Butte Creek have been protected from harvest since 1996, with the adoption of total catch-and-release regulations, few fish longer than 330 mm have been caught in recent years. Comparison of population length structure prior to 1996 with the most recent five-year sampling period suggests that the trout's response to the catch-and-release regulation in this stream has been minimal. Similar findings for rainbow trout were found in Great Smoky Mountains National Park and suggested that factors other than angler harvest (particularly, stream productivity) might be most important in regulating fish populations (Kulp and Moore 2005). Estimated abundance of cutthroat trout in Soda Butte Creek has increased since 2002, but most of the increase appears to be occurring in younger age classes that were previously not affected by the allowable harvest regulation.

A shift in stream channel location further confounds interpretation of long-term population responses in Soda Butte Creek. Downcutting, and the creation of a new stream channel after the record-high stream flows in 1997, resulted in the loss of approximately half of the old monitoring section. The new channel has undercut numerous trees that have been incorporated into the stream. This large woody debris appears to be a preferred habitat of young cutthroat trout during the colonization of the new stream channel area.

Although non-native brook trout had previously been known to reside in the headwater portions of Soda Butte Creek (Shuler 1995), they were not found in the park until 2003. Montana Fish, Wildlife and Parks chemically removed the source population of brook trout from a small upstream tributary in 2004, and re-treated it again in 2005. Although suppression by electrofishing within the park since 2003 has yielded brook trout each year (Figure 13), evidence of a widespread, robust population is lacking. The upstream chemical removal project appears to have reduced the brook trout population to where only an

NPS/DAN MAHONY

Fisheries crew electrofishing Soda Butte Creek in 2005.

occasional individual is now found in the park.

Cutthroat trout collected during brook trout electrofishing suppression were sampled for genetics analysis. Initial results indicate that the cutthroat trout have been recently hybridized with rainbow trout (Olson 2005). In 2005, NPS biologists also collected fin clips from 40 cutthroat trout upstream from Icebox Canyon to obtain the current genetic status of the population there. Although these fish have not yet been analyzed, at least one had the physical appearance of a hybrid.

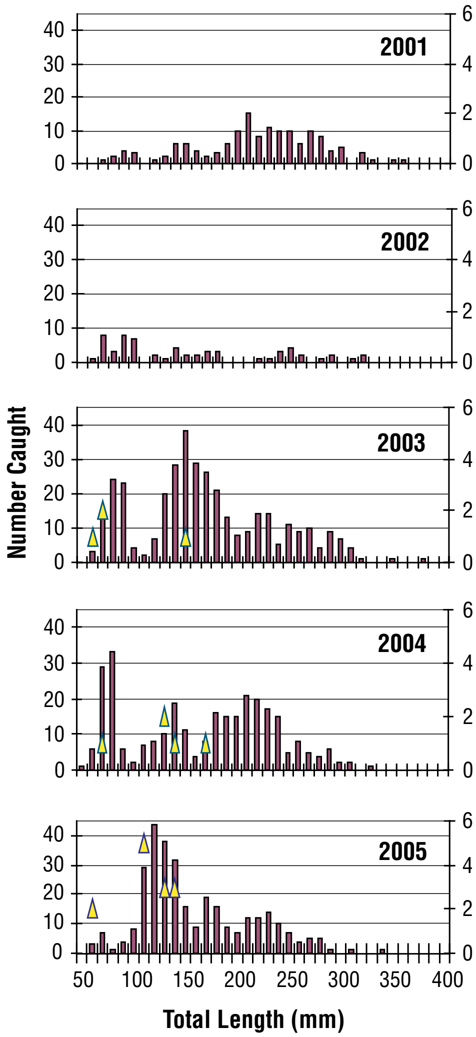


Figure 13. Number of Yellowstone cutthroat trout and brook trout captured in the Northeast Entrance sample section of Soda Butte Creek, 2001–2005. Solid bars denote 10-mm length groups for cutthroat trout. Triangular markers denote number of brook trout captured by length group and year.

Monitoring Associated with Road Reconstruction

Because large sections of many park roads were intentionally located adjacent to stream corridors, road reconstruction projects can potentially impact fish populations. In 2005, we continued to monitor these activities. Most of the projects were at the mid-construction or completion phase; thus, monitoring was restricted to areas sampled in previous years. In 2005, electrofishing surveys were conducted at several sites in Hayden Valley, in the tributary of Cascade Creek at the south end of the Canyon-to-Chittenden road, and at three sites in Antelope Creek. As in previous years, few of the captured cutthroat trout were longer than 250 mm, suggesting that the streams are used primarily as spawning and rearing areas for fish from the Yellowstone River mainstem. However, in Antelope Creek, consistent capture of multiple size-groups and the presence of potential barriers indicate that the population may be comprised of fluvial residents.

Sampling at the two sites of Middle Creek on the east side of Sylvan Pass again revealed a predominance of brook trout over cutthroat trout. Relative abundance of both species was smaller in 2005 than on other sampling occasions, but this may have been due, in part, to reduced capture efficiencies associated with the difficulty of sampling during higher stream flows. This year, in consultation with NPS

Sampling at the two sites of Middle Creek on the east side of Sylvan Pass again revealed a predominance of brook trout over cutthroat trout.

JOANN VOIGT

Non-native brook trout are being removed from upper Soda Butte Creek by electrofishing each year.

geologists and Federal Highway Administration staff, Aquatics Section staff sampled the upper portions of Middle Creek as a result of water quality concerns arising from the gravel-washing operation at the top of the Sylvan Pass divide. In September 2005, sampling of Middle Creek near the input source of the fine materials failed to capture any fish. Additional electrofishing upstream from the affected area also yielded no fish. This brief initial survey suggests that the localized area was historically fishless and remains so today. A more extensive survey of the watershed could reveal the presence of barriers, upstream distribution of cutthroat trout in the stream, and amount of risk to the cutthroat trout population based on its proximity to the input source. Intensive water quality and macroinvertebrate surveys have also been completed to document the potential impacts of sediment from the gravel-washing operation (described below).

One long-term effect of upgraded roads is increased access and usage.

Typically, road projects are a concern to resource managers because they can potentially impact fish populations if excessive sediment is generated during construction or improperly designed or placed road culverts impede fish passage after completion of the project. As such, most monitoring efforts have been focused at local sites where those types of impacts might occur. However, a broader temporal and spatial examination is required for all effects of road projects to be considered (Angermeier et al. 2004). One long-term effect of upgraded roads is increased access and usage. Wider roads and larger parking areas may lead to increased numbers of anglers at streams that are close to a road, but not close enough to be directly affected by the actual construction activities, for instance, at Obsidian Creek, where angler use may increase due to improved access to the stream with an upgraded road or removal of size limits in 2006. This stream was historically fishless, but brook trout were stocked there in the early days of the park. As brook trout have a high catch rate, Obsidian Creek has an unusual status as a park stream where children are allowed to use bait to catch non-native trout. Four years of sampling near the Indian Creek campground area have revealed that small brook trout are abundant in Obsidian Creek. Population data obtained during the pre-construction phase of the Mammoth-to-Norris road project will be useful for examination of longer-term changes.

The close proximity of Middle Creek to the East Entrance Road is a concern to fisheries biologists.

NPS/DAN MAHONY

An upper reach of Middle Creek sampled in 2005.

Wilderness Fisheries of the South

Status of Cutthroat Trout in the Upper Snake River

The Snake River watershed is the third largest in Yellowstone National Park. Historically, Yellowstone cutthroat trout, Snake River finespotted cutthroat trout, and several other native fish species occupied the mainstem river and its tributaries. Much of this basin has not been previously surveyed because of its remote location and difficult access to pre-selected study areas. In 2005, the Aquatics Section continued its native fish inventory of the Snake River in order to describe the distribution of cutthroat trout subspecies in the remote headwaters region within the park. A primary objective of the survey is detection of areas where the two cutthroat trout subspecies may coexist. Equally important is documenting the relative abundance and distribution of other native fishes and potentially harmful non-native species, including brown trout, brook trout, and lake trout in this watershed.

As the mainstem river survey was completed in 2004, our sampling in 2005 was primarily focused on tributary streams. Fish sampling techniques were similar among years and followed the methods of Novak et al. (2005) where each stream was subdivided into ten sections and the lower 100 meters of each section were sampled in an upstream direction. Surveys of two of the most remote tributaries (Forest Creek and Sickle Creek) were completed. As neither of these streams has an established trail access, logistic considerations were an important part of completing the inventory. Surveyed sample sections in these two tributary streams were approximately 1 km apart (Figure 14). Forest Creek watershed was most likely historically fishless due to the presence of a large waterfall (>20 feet high) located about 1 km upstream from the confluence with the Snake River mainstem. According to historical records, about 100,000 eyed Yellowstone cutthroat trout eggs from the Yellowstone Lake hatchery were stocked annually into Forest Creek between 1939 and 1943 (Varley 1981). The relatively high abundance and widespread distribution of cutthroat trout there now suggests that these early stockings were highly successful. Much of the Forest Creek watershed was intensely burned during the 1988 wildfires. The stream channel now contains abundant deadfall and other woody debris from the riparian areas and adjacent uplands. The cutthroat trout population sampled contains numerous size groups representing several year classes. Abundance,

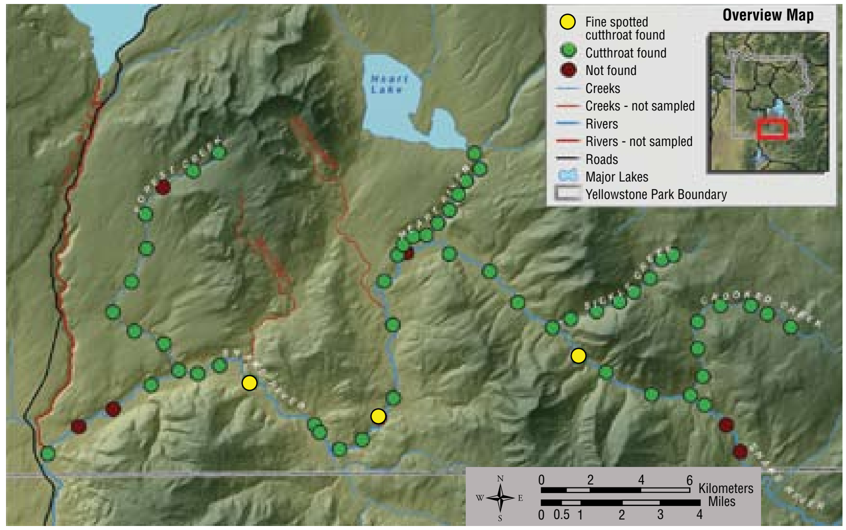


Figure 14. The upper Snake River watershed where fishes were sampled by electrofishing in 2004 and 2005, and Snake River finespotted cutthroat trout were found, Yellowstone cutthroat trout (large spotted) were found ("Cutthroat found" in the legend), or none were found.

NPS/CHRIS ROMANKIEWICZ

Forest Creek was one of several remote Snake River tributaries surveyed for fishes in 2005.

NPS/CHRIS ROMANKIEWICZ

Forest Creek Yellowstone cutthroat trout.

distribution, and utilization of a variety of habitat types by the cutthroat trout all suggest that wildfire effects on this isolated population were negligible.

Sickle Creek, which contains large, low-gradient meadows in its headwater sections, flows out of a steep canyon into the Snake River approximately halfway between the headwaters of the river and the South Entrance of the park. In 2004, two sections near the confluence with the Snake River were sampled. All but one of the cutthroat trout caught in the high-gradient areas, characterized by bedrock pools and unstable stream channels, were small (<150 mm total length). The electrofishing survey of Sickle Creek was completed in 2005. Only cutthroat trout were caught, but their abundance in the upper reaches was one of the highest of any section sampled in the Snake River watershed. Most of the sampled trout had typical Yellowstone cutthroat trout spotting patterns; however, several fish had small- to intermediate-size spots distributed in a pattern characteristic of finespotted cutthroat trout. Several size classes of cutthroat trout were captured throughout the stream, and young-of-the-year were abundant. The largest cutthroat was captured in the headwater section.

This year, we initiated an inventory of a large, unnamed tributary that flows north from Big Game Ridge into the Snake River just slightly upstream from the Crooked Creek-Snake River confluence. This tributary appears to comprise a substantial amount of the total mainstem flow. The cutthroat trout captured here were typically smaller than those caught in the nearby mainstem section in 2004. This tributary is the only location where mottled sculpins were collected in 2005.

The upper Yellowstone River (upstream of Yellowstone Lake) is the largest of 126 tributaries to Yellowstone Lake.


NPS/CHRIS DIXON

Sickle Creek near confluence with Snake River.

A secondary objective of the survey was to collect additional cutthroat trout from previously sampled streams in order to obtain an adequate number of tissue samples for stream-specific genetic analyses. Enough genetic samples now have been collected for subspecific differences (if any) among the Heart River, Sickle Creek, Crooked Creek, and Forest Creek populations to be examined (Janetski 2007). Only Red Creek (which may have permanent barriers located near its mouth) and Basin Creek (which does have an occasional angler report of cutthroat trout) remain to be surveyed. Although these latter two streams have good trail access for much of their length, limited information is available and angler use appears to be minimal.

Status of Cutthroat Trout in the Upper Yellowstone River

The upper Yellowstone River (upstream of Yellowstone Lake) is the largest of 126 tributaries to Yellowstone Lake. More than one third of the water that enters Yellowstone Lake through tributary streams originates from this system. Its mainstem flows more than 84 river km from its source on Younts Peak in the Bridger-Teton Wilderness to its mouth within the Southeast Arm of Yellowstone Lake. The watershed contains more than 200 km of tributary streams and covers an area greater than 1,244 square km.

The year 2005 was the third year of the upper Yellowstone River fisheries assessment. The project, initiated in 2003 by the National Park Service, is now a joint effort between the NPS and the Wyoming Game and Fish Department. Through this coordinated effort, nearly the entire drainage has been surveyed. Until this survey, a comprehensive fishery assessment had not been performed in this region. When completed, the study will help answer questions regarding life-history strategies, movements, and distributional patterns of Yellowstone cutthroat trout in the most remote wilderness remaining in the continental United States.

To monitor movement patterns of adult

Yellowstone cutthroat trout, 151 fish were tagged with radio transmitters from June 2003 through July 2005, in various locations in the upper Yellowstone River basin (Figure 15). Due to the large size of the Yellowstone River and Thorofare Creek, angling was the most effective technique in capturing fish. All fish captured were examined for gender and spawning stage, and were measured for total length and weight. Scale samples for age and growth analysis, and fin clips for genetic testing were collected from a subsample of fish during each tagging trip.

Fish were radio-tagged during the spawn and post-spawn period to increase the likelihood of studying both the lacustrine-adfluvial and fluvial-adfluvial life history types (if they were present in the system). However, lack of fish within the mainstem or lower reaches of large tributaries late in the season (after August 1) prevented us from tagging equal numbers of fish in the spawning and post-spawning periods. Tracking surveys were conducted with a fixed-wing aircraft flying over the river system and portions of Yellowstone Lake (Figure 16). Monitoring flights took place weekly from May through August, twice each month in September and October, and monthly from November through April. Tracking flights were supplemented with walking surveys of the rivers and streams, and boat surveys on Yellowstone Lake as time permitted. Boat surveys proved unsuccessful, and they were discontinued after the first season of the study.

The majority of tagged fish migrated into Yellowstone Lake following the spawning period each year. Of the 109 fish that were relocated, 64% moved downstream to Yellowstone Lake and 14% moved downstream toward the lake before their signals were lost. We were unable to relocate 42 fish after their initial tagging, possibly because several of the fish migrated over large distances in relatively short periods of time. One fish actually migrated more than 40 river and lake miles in just 16 days. Fish also may have migrated to Yellowstone Lake and resided in locations outside of our tracking surveys. Increased coverage of Yellowstone Lake during tracking flights in 2005 showed that fish implanted with transmitters in the upper river system were found in several

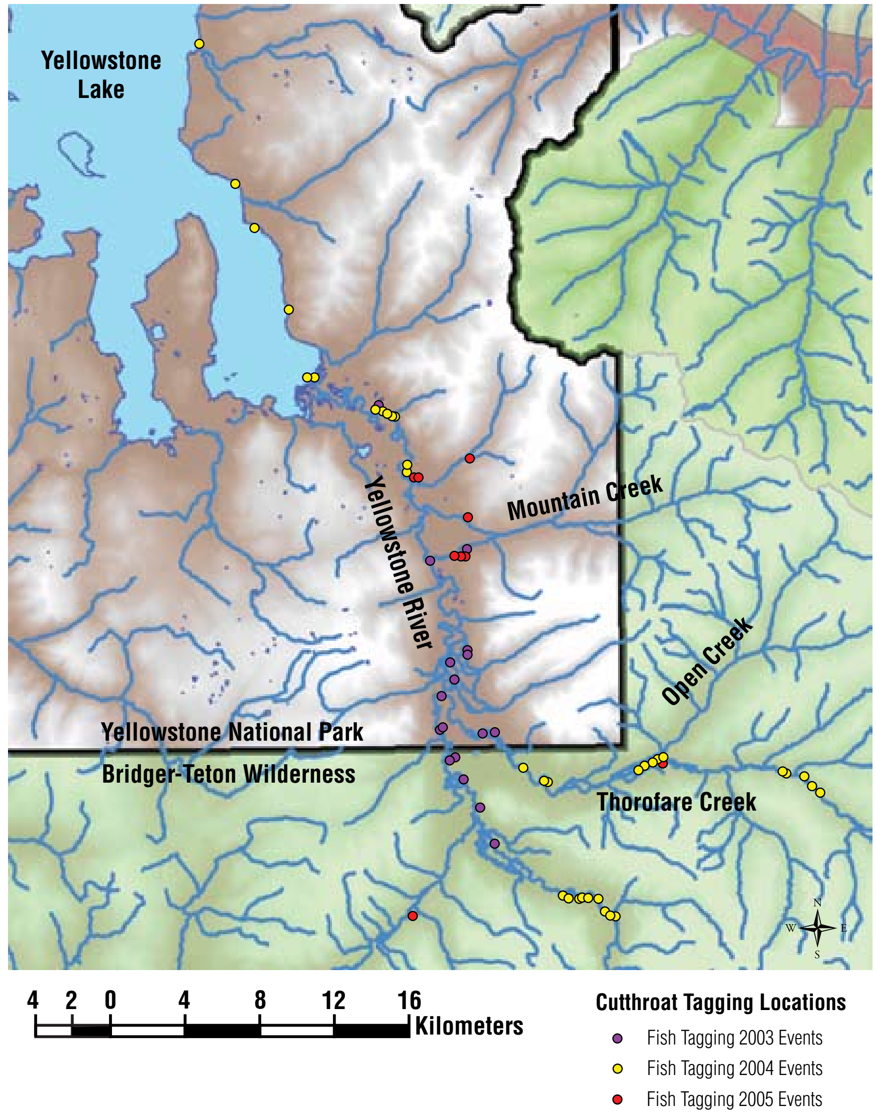


Figure 15. Locations where cutthroat trout were implanted with radio-tags in the upper Yellowstone River watershed, 2003–2005.

locations throughout Yellowstone Lake and also in locations within the Yellowstone River downstream of the lake outlet at Fishing Bridge. Similar results have been found in other tracking studies in the Yellowstone Lake basin (Koel et al. 2003). There is also the possibility of tag failure or of a predator eating the fish and moving out of the system.

To assess distribution of cutthroat trout of all ages in the basin, electrofishing surveys (100-m sections for every km of stream) were conducted in tributaries of the Yellowstone River and Thorofare Creek. Surveys were conducted after August 1, when it is likely that adfluvial

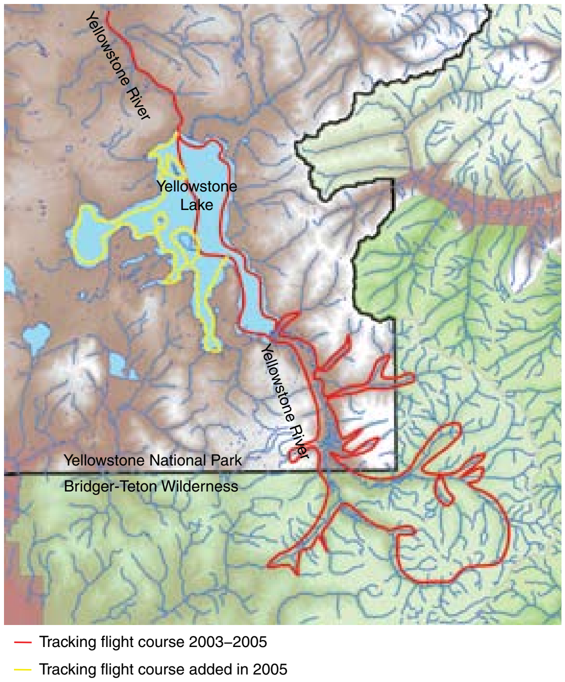
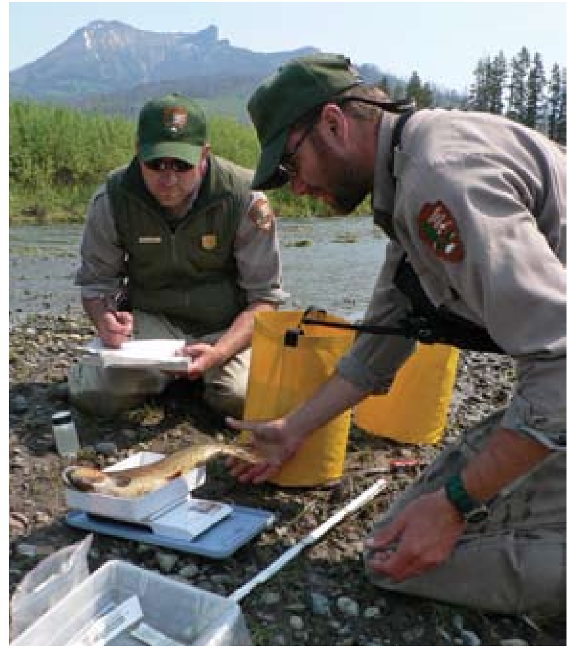


Figure 16. Yellowstone River watershed upstream of Yellowstone Lake and path of flights used to track radio-tagged cutthroat trout, 2003–2005.



Fisheries technicians Brad Olszewski and Brian Ertel processing fish samples.

It remains unknown if fish remain as year-round residents and survive to be adults within the upper Yellowstone River watershed.

fish migrating upstream from Yellowstone Lake would have returned to the lake. To date, surveys have been conducted on Trappers, Mountain, Howell, Cliff, and Phlox creeks within the park boundary, and Open, Dell, Butte, Coyote, Hidden, Castle, and Atlantic creeks south of the park. All fish collected were measured and weighed. Scale samples for age and growth analysis, and fin clips for genetic analysis, were taken from a subsample of fish in each section.

Small cutthroat trout were captured below barriers to fish migration (e.g., waterfalls) during the electrofishing surveys within park boundaries. These fish ranged from 26 mm to 182 mm in length, and analysis of scales showed them to be 0–2 years of age. This indicates that some extended rearing may occur in the river system. It remains unknown if fish remain as year-round residents and survive to be adults within the upper Yellowstone River watershed.

Radio-tagged Yellowstone cutthroat trout from the upper Yellowstone River.

Data collected during movement and distribution surveys (2003–2005) indicate that Yellowstone cutthroat trout in the upper Yellowstone River system primarily exhibit a lacustrine-adfluvial life history strategy, and spend the majority of their lives in Yellowstone Lake, migrating into the river system to spawn. This is similar to what has been observed in the other, much smaller tributaries of Yellowstone Lake. Completion of our surveys and detailed analyses planned during the next 1–2 years should result in a better understanding of movement patterns, habitat use, and life history strategies represented. Overall, through collaboration with our partners in the Wyoming Game and Fish Department, we will have documented the status of this subspecies in a very remote and logistically challenging watershed.

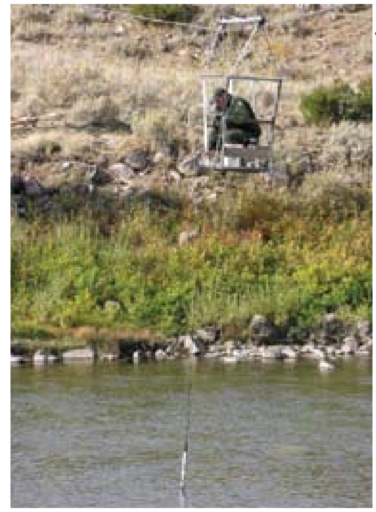
Aquatic Invasive Species Program

Yellowstone's world-class fisheries are threatened by introductions of aquatic invasive species (AIS). These harmful non-native and exotic invading species displace precious native species, such as cutthroat trout and many native macroinvertebrates, upon which Yellowstone fishes depend for growth and survival. AIS also have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears, causing a disruption of the Greater Yellowstone Ecosystem.

The New Zealand mudsnail (*Potamopyrgus antipodarum*; Richards 2002; Hall et al. 2003; Kerans et al. 2005) and the parasite that causes whirling disease in trout (*M. cerebralis*; Koel et al. 2006) are examples of exotic AIS that are already present in park waters. The zebra mussel and Eurasian watermilfoil are examples of AIS that are quickly approaching the park from elsewhere in the United States, and there are more than 300 others now in North America—often so small they are difficult to see (http://nas.er.usgs.gov). Because AIS are often hidden, they frequently "hitchhike" from one lake or stream to another within the water of a boat bilge or livewell, or in mud, dirt, sand, and plant fragments attached to boats, fishing equipment, or clothing. Prevention is key, because once introduced and established in park waters, AIS are virtually impossible to get rid of. The following measures have been taken in the park to help prevent additional AIS introductions:

- A brochure has been developed to provide information on how to conduct boat inspections and clean angling gear (available online at www.nps.gov/yell/planyourvisit/fishingexotics.htm).
- Boat ramp signs have been developed and installed at Yellowstone Lake and Lewis Lake ramps.
- Anyone purchasing a boating permit in the park is now informed about AIS and how to conduct boat inspections.
- Collaboration with partner agencies and non-governmental organizations and development of an Aquatic Nuisance Species Management Plan for the Greater Yellowstone Area.

Yellowstone National Park is a partner in the "Stop Aquatic Hitchhikers" campaign, led by the Aquatic Nuisance Species Task Force and sponsored by the U.S. Fish and Wildlife Service and U.S. Coast Guard (http://www.protectyourwaters.net). Whenever possible, images and other educational materials common to the campaign are used for purposes of AIS prevention within the park. Additional information can be obtained at www.protectyourwaters.net and several other websites.



NPS/JEFF ARNOLD

Water quality technician Jeremy Erickson collecting data at the Lamar River site.

Aquatic invasive species have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears.

Long-term Water Quality Monitoring

All water bodies in Yellowstone National Park are classified as outstanding natural resource waters and designated as Class I waters by the states of Montana and Wyoming. Class I waters are afforded the highest protection possible and, as a result, long-term degradation of these waters is prohibited (WDEQ 2001). Chemical and physical attributes of streams and lakes are a direct reflection of the land use that occurs within a watershed. Consequently, these attributes directly affect the organisms that live within those aquatic systems. For this reason, water quality monitoring is a necessary tool for tracking natural and anthropogenic changes as well as providing an overall evaluation of ecosystem health in Yellowstone National Park. By collecting chemical, physical, and biological properties of aquatic systems, staff can not only evaluate the overall health of those water bodies, but also assess the overall condition of the watershed and the surrounding environment. The Aquatics Section's long-term water quality monitoring program is comprised of two main components: (1) long-term water quality monitoring of major streams and Yellowstone


NPS/JEFF ARNOLD

Water quality technicians Jeremy Erickson and Hunter Hutchinson processing samples for total suspended solids analysis.

Lake, and (2) using aquatic benthic macroinvertebrates as health indicators of aquatic systems.

During 2005, the Aquatics Section continued to conduct routine water quality monitoring at the 12 established sites on major river basins throughout Yellowstone National Park (Figure 1). Sites were sampled once every two weeks (once each month during winter), with sample days randomly selected within a sample week. A multiparameter probe was used to collect *in situ* water quality measurements including water temperature, dissolved oxygen, pH, and conductivity. A portable turbidity meter was used to collect turbidity measurements as a way to quantify water clarity. In addition, water samples were collected during each site visit and filtered and dried for total suspended solids (TSS) analysis. These water quality parameters are important because they directly affect the types and distribution of organisms (plants, invertebrates, and fish) living in aquatic systems.

The park experienced a fairly dry winter in 2005, followed by a relatively wet spring. Temporal and spatial features of individual streams contributed to the wide variation of water quality parameters recorded from individual sites. Examples of environmental factors that affect water quality include diurnal cycles, higher flows during spring snowmelt, rain events, seasonal temperature changes, altitude differences, and the geothermal influences that affect many streams in YNP. The highest mean water temperature (15.6°C, range 6.0–25.1°C) occurred in the Firehole River, a thermally influenced stream. Lowest mean water temperature (4.9°C, range –0.1 to 13.7°C) occurred on upper Soda Butte Creek.

Most organisms become stressed when dissolved oxygen (DO) concentrations fall below 5.0 milligrams/Liter (mg/L-1). Low DO concentrations are not usually a problem in YNP because the water is constantly aerated by downhill movement. However, low DO concentrations may be a concern in some slow-moving and thermal streams. Highest mean DO concentration (11.1 mg/L-1, range 8.6–15.4 mg/L-1) was recorded for the Yellowstone River at Corwin Springs; lowest mean DO concentration (8.1 mg/L-1, range 6.5–9.7 mg/L-1) was recorded for Firehole River (Figure 17). High daily temperatures on the Firehole River probably played an important role in the low DO concentrations recorded.

Within-site variation of pH was quite low, with most differences occurring between sites (Figure 17). Mean pH for the thermally influenced Firehole River was 8.3 standard units (SU) (range 7.7–8.7). This was the highest mean value for all sites sampled, with the exception of the Gardner River, which also had a mean pH value of 8.3 (range 7.9–8.7). The Gibbon River had a mean pH value of 6.9 (range 6.6–7.2). This river receives considerable amounts of water from the Norris Geyser Basin, which is typically more acidic than other geyser basins within the park. The Yellowstone River at Artist Point had the lowest mean pH of all water quality sites, with a value of 6.8 (range 6.3–8.3).

Specific conductance, turbidity, and TSS were highly seasonal, and appeared to be correlated with river discharge (Figure 17). These parameters directly reflect changes in vegetative cover or other patterns that may occur within a watershed. In general, specific conductivity is a measure of the amount of ionic material dissolved in water. While a majority of ions found in water are derived from the weathering of rock material, small amounts of ions originate from atmospheric deposition and precipitation. Higher ion concentrations per volume of water result in higher specific conductivity values. On average, specific conductivity tended to be lowest during spring snowmelt and highest during the base flow period of fall and winter. Higher specific conductivity values were generally found at sample sites with thermal contributions. For example, the highest mean specific conductivity recorded for all sites were from the Gardner, Firehole, Madison, and Gibbon rivers, with 593, 489, 464, and 429 µSeimens per centimeter (µS/cm-1) respectively. All of those waterways receive considerable amounts of thermal contributions. Specific conductance was least variable at the Yellowstone River near Fishing Bridge, and had the lowest mean value of 94 µS/cm-1 (range

85–98 µS/cm-1) (Figure 17). The lowest specific conductivity for all sites sampled was 68 µS/cm-1, recorded at the Lamar River water quality station during a high-flow period on May 20, 2005.

Turbidity and TSS both measure the amount of inorganic (clay, silt, and sand) and organic (detritus and plankton) material suspended in the water column. Typically, turbidity and TSS values increase with increased discharge, which usually occurs during snowmelt and after rain events. Values for these parameters can also increase with an increase in algal production, which is a common occurrence on lakes during the warmer summer months. Turbidity is a measure of water clarity, with higher values reflecting a more turbid condition (i.e., less-clear water). Increases in turbidity can negatively affect aquatic plants (reduce photosynthesis) and animals (influence feeding behavior of visual predators). Most sites had mean turbidity measurements below 10 nephlometric turbidity units (NTU), with the exception of Pelican Creek and the Yellowstone River at Corwin Springs, which had mean NTU values of 18.5 NTU (range 7–118 NTU) and 12.3 NTU (range 0.9–160 NTU) respectively (Figure 17). The lowest mean turbidity measurement of 1.1 NTU (range 0.5–2.2 NTU) was recorded for the Yellowstone River at Fishing Bridge, which is located just downstream of Yellowstone Lake.

TSS is a quantitative measure of the total fraction of inorganic and organic material suspended in the water column. Increases in TSS, primarily in silt and sand, can lead to sediment deposition in the streambed, increasing stream embeddedness and resulting in a decrease of benthic productivity and loss of fish habitat. Concentrations of TSS at stream sites mirrored turbidity readings (Figure 17). The three highest averages for TSS occurred within the Yellowstone River drainage. The highest mean TSS of 23.21 mg/L was recorded for the Yellowstone River at Corwin Springs (range 1.49–337.00 mg/L),

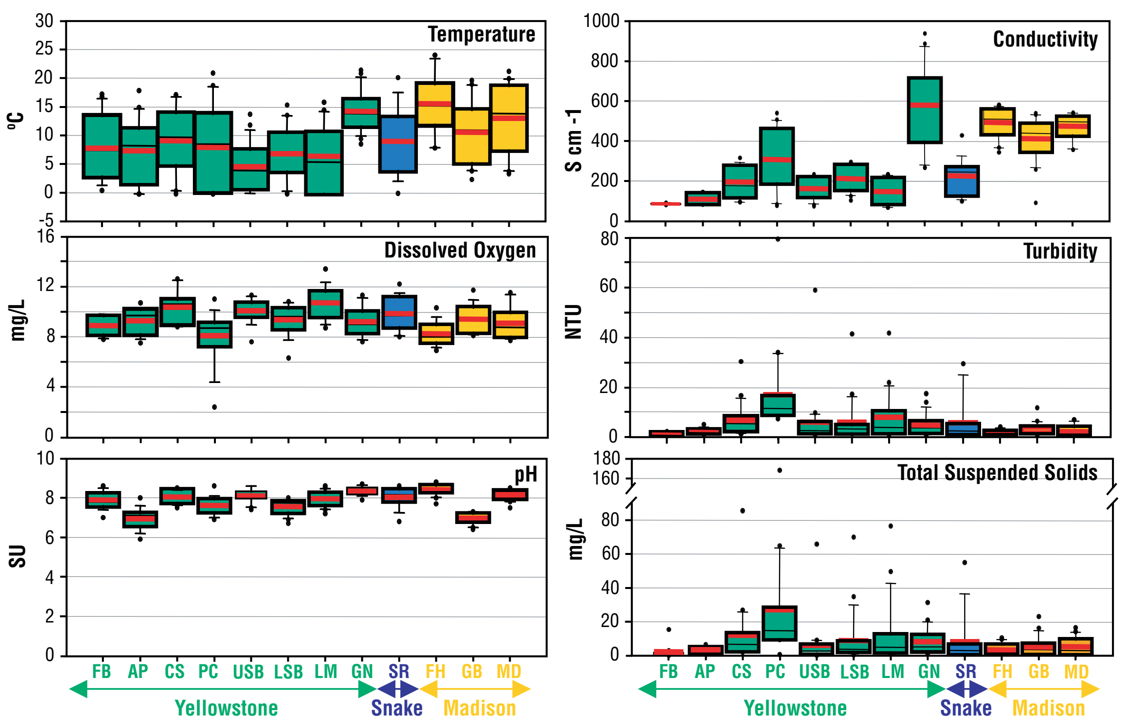


Figure 17. Box and whisker plot illustrating annual variation for selected parameters at each stream water quality location in 2005. Lower and upper portions of boxes represent the 25th and 75th percentile, respectively; lower and upper black horizontal bars represent 10th and 90th percentile, respectively. 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.

followed by the Pelican Creek and Lamar River sites, with mean TSS of 20.71 and 16.79 mg/L, respectively. The lowest mean TSS, 1.06 mg/L, was recorded for the Yellowstone River at Fishing Bridge (range 0.048–2.92 mg/L).

Water Quality Monitoring Goals

Future goals for the water quality program are to continue monitoring at the 12 established sites on major river basins to acquire baseline information and determine inter- and intra-annual variation of water quality core parameters. In addition, through collaboration with the NPS Inventory & Monitoring (I&M) Program, monitoring of the park's state 303(d)-listed streams (Soda Butte Creek and Reese Creek) will continue. (Section 303(d) of the Clean Water Act requires state departments of environmental quality to prepare a list of water bodies that do not meet water quality standards and where Total Maximum Daily Loads will be developed.) Water quality monitoring is also expected to occur relative to piscicide treatment of streams and lakes as a part of the restoration program for fluvial populations of native trout. Samples would be obtained prior to chemical treatment, concurrent with treatment, and post-treatment both within and downstream of the treatment areas. Specifically, analyses would be conducted to detect volatile organic compounds, semi-volatile organic compounds, and rotenone. Antimycin, at concentrations used to remove fish, cannot be detected in water analytically, but the solvents used to disperse antimycin in water (acetone, diethyl phthalate, and nonoxynol-9) would be monitored as a portion of the volatile organic compounds and semi-volatile organic compounds described above.

Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in YNP.

Yellowstone Lake Limnology

Water quality sampling was conducted at seven fixed locations on Yellowstone Lake between May and October (Figure 4). Basic water quality parameters (water temperature, DO, pH, specific conductance, turbidity, and secchi transparency readings) were collected from each site. Surface water samples were collected and analyzed for total and volatile suspended solids. Surface water quality parameters were similar among all sites; for reporting purposes, only the sites at West Thumb and the South Arm of Yellowstone Lake will be described. Surface water temperatures and DO concentrations are closely linked, and vary greatly with season. As expected, lower water temperatures were recorded during spring, and higher temperatures were recorded during the summer months (range 3.3–16.2°C and 4.2–17.4°C, respectively, for West Thumb and the South Arm). Conversely, higher DO concentrations were recorded during spring, and lower DO concentrations were recorded during the summer months (range 8.1–10.1 mg/L and 7.9–10.7 mg/L, respectively, for West Thumb and the South Arm). Values for pH and specific conductivity were less dependent on seasonal changes and relatively more constant throughout the sample period. Ranges for pH were between 7.1 and 7.9 for West Thumb and between 7.5 and 8.1 for the South Arm. Ranges for specific conductivity were between 84 and 100 µS/cm-1 for both sample locations.

In addition to surface water parameters, temperature profiles were collected from the same two locations to give fisheries biologists a better understanding of seasonal temperature changes throughout the water column and of fish movement patterns throughout the lake. In general, water temperatures remain at about 4°C throughout the water column until mid-June (Figure 18). Water temperatures begin to increase rapidly during the last week of June with the development of a thermocline, an area in the water column with noticeable temperature change, becoming prominent from July through mid-September. The thermocline remains at about 15 and 20 meters for the West Thumb and South Arm locations, respectively.

Macroinvertebrates as Health Indicators

Successful water quality monitoring requires a combination of physical, chemical, and biological measurements to effectively evaluate the health of aquatic systems. Physical and chemical measurements directly measure

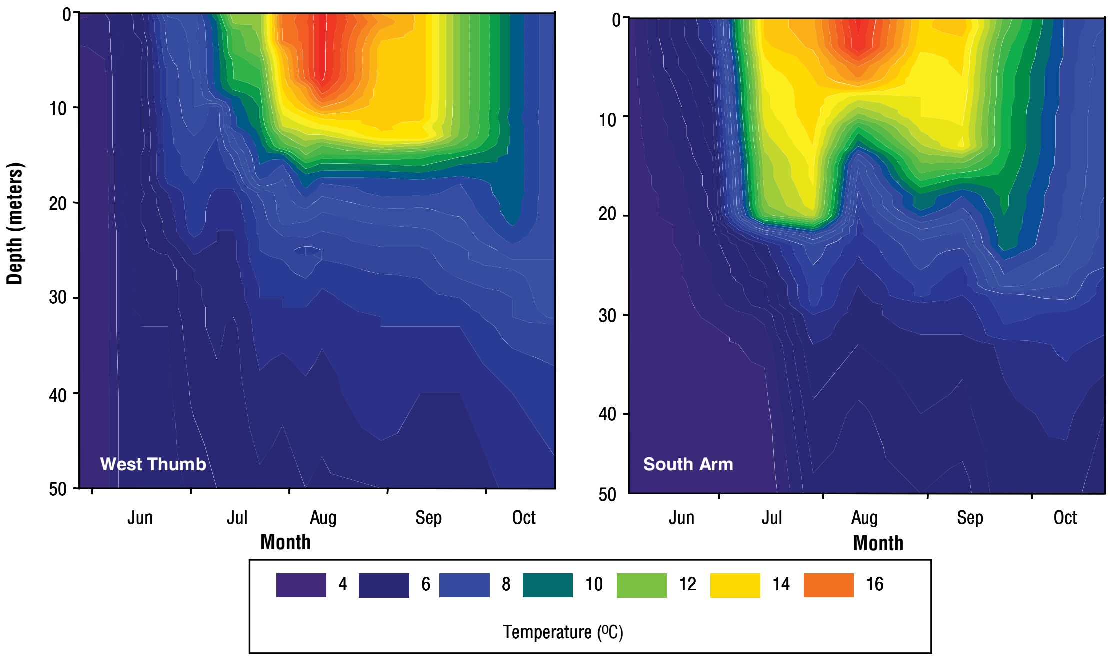


Figure 18. Isopleth of water temperature in West Thumb and the South Arm of Yellowstone Lake during summer 2005. Contour lines represent one-degree intervals. For comparison and greater resolution of surface temperatures, only data from the first 50 meters is displayed for the West Thumb location. Note that the shallow water depth of the South Arm contributes to surface waters that warm more quickly than surface waters associated with deeper portions of the lake.

parameters within the stream channel and water column; biological measurements evaluate the response of organisms (e.g., periphyton, aquatic invertebrates, and fish) to changes within their environments. Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in YNP. These organisms are excellent indicators of aquatic health because they are long-lived, relatively immobile, sensitive to changes in the environment, and important food for resident fishes. By studying aquatic macroinvertebrate communities within a given stream segment, we can assess the current water quality condition of that stream. For each sample, total numbers of invertebrates were tallied for individual taxa and tolerance values (percent tolerant and intolerant taxa) were calculated. In addition, EPT (*Ephemeroptera*, *Plecoptera*, and *Trichoptera* taxa) Richness Index values and modified Hilsenhoff's Biotic Index (HBI) values, which are known water quality indicators, were also calculated for each site (Lenz 1997).

EPT Richness Index is calculated by tallying distinct invertebrate taxa belonging to the insect orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies). EPT taxa are pollution-sensitive and respond readily to environmental changes. Generally, numbers of EPT taxa increase with lower water temperatures, increased DO concentrations, and little organic pollution, and decrease with higher water temperatures, decreased DO concentrations, and increased organic pollution. By contrast, organisms that are least sensitive to water pollution are in the non-insect orders *Oligochaeta* (segmented worms) and *Hirudinea* (leeches), and in the insect orders *Odonata* (dragonflies/damselflies), and *Diptera* (true flies).

Modified HBI values are obtained by evaluating the number of benthic invertebrates in the phylum *Arthropoda* at a site and their tolerance to pollution to ascertain the degree to which organic compounds, elevated temperatures, low DO, and other stressors are likely to be present (Hilsenoff 1987; 1988; USGS 1999). Each benthic invertebrate is assigned a tolerance value from 0 to 10, with 0 assigned to invertebrates least tolerant to pollution and 10 assigned to invertebrates most

tolerant of pollution. A low HBI value indicates excellent water quality with no pollution; a high HBI value indicates poor water quality with high amounts of pollution.

During 2005, sample site selection was based primarily on location, accessibility, water depth, and a minimum riffle or riffle-run stretch of at least 15 meters. Basic water quality measurements collected at each site included water temperature, DO, pH, specific conductance, turbidity, and stream discharge. A Surber net sampler (0.09-m^2 plot and 500-micron mesh) was used to quantitatively sample riffle habitats within the sample reach; an Eckman dredge (0.02-m^2 plot and 500-micron mesh screen) was used for invertebrate sampling in deeper, slow-moving streams. Individual plot areas were characterized by percent coverage of substrate, silt, and vegetation (i.e., aquatic macrophytes and algae) by using a 20-cm^2 piece of Plexiglas to view underwater benthic habitat. Following substrate characterization, aquatic benthic macroinvertebrates were collected by gently rubbing the surface area of cobble and coarse gravel by hand and thoroughly scrubbing the plot area with a soft bristle brush.

Generally, macroinvertebrate collection in the park is focused on aquatic systems threatened by anthropogenic sources. For example, ongoing road construction projects are a continual concern to park resource managers. Many roads within the park are decades old, and in various stages of disrepair. These roads often parallel stream and river corridors. Renovation of these roads poses potential risks to aquatic systems through sedimentation and stream channel alteration. Between 2002 and 2005, the Aquatics Section sampled 21 sites from 13 streams in response to ongoing or proposed road construction projects in YNP. Streams (and number of sites) sampled were: Alum Creek (1), Antelope Creek (1), Elk Antler Creek (1), Gardner River (1), Gibbon River (5), Glen Creek (1), Middle Creek (2) and an associated unnamed tributary (1), Mammoth Crystal Spring (1), Obsidian Creek (4), Otter Creek (1), Pelican Creek (1), and Trout Creek (1) (Figure 1). Soda Butte Creek was also sampled at the park boundary in collaboration with the NPS I&M program. In 2002, the

NPS/JEFF ARNOLD

Stonefly collected from the Gibbon River.

Montana Department of Environmental Quality determined a 4.2-mile segment of Soda Butte Creek, from the McLaren mine tailings near Cooke City, Montana, to the YNP boundary, to be only partially supporting aquatic life and coldwater fisheries due to metals contamination from the McLaren mine tailings (MDEQ 2002). The designation places this section of Soda Butte Creek on Montana's impaired 303(d) list. Soda Butte Creek is not listed as impaired after it enters YNP, but remains at risk from metals contamination during spring snowmelt and after extreme rain events. In addition to invertebrate collections on Soda Butte Creek, Aquatics staff sampled for total and dissolved metals (arsenic, copper, iron, and selenium) in the water column, and for sediment during the spring and fall.

Yellowstone River Between Tower and Yellowstone Lake

This sample area encompasses streams that enter the upper Yellowstone River between Tower Junction and Yellowstone Lake. In fall 2003, reconstruction and resurfacing activities began on two road segments between Lake Village and Tower Junction: (1) the road from Canyon Village to Tower Junction, and (2) the road between Pelican Creek and Canyon Village. In response to these activities, Aquatics Section staff sampled Antelope Creek near Tower Junction (2002–2005) and five streams in Hayden and Pelican valleys (Otter, Alum, Trout, Elk Antler, and Pelican creeks, 2003–2004). Hydrology, flow characteristics, and thermal contributions vary considerably between these two sample areas. Antelope Creek, which

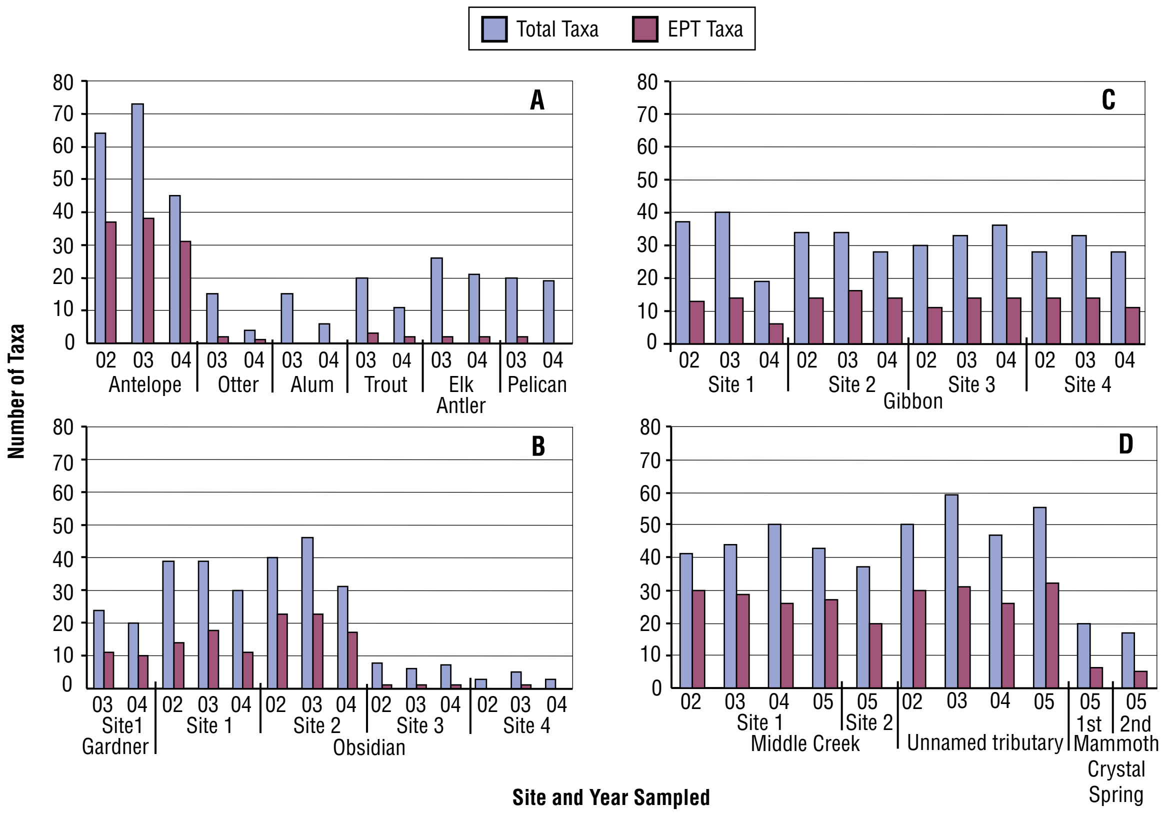


Figure 19. Total aquatic invertebrate taxa and EPT taxa for streams sampled in conjunction with road reconstruction activities in Yellowstone National Park, 2002–2005. Data represents streams sampled within the Yellowstone River drainage (A and B); the Madison River drainage (C); and Middle Creek drainage (D).

parallels the road near Tower Junction, has a moderately steep gradient, considerable canopy cover, and substrates composed almost entirely of large boulders, cobble, and coarse gravel. Thermal areas are absent from this drainage. Streams sampled in Hayden and Pelican valleys have low gradients, little canopy cover, and fine sediments primarily composed of sand and silt. Thermal areas found in the upper reaches of all five watersheds can dramatically alter chemical and physical characteristics of the water, thus affecting aquatic biota. In addition, these sites are inundated by the Yellowstone River (Yellowstone Lake in the case of Pelican Creek) during the spring and summer high-flow periods.

The aquatic invertebrate community on Antelope Creek is quite diverse, with 94 taxa collected over a three-year period (2002–2004). Seventy-three of these taxa were represented in the 2003 sample—the highest number of taxa collected from all sites in YNP since the surveys began in 2002 (Figure 19a). Numbers of EPT taxa were also high for the three sample years, ranging between 31 and 38 taxa. The high diversity of aquatic invertebrates on Antelope Creek can be attributed to the wide range of in-stream habitat, including a mixed variety of substrate sizes (boulders, cobble, gravel, and sand) and abundant coarse woody debris that is present throughout the stream reach. The shaded stream and moderately high gradient provide the lower temperatures and higher DO favored by EPT taxa. This stream ranked from very good to excellent on the HBI for the three-year period (2002–2004).

Invertebrate communities found within the five streams sampled between Lake and Canyon villages represented a stark contrast to those within Antelope Creek. Water temperature and DO varied considerably among all sites depending on time of day sampled. During both sample years, Alum Creek, which has the greatest contribution of thermal activity, had the highest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Water quality technician Hunter Hutchinson filtering water for chloride analysis.

pH (range 8.3–8.9) and specific conductance (range 1,055–1,101 µScm-1) of the five streams sampled. Trout and Elk Antler creeks, located near the south end of Hayden Valley, had comparable pH (range 7.3–7.7) and specific conductance values (range 170–236 µScm-1) for both years sampled. A total of 56 taxa were collected from the five streams, with most invertebrate taxa obtained from Elk Antler Creek (Figure 19a), which also had the most diverse in-stream habitat (i.e., greater variety of substrate) than the other four sites. Numbers of EPT taxa were low among all sites; three was the highest number, collected from Trout Creek in 2003. Although the numbers and types of aquatic invertebrates found in this section of the park are not typical of most coldwater streams, they are characteristic of streams that exhibit low gradient and very little in-stream habitat. The lower numbers of invertebrates encountered during the second year of sampling can likely be attributed to annual variation of aquatic communities rather than effects of road construction activities.

Impacts of Roads on the Gardner River

The Gardner River, located in the north-central portion of YNP, is a major tributary to the Yellowstone River. Sampling in this area primarily focused on the road segment between Norris Junction and the North Entrance (Figure 1). Road improvement activities here have been sporadic over the past five years, mainly consisting of localized repair work and a resurfacing project between Norris Junction and Golden Gate in summer 2003. Streams (and number of sites sampled), included the Gardner River (1), Obsidian Creek (4), and Glen Creek (1). Sampling on the Gardner River was conducted near the main road just south of the park boundary. This area is several miles downstream of Boiling River (a thermal feature), and has a high gradient, low canopy cover, and a high percent of large substrates. Twenty-eight taxa were collected from this site between 2003 and 2004, of which 24 were collected during the 2003 sample year. The number of EPT was relatively low, with 11 and 10 EPT taxa collected, respectively, in 2003 and 2004. HBI indices for both sample years rated this stream from fair (2004) to fairly poor (2003). The lower HBI rating for this stream is most likely attributed to the high volume of thermal waters entering from the Boiling River.

Beginning in 2002, macroinvertebrates have been collected annually from four sites on Obsidian Creek to obtain baseline information from this stream with heavy geothermal contributions. Eighty-three taxa were collected from four sites on Obsidian Creek between 2002 and 2004. The greatest number of taxa collected during a sampling event was 46, occurring at site 2 during 2003 (Figure 19b). Sites 3 and 4 had the fewest numbers of taxa (range 3–8) during the three-year sample period. These two sites receive waters from various geothermal sources and, as a result, typically exhibit low DO and high temperatures. They are also very acidic. These features contribute to a benthic macroinvertebrate community with low diversity and a tolerance for extreme environmental conditions. Typically, invertebrates collected from these two stream sections belong to the insect orders *Diptera* (true flies) and *Odonata* (dragonflies/damselflies).

Road Re-route in the Gibbon River Canyon

The Gibbon River is located in the west-central portion of YNP, and is a major tributary to the Madison River. During the summer of 2001, major reconstruction and widening activities began on the road segment between Norris and Madison junctions, a large portion of which parallels the Gibbon River. Aquatics Section staff began to monitor aquatic macroinvertebrates and other water quality parameters here in 2002 (Figure 1). In general, all sites on the Gibbon River exhibited similar patterns for total numbers of taxa and EPT taxa for all sample years (Figure 19c). The greatest

number of total taxa (40) and least number of total taxa (19) were collected from site 1 during 2003 and 2004, respectively. Generally, HBI values rated this stream between fair and fairly poor. This is likely a result of thermal activity rather than road construction. In addition, the New Zealand mudsnail, an exotic species that competes with native invertebrates for food and habitat, was collected from the first three sites on the Gibbon River, and is now documented to occur above Gibbon Falls. During 2002, this species alone comprised between 38 and 60% of the total invertebrates collected from these three sites. However, through subsequent sampling, it appears that this nuisance species has been declining within the sampling areas (Figure 20).

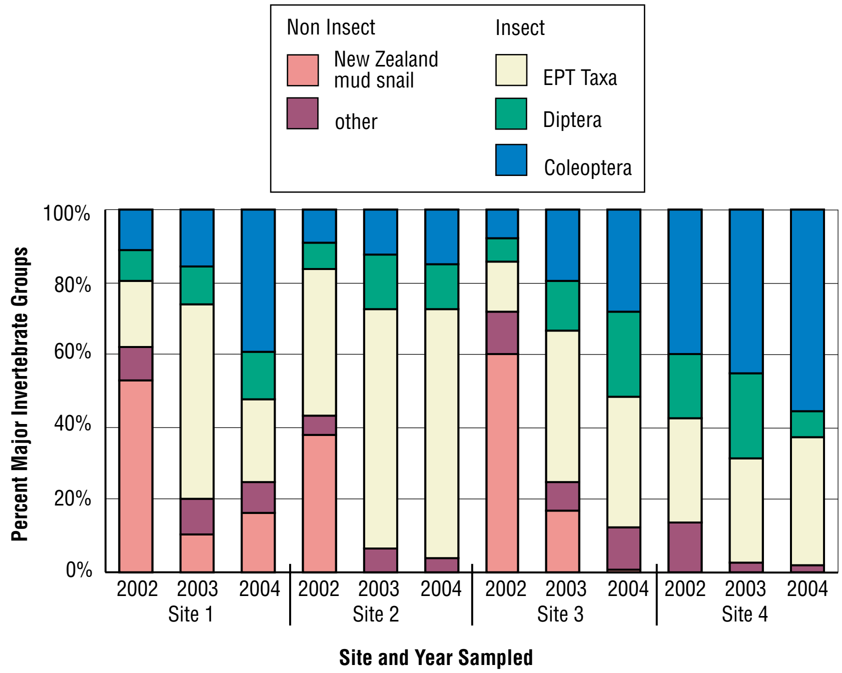

Figure 20. Percentage of major invertebrate groups collected from four sites on the Gibbon River, 2002–2004.

Water Quality Monitoring at Mammoth Crystal Spring

Middle Creek is located in the east-central portion of YNP; its headwaters are near the base of Top Notch Peak of the Absaroka Mountain Range. The mainstem of Middle Creek flows in an easterly direction for approximately 12 km before leaving the park. Within YNP, the lower 10 km of the creek parallel the East Entrance road, with the last three km flowing directly adjacent to the road. The watershed of Middle Creek is relatively small, with a total catchment area of approximately 8,414 hectares contained within the borders of YNP. Middle Creek exits YNP near the East Entrance and flows another three km before it merges with the North Fork Shoshone River.

Benthic macroinvertebrate sampling began within the Middle Creek drainage during late August 2002 (Arnold and Koel 2006). Two sites were established: one on the mainstem of Middle Creek near the East Entrance, another on an unnamed tributary at a location directly downstream from the East Entrance road crossing (Figure 1). Between 2002 and 2005, both sites were sampled once each year during late August or early September. Because of recent concerns about road construction activity within the Middle Creek drainage, two additional stream sites were sampled during late August 2005, near the vicinity of Mammoth Crystal Spring. Mammoth Crystal Spring is a small tributary of Middle Creek whose headwaters originate near Sylvan Pass. The geology of the Sylvan Pass area is dominated by talus generated by adjacent mountains. A large gravel mine and rock-crushing operation is the primary land use in the vicinity, and there is concern that increased turbidity and sediment loads from the operation could threaten the aquatic biotic

NPS/JEFF ARNOLD

Mammoth Crystal Spring.

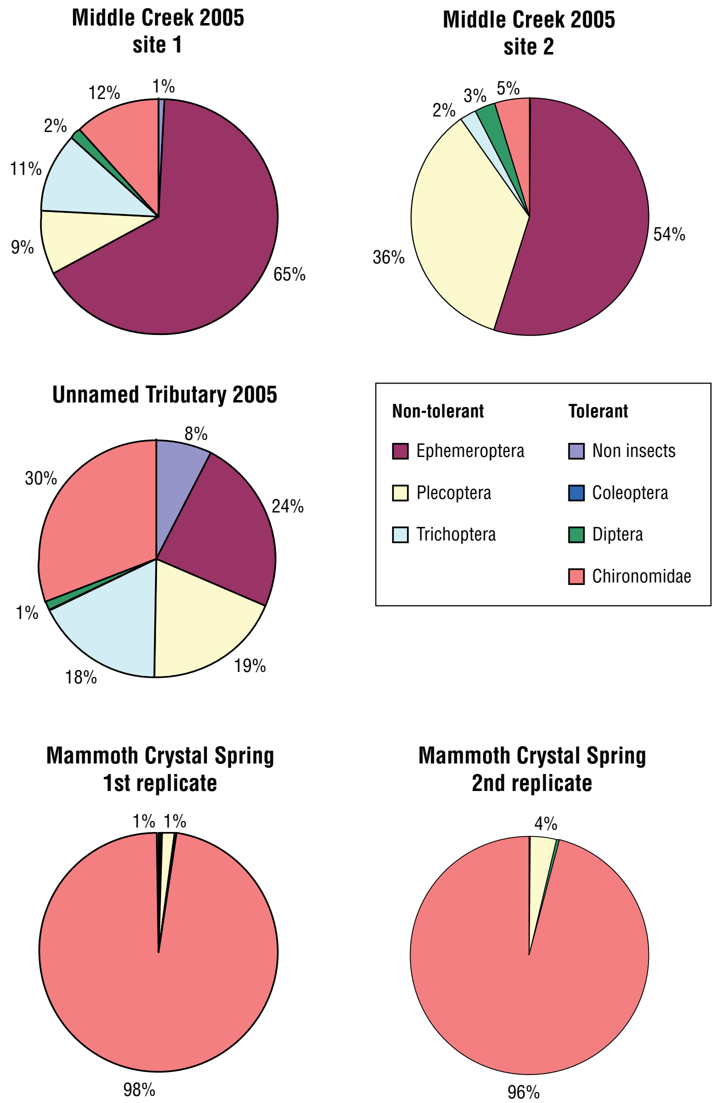

Figure 21. Percentage of major invertebrate groups collected from the Middle Creek drainage during 2005.

community and the overall health of Middle Creek.

A total of 113 unique invertebrate taxa were collected from the Middle Creek drainage from 2002 to 2005. Distinct benthic invertebrate taxa from individual locations ranged from 23 at the Mammoth Crystal Spring site (one year of collection) to 82 at the unnamed tributary (four years of collection). Chironomids (midges), a group of aquatic insects that are generally tolerant of adverse environmental conditions, dominated the invertebrate community at Mammoth Crystal Spring. The high abundance of chironomids is one indication that this stream reach is under severe environmental stress, most likely caused by increases in turbidity and stream embeddedness.

EPT taxa were most abundant on the unnamed tributary (range 26–32) and least abundant at the Mammoth Crystal Spring site (range 5–6). By comparison, 20 EPT taxa were collected from the Middle Creek site adjacent to Mammoth Crystal Spring. Middle Creek near the park boundary also had a high number of EPT taxa for all years combined (range 27–30) (Figure 19d).

As a group, EPT taxa dominated the mainstem of Middle Creek and the unnamed tributary segment. Total percent of EPT taxa combined for Middle Creek near the park boundary had a range between 74 and 86%, with the lowest percentage occurring during the 2004 sample year. Total percent of EPT taxa combined for the unnamed tributary was between 29 and 62%, with the lowest percentage also occurring during the 2004 sample year. The upstream site on Middle Creek exhibited the highest percent of EPT taxa for all sites and all years combined (92%), while the invertebrates collected at Mammoth Crystal Spring had the lowest percent of EPT for all sites and combined years, with <2% EPT taxa for the first replicate sample and <4% EPT taxa for the second replicate sample. Dipterans, primarily chironomids, made up the remainder of the invertebrate taxa collected from each sample location (Figure 21).

Regulatory Monitoring on Soda Butte Creek

During 2005, field parameters including water temperature, dissolved oxygen, pH, specific conductivity, and turbidity were collected from this site once every two weeks as part of YNP's long-term water quality and ecosystem health program. Water samples were also brought back to the Aquatics Section's field laboratory for total suspended solid analysis (TSS). Water and sediment samples were analyzed for metals (arsenic, copper, iron, and selenium) in conjunction with the NPS I&M program during June and September (Table 2). To better assess the overall health of Soda

Butte Creek at the park boundary, benthic macroinvertebrate samples were also collected on August 16, 2005. These samples were sent to an independent laboratory for processing and analysis.

All required field parameters were within ranges expected of high-elevation, coldwater streams. Natural variations were observed depending upon the time of day and month sampled. Mean water temperature was 5°C (range –0.1 to 13.7°C). Dissolved oxygen concentrations (range 7.7–10.5 mg/L) tended to correspond with changes in water temperature, with high concentrations recorded during the cold winter months and lower concentrations recorded during July and August. The pH of Soda Butte Creek was neutral to slightly basic (range 7.3–8.4), and considerably higher than pH values consistent with acid mine drainage. Values for specific conductance, turbidity, and TSS tended to be directly related to flow. In general, specific conductance tended to be lower during the spring high-flow period, turbidity and TSS higher. During the low-flow fall and winter periods, the opposite seemed to be true, with higher specific conductance values and lower turbidity and TSS values.

During June and September 2005, arsenic and selenium were below the specified laboratory reporting limits for both aqueous and sediment samples collected. Both dissolved and total

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Water quality technician Hunter Hutchinson collecting water for heavy metal analysis on Soda Butte Creek.

copper concentrations were detected in water samples collected on the evening of June 17, 2005 (Table 2). Dissolved copper concentration (3 µg/L) was below the Montana aquatic life standards for acute and chronic levels (5.2 µg/L @ 50mg/L hardness for acute and 7.3 µg/L @ 50mg/L hardness for chronic aquatic life standards); however, total copper concentrations

Table 2. Concentrations for select metal concentrations on Soda Butte Creek at the park boundary during June and September 2005.

				Measured Analyte			
Date	Matrix	Analysis	Time	Arsenic	Copper	Iron	Selenium
June 17	Aqueous*	Dissolved metals	0904	<8	<3	112	<20
			1846	<8	<3	85	<20
		Total metals	0904	<8	3	658	<20
			1846	<8	11	3,270	<20
September 22	Aqueous*	Dissolved metals	0917	<8	<3	55	<20
			1809	<8	<3	51	<20
		Total metals	0917	<8	<3	219	<20
			1809	<8	<3	237	<20
September 22	Sediment**	Total metals	1809	<5	17	14,000	<5

*Aqueous measurement units are in µg/L.
**Sediment measurement units are in mg/kg.

(11 µg/L) were above the specified chronic levels of copper in water. Although copper did exceed Montana's chronic aquatic life standard, the data may not be comparable because water hardness was not measured at the time of sample collection. Copper in sediment was recorded at 17 mg/kg, which is below the 33 mg/kg listed by Montana's aquatic life standards. Samples analyzed for dissolved iron did not exceed the Montana aquatic life standard of 1,000 µg/L. However, samples analyzed for total iron exceeded this standard on the evening of June 17, 2005. During September 2005, total iron concentration was 14,000 mg/kg; there are no recognized standards for iron in sediments.

Specimen Creek Prior to Cutthroat Trout Restoration

During August 2004 and 2005, the Aquatics Section sampled the Specimen Creek drainage as part of the proposed westslope cutthroat trout restoration project.

Specimen Creek, a tributary of the Gallatin River, is located in the northwest corner of YNP, near the northwestern boundary. Specimen Creek exhibits geophysical, hydrological, and chemical characteristics that are common for high-elevation, coldwater systems of the northern Rocky Mountains. The drainage is generally covered by snow during the first part of the year, with snowmelt usually beginning in May. Snowmelt contributes to the low water temperatures and high streamflow during May and June. These high-flow conditions ultimately lead to higher turbidity and lower conductivity values. During July and August, water temperatures and specific conductivity values generally increase while turbidity values decrease. Substrate within Specimen Creek is primarily composed of cobble and coarse gravel, which is ideal for aquatic invertebrates and larval fishes. Submersed aquatic vegetation is sporadically dense in some stream segments and primarily consists of rooted aquatic bryophytes.

During August 2004 and 2005, the Aquatics Section sampled the Specimen Creek drainage as part of the proposed westslope cutthroat trout restoration project. Chemical, physical, and biological parameters were sampled at six stream locations during 2004, and at three stream locations (East Fork Specimen Creek only) during 2005 (Figure 22). High Lake, which forms the headwaters of East Fork Specimen Creek (EFSC), was also sampled for basic water quality parameters and aquatic invertebrates

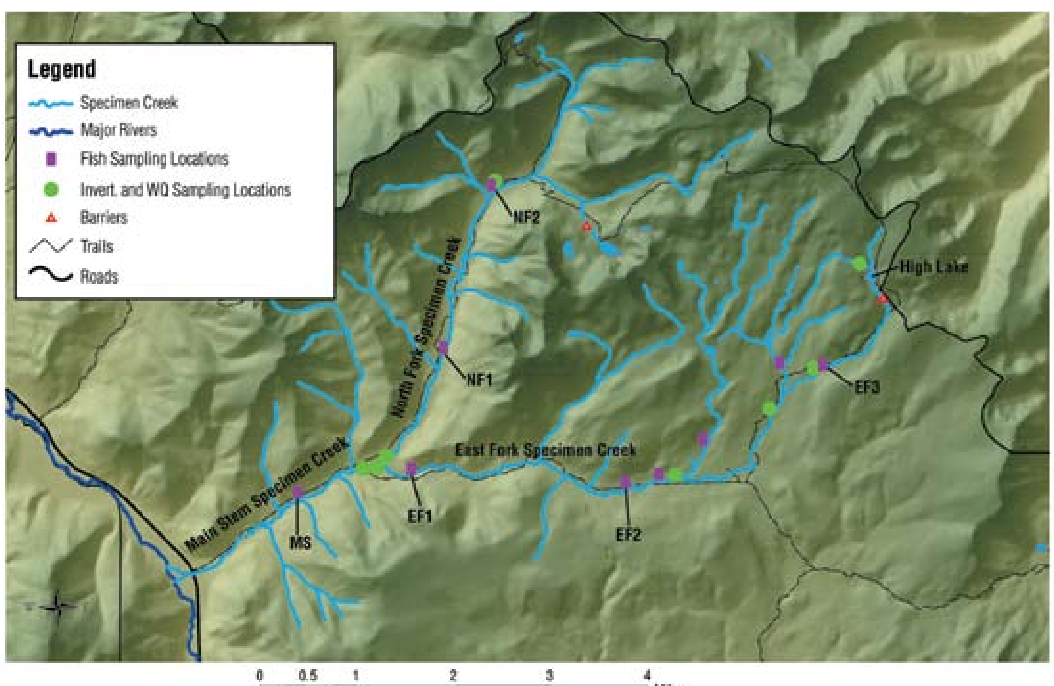


Figure 22. Sites where pre-treatment surveys were conducted for fish, macroinvertebrates (Invert.), and water quality (WQ) in the East Fork (EF), North Fork (NF), and mainstem (MS) Specimen Creek.

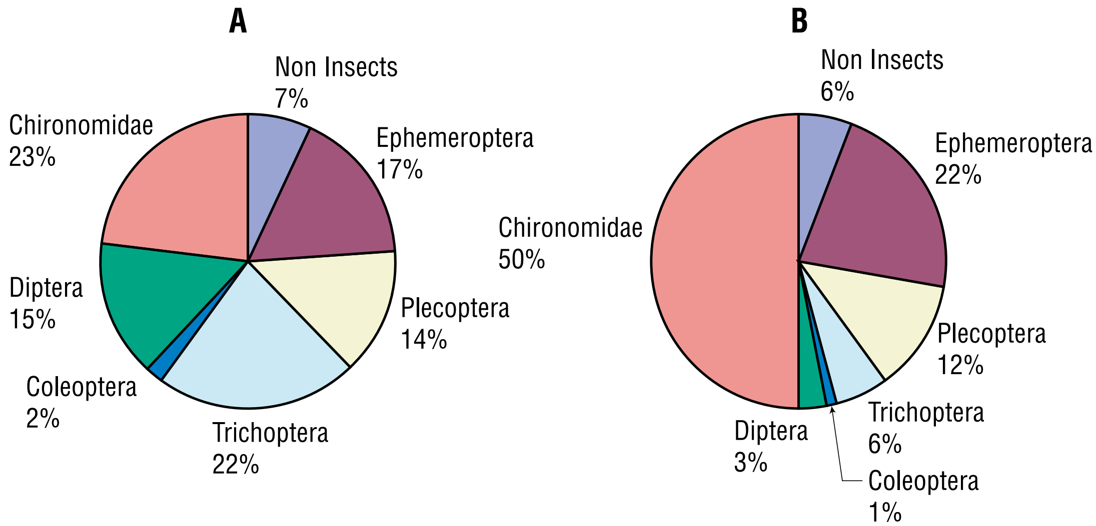


Figure 23. Percentage of major invertebrate taxa (A) and percent invertebrate abundance (B) belonging to major taxonomic groups collected from the Specimen Creek watershed, August 2004.

during August 2005. Water quality parameters collected at each site included temperature, DO, pH, specific conductivity, turbidity, and stream discharge. Aquatic invertebrates were collected to gain supplementary information regarding their presence and distribution throughout the watershed and because they are relatively long-lived, immobile, and sensitive to environmental changes.

During August 2004, 87 invertebrate taxa were collected in the Specimen Creek drainage. The least number of taxa (39) identified was collected from the mainstem of Specimen Creek; the greatest number (51) was collected from the uppermost site on EFSC. Ten taxa were found at all six locations: water mites (*Acari* spp.), two mayflies (*Baetis bicaudatus* and *Cinygmula* spp.), three stoneflies (*Sweltsa* spp., *Zapada columbiana*, and *Zapada oregonensis*), and four midge taxa (*Cricotopus nostococladius*, *Eukiefferiella* spp., *Orthocladius* spp., and *Pagastia* spp.). EPT taxa comprised 53% of the total taxa identified from all sites combined (Figure 23), while midges (order *Diptera*, family *Chironomidae*) comprised 51% of total invertebrate abundance within the Specimen Creek drainage.

During August 2005, additional benthic invertebrate samples were collected from three sites on EFSC. In addition, both benthic and plankton samples were collected from several locations on High Lake. A D-frame net was used to collect supplementary information regarding invertebrate and larval frogs from the littoral zone surrounding High Lake. Generally, sediments in High Lake are composed of fine silt and organic material. Benthic invertebrate fauna consisted of midge larvae in the deeper portions of the lake, and abundant midge larvae and fingernail clams (family *Sphaeriidae*) in shallow portions of the lake. Amphipods, fingernail clams, and dragonfly larvae were collected within the littoral zone. Open-water areas were dominated by several species of Cladocerans and Copepods, both of which are planktonic crustaceans. No larval amphibians were collected during the lake survey; however, one adult frog was collected on a subsequent trip in September 2005.

Monitoring for potential impacts of the piscicides antimycin and rotenone and/or KMnO4 (potassium permanganate, used to detoxify the piscicides) on aquatic macroinvertebrate communities and amphibian species would be conducted immediately following treatment and for several years thereafter. Impacts would be judged by comparing post-treatment data to that collected during pre-surveys at sites throughout the EFSC watershed (both treated and untreated streams) and in High Lake.

During August 2004, 87 invertebrate taxa were collected in the Specimen Creek drainage.

Disease Surveys

Fish Health Surveys

The Aquatics Section continues to participate in the U.S. Fish and Wildlife Service National Wild Fish Health Survey to monitor the physical health of sampled fish populations that have not yet had a population-level health diagnosis. According to the established 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. Through collaboration with the Bozeman Fish Health Laboratory, approximately 27 sites within YNP have been examined by the survey (1995–2005), with many additional sites examined in the Yellowstone Lake drainage as part of the park's whirling disease research program (Figure 24). To date, two significant fish pathogens have been documented within the park: *Renibacterium salmoninarum*, the agent of bacterial kidney disease, and *Myxobolus cerebralis*, the parasite responsible for salmonid whirling disease (Koel et al. 2006).

R. salmoninarum was confirmed by DNA polymerase chain reaction (PCR) to exist in several waters, including Canyon, Fan, and Soda Butte creeks, the Gardner, Gibbon, and Firehole rivers, and Yellowstone Lake. It is suspected that several other streams harbor *R. salmoninarum*, but its presence was not confirmed with PCR. There have been no documented fish population declines due to this pathogen in the park, and it is suspected that the pathogen may be endemic to the region. *M. cerebralis* (*Mc*) was confirmed by PCR from the Firehole River and several locations in the upper Yellowstone River drainage above the upper falls. This parasite is an introduced, exotic species native to Europe, and it has resulted in severe declines in the native cutthroat trout of Pelican Creek and, possibly, the Yellowstone River downstream of Yellowstone Lake and through the Hayden Valley reach (Koel et al. 2005).

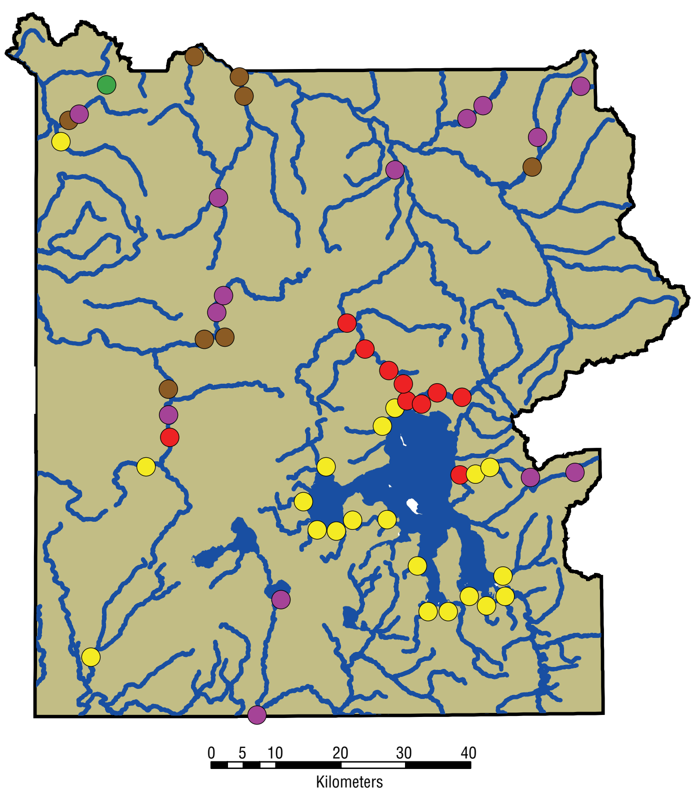


Figure 24. Stream sites examined by the U.S. Fish and Wildlife Service Wild Fish Health Survey or by sentinel cutthroat trout fry exposures, 1995–2005. Sites that tested positive for Myxobolus cerebralis (Mc), *the cause of whirling disease, are in red.*

Mc Infection of Worms and Cutthroat Trout in the Pelican Creek Watershed

M. cerebralis was first documented in YCT in Yellowstone Lake in 1998, and has since become established in two spawning tributaries within this system. Surveys conducted in 1999–2001 detected *Mc* in Pelican Creek (high infection) and in the Yellowstone River downstream of the lake outlet (moderate infection). However, sentinel fry exposures have failed to detect *Mc* in other spawning tributaries to the lake. Numbers of spawning YCT have declined significantly in the Pelican Creek tributary, but similar declines have not been observed in the Yellowstone River below the lake. Declines have been attributed to high infection risk, detected >20 kilometers upstream from the outlet in Pelican Creek in combination with increased predation pressure by non-native lake trout within Yellowstone Lake (Koel et al. 2006).

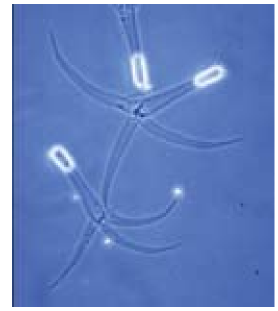
Understanding the factors that affect *Mc*

infections and YCT population declines, and the potential for the YCT population to return to historical numbers, will require knowledge of the spatial variation in *Mc* in the upper reaches of the Pelican Creek watershed. The logistics of working in these remote, backcountry areas, however, preclude using sentinel fish exposures for documentation of infection risk. In 2005, the park continued its close partnership with Montana State University's Department of Ecology, with work now aimed at the Pelican Creek backcountry. Project goals were to (1) quantify *Mc* infection risk in Pelican Creek using *Tubifex tubifex* worms (which serve as a host for *Mc*) and compare the results to those obtained by sentinel fish exposures and (2) measure variation among tubificids and habitat.

Graduate Research Assistant Julie Alexander found a uniform (100%) infection prevalence and similar high grades of infection severity in sentinel fish among six sites where fry were exposed, suggesting that whirling disease (WD) risk is high among remote, upper tributaries to Pelican Creek (Figure 25) (Alexander et al. 2006). In contrast, patchy patterns of *Mc* infection were observed in tubificids, suggesting that WD risk varies among the 25 sites she has examined for worms in the watershed. The highly variable patterns of infected tubificid abundance relative to habitat type warrants investigation. Now that infected reaches have been found in the upper Pelican Creek watershed, the next steps will be to monitor uninfected sites for colonization by the parasite, examine variation in the relative abundances of worm species, and evaluate any potential vectors of dissemination.

Potential of Avian Piscivores as Dispersal Vectors for Mc

In 2005, the park partnered with Montana State University's Department of Ecology and the USDA Animal and Plant Health Inspection Service's National Wildlife Research Center (Mississippi Field Station, Mississippi State University) to examine the role of several common fish-eating birds in the movement of *Mc* in YNP (Koel and Kerans 2004). The cutthroat trout of this system are a source of energy for many important consumer species, including several avian piscivores. Dissemination of *Mc* in the region has been attributed primarily to movement of infected fishes by humans. However, no fishes have been (legally) transported to the waters of the Yellowstone Lake basin or to many places elsewhere in Wyoming where the parasite now exists. The goal of this study is to determine the potential of American white pelicans, great blue herons, great egrets, and double-crested cormorants as dispersal vectors for *Mc*. In the Yellowstone Lake ecosystem and elsewhere, these birds feed, move among waters, and defecate. The range of these bird species includes western states with high WD severity. Daily foraging movements can be more than 150 miles. This study will closely examine the impacts of digestion on the viability of myxospores. Results will provide some of the first knowledge of avian piscivores as a potential dispersal mechanism for *Mc*, and will have far-reaching implications in assisting resource managers concerned with the protection of wild and native salmonid fisheries.



Mc *triactinomyxons (TAMs) float freely in the water column after release by* Tubifex tubifex *worms.*

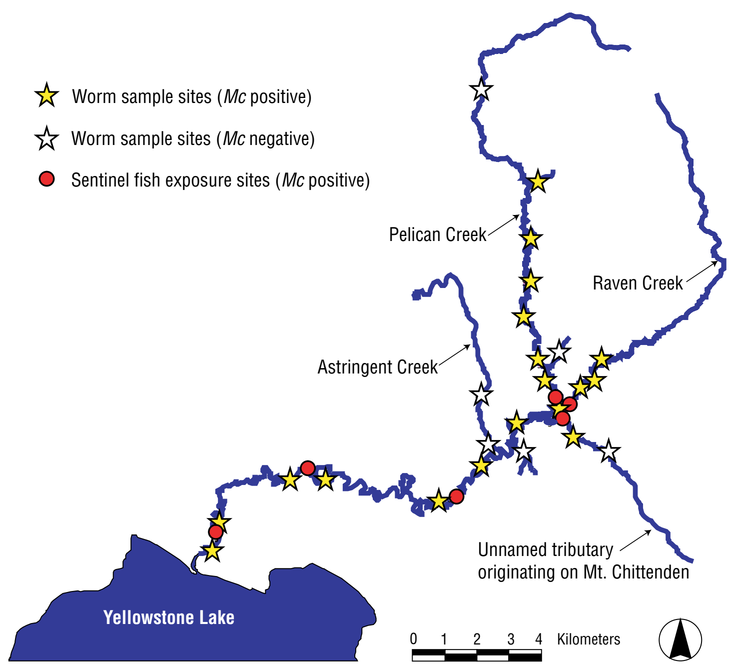


Figure 25. Pelican Creek watershed with locations that were positive for Myxobolus cerebralis (Mc) *as determined by cutthroat trout sentinel fry exposures and tubificid worm survey sites during 2004. (Image provided by Julie Alexander, Montana State University.)*

Angling in the Park

A New Framework for Regulations Proposed in 2005

Native cutthroat trout, fluvial Arctic grayling, and mountain whitefish are protected by catch-and-release-only fishing rules in the park to reduce mortality due to angling. In most waters, current park regulations allow for the harvest of only two rainbow or brown trout. However, hybridization with non-native rainbow trout and predation by non-native brook trout, brown trout, and lake trout continue to negatively affect native sportfish populations in the park.

In 2005, to reduce competition, predation, and hybridization stress on native fishes, park managers proposed to increase harvest limits of rainbow and brown trout in waters where they co-exist with cutthroat trout and Arctic grayling. The proposed regulations change is based on the presence or absence of native sportfish species, and contains a Native Trout Conservation Area and a Wild Trout Enhancement Area (YNP 2006). The proposal simplifies the regulations structure used in the past. In addition, the park sought input on the idea of requiring the use of barbless hooks as a way to reduce injury to fishes, especially in popular, heavily fished waters such as the Yellowstone River, Soda Butte Creek, and others.

Five local public meetings were held from April 4 through 18, 2005. These meetings included an update on the status of the park's fish populations and an explanation of the proposed changes in fishing regulations, followed by a question-and-answer session. In addition, a period for written public comments remained open from March 14 through August 31, 2005. A total of 506 comments were received, of which 352 (70%) were in favor of the proposed regulation changes and 18 (4%) were opposed. Three hundred seventy-six (74%) were in favor of a parkwide policy for barbless hooks, and 10 (2%) were opposed. Given the strong public support for the proposal, the park plans to implement the regulation changes in 2006.

NPS/MIKE RUHL

A barbless hook rule was proposed due to the incidence of scarred trout in several popular streams.

Trends from the Volunteer Angler Report Cards

Angling remains a popular pastime for those visiting, living near, and working in Yellowstone National Park. During 2005, a total of 51,870 people obtained special use permits for fishing the park's waters. Most anglers purchasing a special use fishing permit (required for fishing in park waters) receive a volunteer angler report (VAR) card. These cards have been distributed to anglers since 1973, and provide anglers an opportunity to share their fishing success and opinions with park fisheries managers. There was a response of almost 3,000 angler outings in 2005 through this program.

VAR cards also provide managers with an overview of angler use, fish population dynamics, and attitudes toward the fisheries resource throughout the waters of YNP. Data from 2005 indicated that anglers fished an average of 2.8 hours a day during a typical outing and fished 1.69 days during the season. Anglers who fished only one day comprised 63% of total park anglers, and 81% of them caught fish. Only 5.4% of these anglers kept fish. Anglers reported being satisfied with the overall fishing experience (75%), with the number of fish caught (62%), and with the size of fish caught (65%).

Anglers caught an estimated 522,258 fish in YNP during the 2005 fishing season. Native cutthroat trout remained the most sought-after and caught fish species, comprising 52% of the total catch, followed distantly by rainbow trout (20%), brown trout (13%), brook trout (6%), lake trout (4%), grayling (3%), and mountain whitefish (2%) (Figure 26). Overall, native species comprised 57% of the total catch.

Yellowstone Lake remained the most popular destination for anglers. An estimated 10,267 anglers fished Yellowstone Lake in 2005, representing one-quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching 0.71 cutthroat trout per hour of fishing. This catch rate is less than in recent years and follows a six-year downward trend since a record high in 1998. The average length of cutthroat trout caught by anglers did not increase in 2005. At 447 mm (17.6 inches), though, it is still at an all-time high (Figure 27). The angler-reported catch rate for lake trout in Yellowstone Lake decreased in 2005 for the second consecutive year to 0.05 fish per hour. This is a positive sign that efforts to reduce lake trout are having some success. In the effort to decrease non-native lake trout, the park administration encourages anglers to fish for, and requires them to kill all lake trout caught in Yellowstone Lake, with no size or number limitations. An estimated 5,529 lake trout were caught by anglers in Yellowstone Lake during the 2005 angling season.

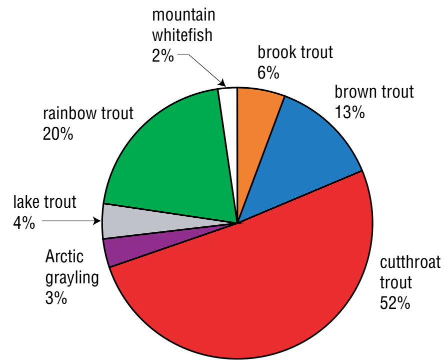


Figure 26. Total angler-reported catch by percent of fish species in Yellowstone National Park during the 2005 fishing season.

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

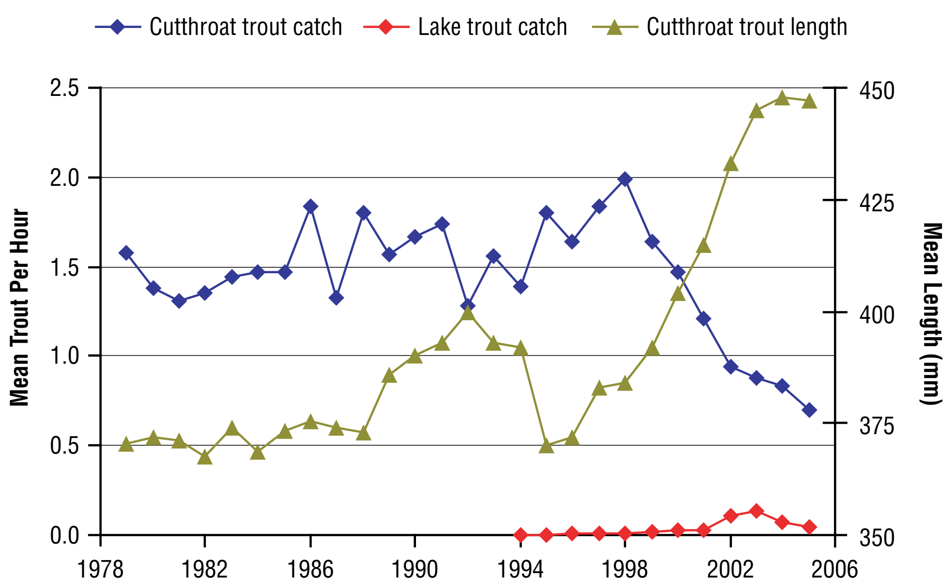


Figure 27. The 2005 angler-reported catch in Yellowstone Lake continued the trend of fewer but larger Yellowstone cutthroat trout, while the lake trout catch per hour decreased.

Public Involvement

Yellowstone Volunteer Flyfishing Program

Although Yellowstone's fisheries staff have directed much of their efforts at emerging crises such as lake trout removal and whirling disease in recent years, there are a multitude of other fisheries issues and questions that need attention. There are an estimated 2,650 miles of streams and 150 lakes with surface waters covering 5% of Yellowstone's 2.2 million total acres. Because NPS staff cannot address all of the park's aquatic issues, a program was established wherein flyfishing volunteers use catch-and-release angling as a capture technique for gathering biological information on fish populations throughout the park. In 2005, the Volunteer Flyfishing Program was coordinated by Dr. Timothy Bywater and Mr. Bill Voigt, both avid flyfishers and long-time supporters and promoters of Yellowstone's fisheries. Projects included determination of the range of hybridized Yellowstone cutthroat trout in the Lamar River, its major tributaries, and several other park waters; and documentation of the status and movement patterns of Arctic grayling in the Gibbon River system. Under this incredibly successful program, volunteer anglers from across the U.S. traveled to the park to participate as an active component of the Aquatics Section. Volunteers experienced many fisheries issues first-hand, and the biological data collected will contribute to understanding the park's fisheries.

NPS/TIMOTHY BYWATER

Coordinator Tim Bywater (third from left) leads volunteer anglers to destinations throughout the park.

Long-term Volunteer Assistance

The Aquatics Section recruits long-term (more than 12 weeks) volunteers from the Student Conservation Association and other sources (see Appendix iii). 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 greatly benefit from both long- and short-term volunteer support.

Educational Programs

Aquatics Section staff continued to provide a variety of short-term educational programs for visiting schools and other interested groups, with an emphasis on native fish conservation. The staff also provided American Red Cross certification in first aid and CPR for employees of YNP and other agencies.

Collaborative Research

The Yellowstone Center for Resources, through the Aquatics Section, provides both direct and indirect support for collaborative research with scientists at other institutions, primarily universities. These 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: Julie Alexander (Doctor of Philosophy candidate).
Committee co-chairs: Drs. Billie Kerans and Todd Koel, Department of Ecology, Montana State University.
Title: Detecting *Myxobolus cerebralis* infection in *Tubifex tubifex* of Pelican Creek, Yellowstone National Park.

Graduate student: Patricia Bigelow (Doctor of Philosophy candidate).
Committee chair: Dr. Wayne Hubert, U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department

of Zoology and Physiology, University of Wyoming.
Title: Predicting suitable spawning areas and potential colonization by lake trout on Yellowstone Lake.

Graduate student: Brian Ertel (Master of Science candidate).
Committee chair: Dr. Thomas McMahon, Department of Ecology, Montana State University.
Title: Cutthroat trout life history strategies in the Yellowstone River upstream of Yellowstone Lake.

Graduate student: Lynn Kaeding (Doctor of Philosophy candidate).
Committee chair: Dr. Daniel Goodman, Department of Ecology, Montana State University.
Title: Comprehensive analysis of historic and contemporary data for the Yellowstone cutthroat trout population of Yellowstone Lake.

Graduate student: Silvia Murcia (Doctor of Philosophy candidate).
Committee co-chairs: Drs. Billie Kerans and Todd Koel, 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: Amber Steed (Master of Science candidate).
Committee co-chairs: Drs. Al Zale, U.S. Geological Survey Cooperative Fisheries Research Unit, and Todd Koel, Department of Ecology, Montana State University.
Title: Spatial dynamics of Arctic grayling in the Gibbon River, 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: The ecosystem consequences of invasive lake trout in Yellowstone Lake and tributary streams.


NPS/TIMOTHY BYWATER

Flyfishing volunteers collect information used for management of the park's fishery resources.

Interagency Workgroups

Yellowstone National Park actively participates in the Yellowstone Cutthroat Trout Interstate Workgroup, the Montana Cutthroat Trout Steering Committee, and the Fluvial Arctic Grayling Workgroup. Shared goals and objectives among partner agencies and non-governmental organizations are defined in a memorandum of agreement for the rangewide conservation and management of Yellowstone cutthroat trout, a memorandum of understanding (MOU) and conservation agreement for westslope cutthroat trout and Yellowstone cutthroat trout in Montana, and an MOU concerning the recovery of fluvial Arctic grayling.

Cutthroat Trout Broodstock Development

Wyoming Game and Fish employees collect a limited number of Yellowstone cutthroat trout gametes from the Yellowstone River at LeHardys Rapids. Gametes are used for enhancement of the native Yellowstone cutthroat trout broodstock (now located at Ten Sleep, Wyoming) and restoration activities in Montana and Wyoming. As an added benefit for Yellowstone fisheries, 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

Don Wethington operates the NPS gillnetting boat *Freedom* each day. Joe Facendola, Brad Olszewski, and Stacey Sigler have returned to Lake for many seasons. These individuals, as well as several other seasonal staff, have made significant contributions to our understanding of lake trout ecology and have been a driving force behind the suppression of these fish to preserve the Yellowstone Lake cutthroat trout.

Much-appreciated administrative support for the Aquatics Section was provided by Becky Wyman, Barbara Cline, Melissa McAdam, and Joy Perius, with special thanks to Mary McKinney for all of her assistance and patience when working with the fisheries staff at the Lake office.

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). In 2004–2005, additional funding was received from the following sources:

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

NPS/MIKE RUHL

Fairies' Fall, Amethyst Creek.

We would like to extend special thanks to the Yellowstone Park Foundation board and staff, and to the many private individuals who have graciously provided support for our critical fisheries projects in the park. Chessie Thacher was especially instrumental in the development of the Fisheries Fund Initiative in 2005, and for that we are truly grateful. Special thanks also to Andy Dana and The Anglers Club of New York City for hosting the Yellowstone Fisheries event on February 8, 2005.

S. Thomas Olliff, Natural Resources Branch Chief; Wayne Brewster, Deputy Director; and John Varley, Director, Yellowstone Center for Resources, provided guidance and support for the Aquatics Program.

Lisa Graumlich and Diane Eagleson of the Big Sky Institute, Montana State University, have graciously provided much-needed staff support for the Fisheries Fund Initiative. This support made it possible to move aggressively forward with cutthroat trout restoration in the park.

Matt Campbell, Idaho Department of Fish and Game, Eagle Fish Health Laboratory, kindly provided analyses of westslope cutthroat trout genetics samples from Fan Creek and the unnamed Grayling Creek tributary. Dennis Shiozawa, Brigham Young University, has provided genetics analyses of Yellowstone cutthroat trout. Results of these analyses have been instrumental in the progress made toward restoration of these subspecies within the park.

Cathie Jean and the staff of the Greater Yellowstone Network have been instrumental in the development of and provided funding for the park's water quality monitoring program.

Crystal Hudson and the staff at the USFWS Bozeman Fish Health Center have provided the park with an incredible amount of critical information on the health of our native fish populations each year.

Special thanks to Cal Frasier of the Montana Water Center's Wild Trout Laboratory for years of support for our whirling disease research program. In 2005, Trey Kucherka also patiently provided care for exposed trout and made it possible for us to conduct avian piscivore feeding studies.

We also thank the many volunteers who have dedicated their time and a great deal of other expense to our Aquatics Section. Without them, much of what we do would not be possible. Flyfishing anglers from Trout Unlimited, the Federation of Fly Fishers, the 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.

Many additional 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, Michael Keator, Dave Phillips, Brad Ross, Steve Swanke, Boone Vandzura, and Kim West from the South District Rangers; and Dave Elwood, Monte Simenson, and Wally Wines from Corral Operations.

This report is made possible only by the dedicated work of the Resource Information Team, Yellowstone Center for Resources. Special thanks to Tami Blackford, Virginia Warner, and Alice Wondrak Biel for making this report a reality.

NPS/JEFF ARNOLD

Water quality technician Jeremy Erickson and Student Conservation Association volunteer Matt Christianson sample Soda Butte Creek.

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NPS/TIMOTHY BYWATER

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
	Arctic 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

* Scientific name suggested by Behnke (2002), *Trout and Salmon of North America* (New York: The Free Press), and not currently recognized by the American Fisheries Society.

Appendix ii. The Waters of Yellowstone (adapted from Varley and Schullery, 1998)

Size of the park	898,318 hectares
Water surface area	45,810 hectares (5% of park)
Number of lakes	150
Lake surface area total	43,706 hectares
Number of fishable lakes	45
Yellowstone Lake surface area	36,017 hectares
Number of streams	>500
Stream length total	4,265 kilometers
Stream surface area total	2,023 hectares
Number of fishable streams	>200

JORDAN ALLISON

Arctic grayling from the Gibbon River system.

NPS/PHILIP DOEPKE

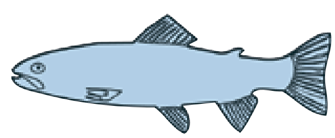
Fisheries volunteer Siana Wong with a record 22.5-pound non-native lake trout from Yellowstone Lake.

Appendix iii. Long-term Volunteers, 2005

Name
Allison, Jordan
Behncke, Jeff
Christianson, Matthew
Rudolph, Dominique
Talbott, Mariah
Tong, Amanda
Voigt, JoAnn
Wong, Siana

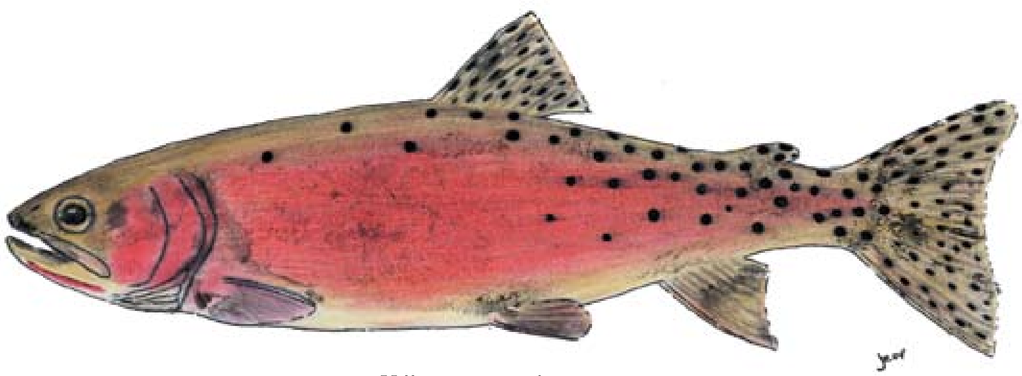
Appendix iv. Seasonal Staff, 2005

Name
Bywater, Timothy
Erickson, Jeremy
Facendola, Joseph
Hutchinson, Hunter
Legere, Nicole
Naughton, Joe
Olszewski, Brad
Romankiewicz, Christopher
Schamberry, Nicole
Sigler, Stacey
Varian, Anna
Voight, Bill
Wethington, Don



JORDAN ALLISON

Cache Lake, located at the headwaters of Reese Creek, has retained its historically fishless condition.



JOE FACENDOLA

Yellowstone cutthroat trout.