Yellowstone Fisheries & Aquatic Sciences

Annual Report

2004

NPS/TODD KOEL

The Yellowstone Center for Resources lake trout gillnetting boat Freedom *on Yellowstone Lake in 2004.*

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

Predatory, non-native lake trout, illegally introduced to the lake at least 20 years ago and not discovered until 1994, can annually consume at least 41 cutthroat trout each. They have the potential to decimate the Yellowstone Lake fishery in our lifetime without heightened and maintained management efforts. Lake trout also occupy an ecological niche unavailable to cutthroat-eating predators, imperiling the many species, such as grizzly bears, bald eagles, and river otters, that depend on the cutthroat for survival.

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

An additional fisheries program emphasis is the restoration of fluvial populations of native trout, including isolated populations of westslope cutthroat trout, Yellowstone cutthroat trout of the park's northern range, and Arctic grayling of the Gibbon River. The program also conducts intensive monitoring to track aquatic ecosystem health, and to expedite early warnings for other aquatic invasive species, and encourages public involvement in various fisheries programs.

The stakes are high, raising the bar for innovative management and fundraising. The increased magnitude of the problems faced by the park's fisheries, and the accelerated rate at which they are occurring, are straining Yellowstone's resources. This annual report describes historic and continuing park aquatics programs as well as specific initiatives for 2004. In several instances, the report also outlines project goals and objectives for future years. This was done in an attempt to ensure transparency of our program; we want to make sure that everyone with an interest has a solid understanding of our intent and direction in our efforts to preserve and restore native fishes in the waters of this tremendous park.

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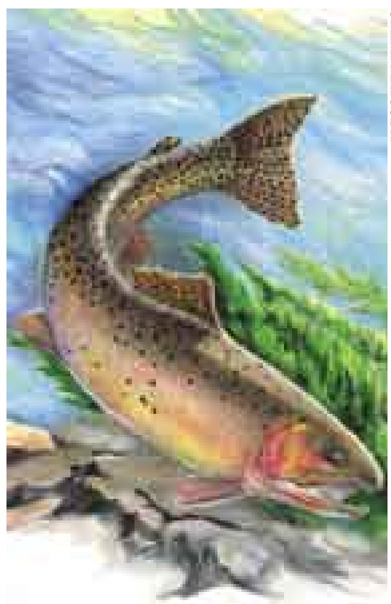

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Yellowstone cutthroat trout.

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Yellowstone National Park, Wyoming
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Title page art courtesy Mimi Matsuda. Inside back cover art courtesy Joe Facendola.

Front cover photo captions (left to right): Fisheries technician Shane Keep checks a whirling disease sentinel cage in the upper Pelican Creek watershed during 2004 (photo by NPS/Todd Koel); NPS Student Temporary Employment Program biological technician Charles Walton with a Yellowstone Lake cutthroat trout (photo by Joe Facendola); fisheries technicians Brad Olszewski and Stacey Sigler set a gillnet out the stern of the *Freedom* (photo by Zac Sexton). Back cover photo captions: Jeff Arnold, NPS aquatic ecologist, deploying water quality multi-probe from the bridge, Yellowstone River (photo by NPS/Todd Koel); the finespotted form of Yellowstone cutthroat trout was found within the Snake River in 2004 (NPS/Dan Mahony); hiking in along Nine Mile trail to set up the Clear Creek fish trap, April 2004 (photo by NPS/Todd Koel).

Facing page photo: Stonefly nymph on Soda Butte Creek (photo by NPS/Jeff Arnold).

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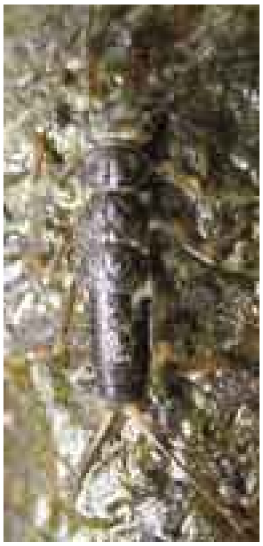


Background

Because 40% of Yellowstone's waters were once fishless, the stocking of non-native fishes has had profound ecological consequences.

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

To supplement fishing and to counteract this "destructive" consumption by wildlife, a fish "planting" program was established in Yellowstone. Early park superintendents noted the vast fishless waters of the park, and immediately asked the U.S. Fish Commission to "see that all waters are stocked so that the pleasure seeker can enjoy fine fishing within a few rods of any hotel or camp."[2] The first fishes from outside the park were planted in 1889–1890, and included brook trout in the upper Firehole River, rainbow trout in the upper Gibbon River, and brown trout and lake trout in Lewis and Shoshone lakes.[3] During the early history of the park, stocked fisheries were extremely important. 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.[4]

Largely due to these activities in Yellowstone National Park and the popularity of its fisheries, recreational angling became a long-term, accepted use of national parks throughout the country. In

YELLOWSTONE NATIONAL PARK ARCHIVES

U.S. Bureau of Sport Fisheries boat on Yellowstone Lake in 1932.

YELLOWSTONE NATIONAL PARK ARCHIVES

*Fisheries staff mixing a fish toxicant to successfully remove non-native yellow perch (*Perca flavescens*) from Goose Lake (Firehole River drainage) in 1939.*

Yellowstone, fisheries management, as we understand that term today, began with the U.S. Army, and was assumed by the National Park Service in 1916. Fish stocking, data gathering, and other monitoring activities began with the U.S. Fish Commission in 1889, were continued by the U.S. Fish and Wildlife Service until 1996, and have been the responsibility of the National Park Service since then.

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

A perceived conflict exists in the National Park Service mandate to protect and preserve our pristine, natural systems, and also provide for use and enjoyment.[7] To date, we know of 18 fish species or subspecies in Yellowstone National Park; 13 of these are considered native (they were known to exist in park waters prior to Euro-American settlement), and five are introduced

(non-native or exotic; see Appendix i).[8] 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. As our primary mission is the preservation of natural ecosystems and ecosystem processes, we will not emphasize maintenance of established non-native fish stocks. Along with native fish preservation, our Fisheries and Aquatic Sciences Section (Aquatics Section) activities include native fish restoration, stream and lake inventory and monitoring, and an emphasis on aquatic ecosystem health, including water quality and macroinvertebrate monitoring of lakes and streams to serve as an early warning for advancing aquatic invasive species.

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

Fisheries authority David Starr Jordan produced this map of Yellowstone waters in 1889, showing the large portion of the western side of the park as an AREA WITHOUT TROUT, in anticipation of the extensive stocking program that followed. (From 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 species, while allowing for use of these fisheries by visiting anglers.

2004 Summary

The 2004 field season represented another record year for lake trout suppression efforts on Yellowstone Lake. A total of 27,770 of the non-native predators were killed to preserve the remaining native Yellowstone cutthroat trout of this system. Because each of the non-native lake trout would consume many cutthroat trout each year, the gillnetting effort has saved a tremendous number of cutthroat trout; more than 100,000 lake trout have been killed by gillnetting since they were first discovered in 1994. The angling community has also joined the effort, and has been contributing to 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 each year.

Two additional stressors are in some ways confounding our ability to interpret the success of the suppression program. Whirling disease has caused the loss of great numbers of cutthroat trout in Pelican Creek, and all Yellowstone Lake spawning tributaries have been significantly impacted by the drought in recent years. In many cases, lack of water has resulted in a complete disconnect between tributary streams and their outlets, especially during middle-to-late summer, when fry would be expected to out-migrate to Yellowstone Lake. These two additional stressors appear to be contributing to cutthroat trout recruitment failure, along with lake trout predation within Yellowstone Lake.

The number of upstream-migrating Yellowstone cutthroat trout at Clear Creek, a major Yellowstone Lake spawning tributary, was 1,438 in 2004; these were the fewest to migrate upstream since 1954, when only 3,161 fish migrated due to impacts of angler harvest and removal of eggs by the hatchery operations in the park. Similar results have been documented at many other, smaller spawning tributaries.

Within Yellowstone Lake, cutthroat trout abundance as indicated by the fall netting assessment suggested an increase in fish densities. During 2003–2004, this assessment provided some of the first indications that the cutthroat trout population may be responding positively to efforts to remove non-native lake trout. An average of 7.4 fish were caught per net in 2003, and 7.9 fish were caught per net in 2004. Prior to 2003, the fall netting program catch had been reduced by 0–21% each year (averaging 11% per year) since 1994, the year lake trout were first discovered in Yellowstone Lake.

The fisheries program is also moving forward with restoration of fluvial populations of native trout. Given the uncertain genetic status of the North Fork Fan Creek westslope cutthroat trout population, we are focusing efforts on Specimen Creek, another tributary to the Gallatin River, for a future westslope cutthroat trout restoration project. Efforts have also begun for Yellowstone cutthroat trout restoration in streams of the park's northern range and determining the status of any remaining fluvial Arctic grayling within the Gibbon River.

Research focusing on the status and life history strategies of cutthroat trout in the Yellowstone River and its tributaries upstream of Yellowstone Lake continued in 2004. We also began an inventory of fishes in the remote reaches of the Snake River and its tributaries. 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 biweekly at 12 fixed sites located near the confluences of major streams and rivers (Figure 1). The physical and chemical characteristics of Yellowstone Lake are monitored seasonally to assist the targeting of non-native lake trout. Macroinvertebrates continue to be sampled using regionally standardized methods

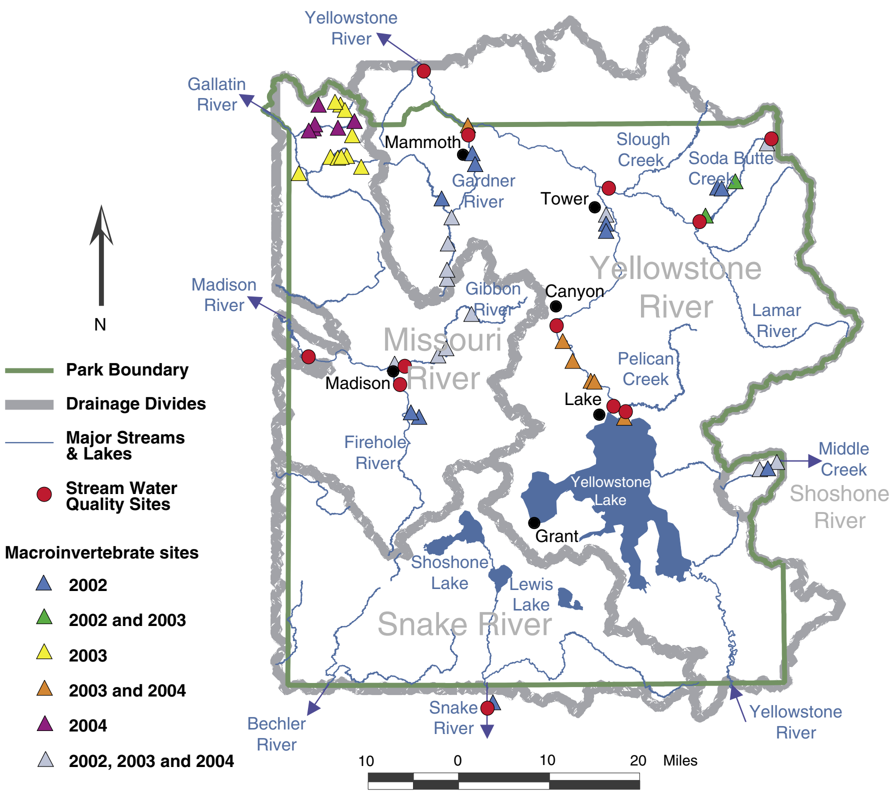


Figure 1. Major surface waters of Yellowstone National Park, with 12 stream sites established for long-term monitoring of water quality and all sites sampled for macroinvertebrates, 2002–2004. No label is shown for Fan Creek.

Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 fishing season.

to allow for easy comparison of data among agencies. Results are being used to assist with the development of NPS Vital Signs Monitoring protocols for the Greater Yellowstone Network. A study was also completed that provided some of the first information on the effects of snowmobile emissions on the quality of snowmelt runoff in the park.

Intensive research on whirling disease continues, with efforts focused on Pelican Creek (where the disease was most severe); tubificid worms are used to monitor infection in the drainage. Wild-reared fry and fingerling cutthroat trout were found in upstream tributaries of Pelican Creek, suggesting that at least some fish are avoiding the disease there. Monitoring unfortunately confirmed the presence of this exotic parasite in the Hayden Valley reach of the Yellowstone River. The extent to which whirling disease has impacted Yellowstone River cutthroat trout is unknown, but anglers have reported seeing fewer fish in this river in recent years, similar to what we are noting on Yellowstone Lake.

A total of 45,573 special use fishing permits were issued in 2004. Anglers fished 2.87 hours per day during typical fishing trips in the park, which lasted 1.69 days on average. Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 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 16%, brown trout 12%, brook trout 9%, lake trout 5%, mountain whitefish 3%, and grayling 3%. Yellowstone Lake remained the most popular destination for anglers; an estimated 10,326 anglers fished this lake in 2004, representing one quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching nearly one (0.83) cutthroat trout per hour of fishing.

Public involvement with the Aquatics Section continued to greatly increase, primarily through the incorporation of many volunteers. In 2004 alone, volunteers dedicated 4,441 hours to Aquatics Section activities. A highlight again 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

Program Guidance by the National Park Service

Specific guidance for Aquatics Section activities is provided in a number of documents, including the National Park Service's Management Policies, especially section 4.1.5 *Restoration of Natural Systems*, 4.4.2.2 *Restoration of Native Plant and Animal Species,* 4.4.3 *Harvest of Plants and Animals by the Public,* and 4.4.4.2 *Removal of Exotic Species Already Present.*[9] Additional guidance is found in the National Park Service's Interim Technical Guidance on Assessing Impacts and Impairment to Natural Resources, and the *Yellowstone National Park Resource Management Plan.*[10] Most work performed falls under Yellowstone National Park's *Strategic Plan* and *GPRA* Mission Goal Category I: *Preserve Yellowstone National Park Resources*. However, angling is considered an important recreational opportunity, and is covered by Mission Goal Category II: *Provide for the public use and enjoyment and visitor experience of Yellowstone National Park*.

Yellowstone National Park actively participates in the Yellowstone Cutthroat Trout Interstate Workgroup, the Montana Yellowstone Cutthroat Trout Workgroup, 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 Cooperative Conservation Agreement for Yellowstone cutthroat trout within Montana, and a Memorandum of Understanding concerning the recovery of fluvial Arctic grayling.

A Model for the YNP Fisheries Program

Over the past decade, the aquatic resources of Yellowstone National Park and the ecosystems that they support have become seriously threatened by introductions of non-native and exotic species. At the same time, funding to support resource management activities within the park has become increasingly difficult to obtain. Because of this, the Aquatics Section has set two main priorities for the future preservation of the park's fisheries resources. There is an increased need to prevent an additional loss in abundance and reverse the declining trend in genetic integrity of our native cutthroat trout populations. There is also an urgent need to understand the status of, and work to preserve any remaining fluvial (stream resident) Arctic grayling (*Thymallus arcticus*) that may remain in the park. Because of these needs, for the foreseeable future, the Aquatics Section will focus the greatest amount of effort possible on conducting activities that are aimed at supporting:

1. Preservation of Yellowstone Lake cutthroat trout, which is the largest remaining concentration of (genetically pure) inland cutthroat trout in the world.

2. Restoration of fluvial populations of native trout, largely lost due to introduced species (see Figure 2).

The specific activity currently conducted to preserve Yellowstone Lake cutthroat trout is the lake trout (*Salvelinus namaycush*) suppression

A Model for the Fisheries Program at Yellowstone

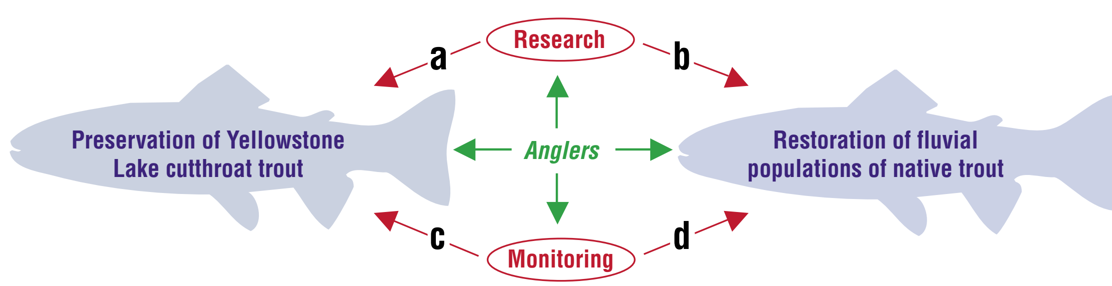


Figure 2. A model for the fisheries program at Yellowstone National Park.

program, which is the largest non-native fish removal program occurring in the United States. Activities specific to the restoration of fluvial populations of native trout include all the work that has been conducted to date in the Gallatin Range for the future restoration of westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Also, a new project has been initiated to move toward the future restoration of Yellowstone cutthroat trout (*O. c. bouvieri*) in streams of the park's northern range.

The Aquatics Section research program is now aimed specifically at supporting and enhancing the two primary Section priorities. Research to support the preservation of Yellowstone Lake cutthroat trout (Figure 2a) 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 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 2b) 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.

The Aquatics Section's monitoring and inventory activities supporting the preservation of Yellowstone Lake cutthroat trout (Figure 2c) include the long-term, annual cutthroat trout spawning migration assessment at Clear Creek; the annual counts of spawning fish at Bridge Creek; annual assessment of the spawning cutthroat trout at LeHardys Rapids; 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 2d) 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 of streams, so any potential impacts of future restorations are well understood.


JOE FACENDOLA

NPS Student Temporary Employment Program biological technician Charles Walton with a Yellowstone Lake cutthroat trout.

Anglers are an integral component of the fisheries program model, as they assist with all aspects of native species conservation (Figure 2). For example, anglers contribute significantly to the reduction of lake trout within Yellowstone Lake. They assist with removal of non-native species (in streams where they co-exist with native trout), and will participate in "fish rescue" when stream restoration occurs in the future. Anglers also provide research assistance; they have already tagged >300 Arctic grayling from Grebe and Wolf lakes in our attempt to understand the dynamics of these fish in this river system. Lastly, anglers annually provide an incredible amount of monitoring and inventory information through the Volunteer Flyfishing Program, and through returns of the Volunteer Angler Report Cards provided to all anglers upon purchasing a special use fishing permit in the park.

Anglers are an integral component of the fisheries program model, as they assist with all aspects of native species conservation.

Preservation of Yellowstone Lake Cutthroat Trout

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 3). 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 4). With this relief, and the implementation of restrictive angling regulations, the population rebounded during the 1960s and 1970s, and 70,105 cutthroat trout were counted at Clear Creek in 1978.[11] 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, and 19.1 fish were caught per net in 1984.

Contemporary data suggest that a significant decline has recently occurred in the Yellowstone Lake cutthroat trout population. The number of upstream-migrating cutthroat trout counted at Clear Creek was 1,438 during 2004 (Figure 4a). This count was down from 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 operated on Bridge Creek, a small northwestern tributary, indicated that only a single fish migrated upstream during 2004 (Figure 4a). The number of spawning cutthroat trout in recent years has declined by more than 50% annually in Bridge Creek, and has decreased by over 99% since counts began in 1999 (when 2,363 cutthroat trout ascended the stream to spawn). The decline was also evident in results of the fall netting assessment, where an average of 15.9 cutthroat trout were caught per net in 1994, and only 6.1 were caught per net in 2002 (Figure 4b).

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

Length–frequency data from the fall netting program, 1997–2004, indicated an increase in length and reduction in numbers of adult cutthroat trout (>325 mm) in Yellowstone Lake (Figure 5). In 2004, fewer fish between the lengths of 325 and 425 mm were collected compared to earlier years. Historically, most cutthroat trout sampled in spawning tributaries such as Clear Creek were in this size range.[12] Despite this, an apparent increase in numbers of juvenile cutthroat trout (100–325 mm) has been noted in recent years (2002–2004). Many of these juveniles have been collected in the southern arms of Yellowstone Lake, which may act as refuges for cutthroat trout due to the low numbers of lake trout and low incidence of *M. cerebralis* in these areas.[13]

Lake Trout, Whirling Disease, and Drought as Stressors

In streams throughout Yellowstone National Park and elsewhere in the natural range of Yellowstone cutthroat trout, populations have been compromised by introgression with introduced, non-native rainbow trout (*O. mykiss*) or other cutthroat trout subspecies.[14] The cutthroat trout of Yellowstone Lake and its associated drainage have remained genetically pure due to isolation provided by the Lower and Upper Falls of the Yellowstone River, located 25 km downstream from the lake outlet near Canyon. The genetic purity of these fish makes them extremely valuable; however, the population has recently been exposed to three other potential stressors, including introduced non-native lake trout, invasion by the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease), and the drought that has persisted throughout the Intermountain West.[15]

Yellowstone cutthroat trout populations have been compromised by introgression with introduced, non-native rainbow trout (*O. mykiss*) or other cutthroat trout subspecies.

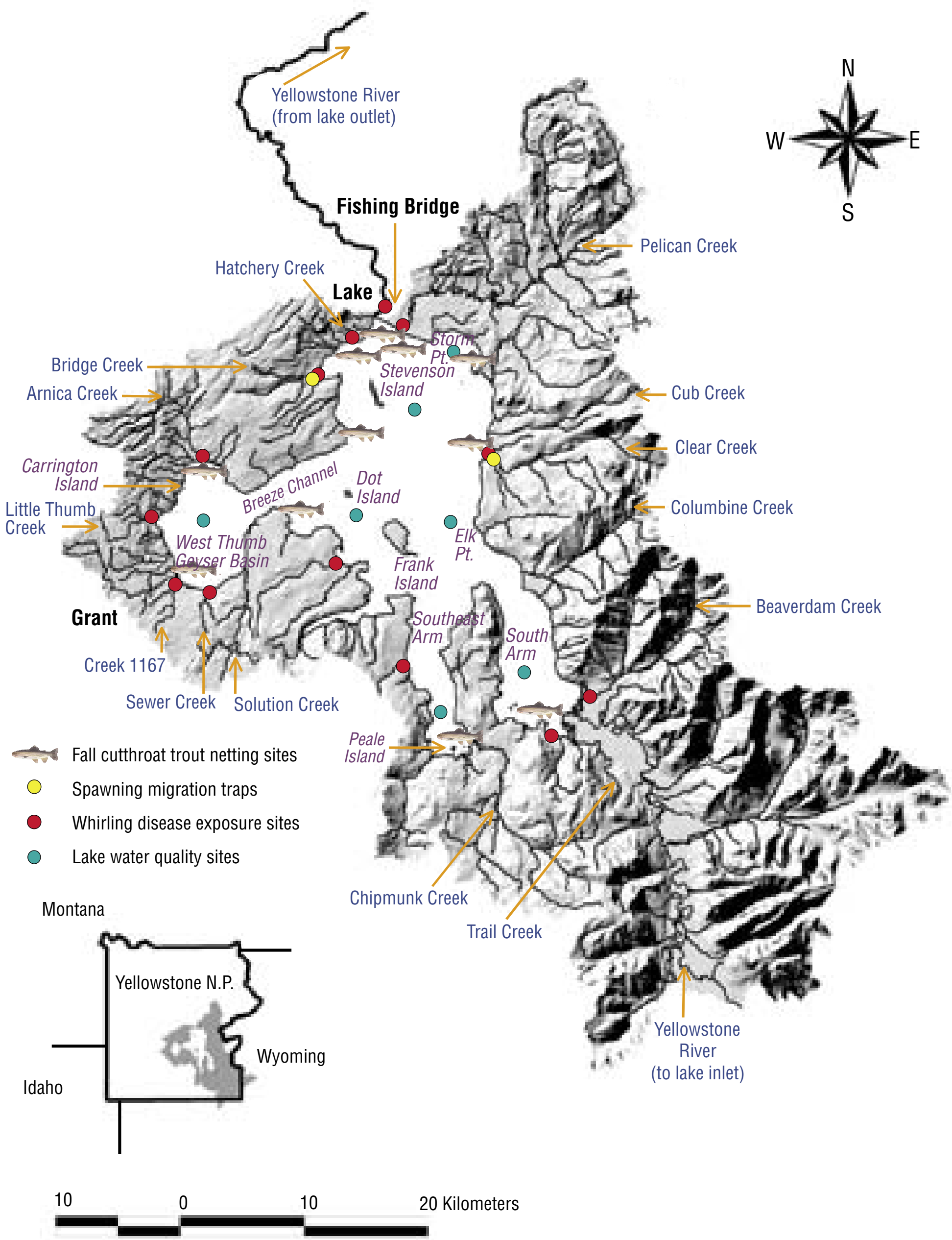


Figure 3. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

The presence of lake trout in Yellowstone National Park is the result of deliberate, historical introductions of this non-native species to Lewis and Shoshone lakes in the upper Snake River drainage (in 1890). Contemporary research points to non-native fish species as the greatest threat to cutthroat trout of the Intermountain West.[16] The park places a high priority on preservation and recovery of the cutthroat trout, because of their importance in maintaining the integrity of the Greater Yellowstone Ecosystem, arguably the most intact naturally-functioning ecosystem remaining in the continental United States. Grizzly bears (*Ursus arctos*), bald eagles (*Haleaeetus leucocephalus*), and many other avian and terrestrial species use cutthroat trout as an energy source in the Yellowstone Lake area.[17] In fact, activity by bears drastically declined at Yellowstone Lake spawning streams from 1989 to 2004, and has mirrored that of the cutthroat

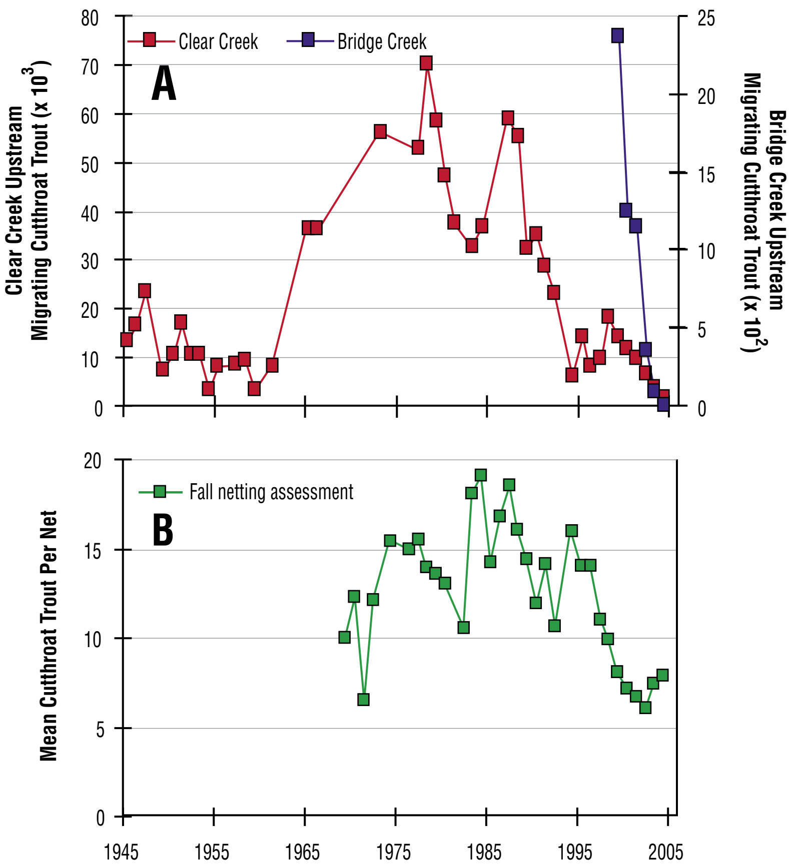


Figure 4. Number of upstream-migrating cutthroat trout counted at Clear Creek (1945–2004) and Bridge Creek (1999–2004) spawning migration traps (A), and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake, 1969–2004 (B).

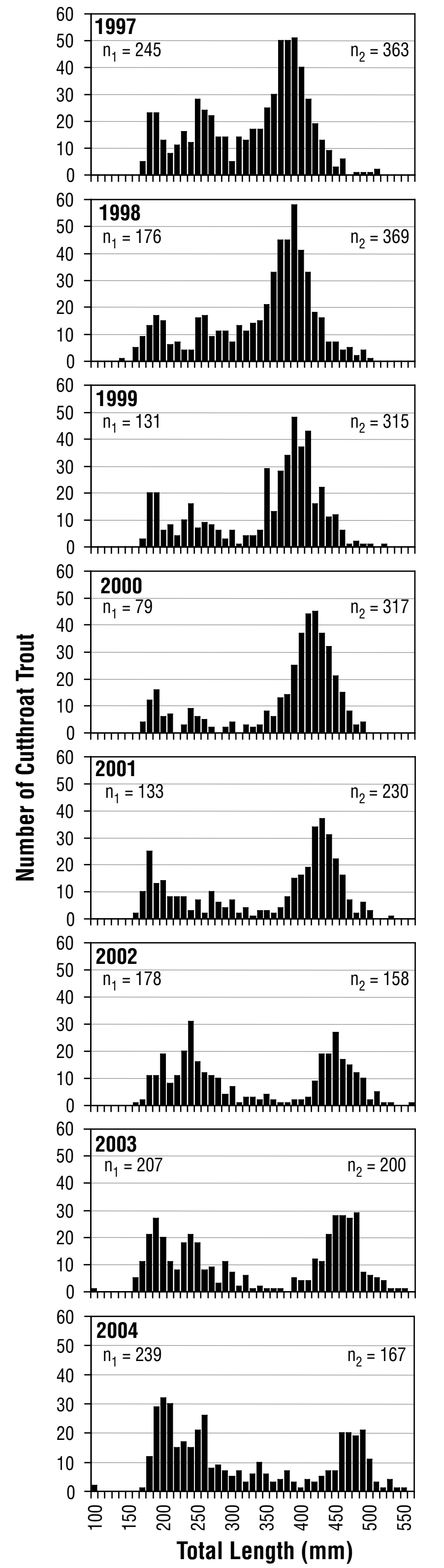


Figure 5. Length–frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake with total number of trout <325 mm (n_1) and >325 mm (n_2), 1997–2004.

trout reductions, indicating cascading interactions in the food web of this system (Figure 6).[18]

Non-native lake trout would not be a suitable ecological substitute for cutthroat trout in the Yellowstone Lake system because they are inaccessible to most consumer species. Lake trout tend to occupy greater depths within the lake than do cutthroat trout. Lake trout remain within Yellowstone Lake at all life stages; they do not migrate into tributary streams, as do cutthroat trout. Evidence from other, similar systems suggests that introduced lake trout will result in the decline of cutthroat trout.[19] Following the guidance of a lake trout expert advisory panel, the National Park Service has used gillnetting to determine the spatial and temporal distribution of lake trout within Yellowstone Lake.[20] The efforts have led to a long-term lake trout suppression program for the protection of the cutthroat trout in this system.[21]

Myxobolus cerebralis was first found in Yellowstone National Park in 1998, in juvenile and adult cutthroat trout collected from Yellowstone Lake.[22] Examination of gillnetting mortalities has since confirmed the parasite's presence throughout Yellowstone Lake, with highest prevalence existing in the northern region, near known infected streams. Although the widespread presence of this harmful parasite in the lake is disturbing, the discovery of *M. cerebralis* spores in adult fish each year suggests that at least some cutthroat trout are surviving initial *M. cerebralis* infection.

In addition to lake trout and whirling disease impacts, drought in the Intermountain West during the past six years has resulted in increased water temperatures and a reduction in peak streamflows. In many cases, tributary streams have become sub-terminal near the lake, flowing through large sand and gravel bars. This disconnect of tributary streams from the lake has been occurring during mid-summer and fall, when cutthroat trout fry would typically be out-migrating to Yellowstone Lake. Biologists have consistently noted cutthroat trout fry that are stranded in isolated side channels and pools in seasonally-disconnected tributaries. Although cutthroat trout have existed in the Yellowstone Lake ecosystem since glacial recession, and evolved in the face of great variation in thermal and other environmental regimes, the current drought is occurring during a period when the cutthroat trout are also impacted by lake trout predation and *M. cerebralis*.[23] The recent drought may be a significant contributor adding to a reduction in the overall recruitment of cutthroat trout.

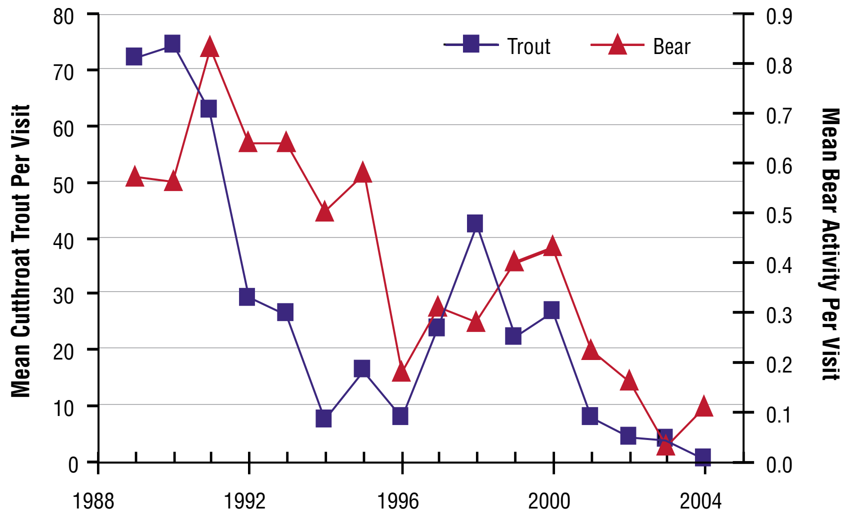


Figure 6. Mean number of cutthroat trout and mean activity by black bears and grizzly bears observed during weekly spawning visual surveys of 9–11 tributaries located along the western side of Yellowstone Lake between the Lake and Grant areas, 1989–2004.

NPS/KERRY GUNTHER

When trout are abundant, grizzlies tend to high-grade this food source and eat only the heads; the brains are highly nutritious.

Columbine Creek, at its mouth along the eastern shore, disconnected from Yellowstone Lake in August 2004.

Lake Trout Suppression Program

Following the discovery of lake trout in Yellowstone Lake in 1994, efforts to counteract this non-native threat have continually intensified. Each year, lake operations staff improve their knowledge of lake trout seasonal distribution patterns and their ability to target lake trout while avoiding bycatch of the native Yellowstone cutthroat trout. In 2004, 26,707 lake trout were removed from Yellowstone Lake by gillnetting (Figure 7a). The concurrent ratio of lake trout killed to cutthroat trout sacrificed remained low (0.07 cutthroat trout lost for every lake trout killed, up slightly from 0.04 in 2003). Although down from 2003, total gillnetting effort was maintained at a high rate, almost a tenfold increase over the 1999 level. Catch per unit of effort (CPUE) rose slightly in 2004 (1.69), but was still dramatically below the 1998 level, when an average of 5.51 lake trout were caught with each unit of effort.

The majority of removal efforts were targeted at young lake trout residing in depths greater than those occupied by cutthroat trout (control sets). Small mesh (19–44-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 this relatively nutrient-poor system. On a typical day during the open water season on Yellowstone Lake, more than 10 miles of gillnet were in place fishing for lake trout.

As in past years, we conducted distribution and spawner gillnetting. Distribution netting was conducted lake-wide, using multi-sized mesh gillnets set at varying depths to collect information on both lake trout distribution and the percentage of fish species at varying depths. This information will be used in a time series analysis to monitor lake trout population expansion. It will also aid in deciphering acoustic targets collected during hydroacoustic surveys (discussed below).

Lake trout in Yellowstone Lake congregate from late August until early October in preparation for spawning. This is a prime time to target the mature fish of the population without harming cutthroat trout. Approximate locations of three spawning areas are known in Yellowstone Lake: near Carrington Island, west of the mouth of Solution Creek, and northeast of West Thumb Geyser Basin (Figure 3). These areas were intensely gillnetted during the spawning season using net sizes ranging from 38- to 76-mm bar mesh. Nets were also deployed in Breeze Channel (a corridor into West Thumb) and throughout West Thumb. With these spawner gillnet sets, we were able to remove 7,283 lake trout from Yellowstone Lake (Figure 7b).

In an effort to capitalize on the lake trout's spawning behavior, a second capture method was attempted in 2004. Electrofishing, using a boat loaned by the U.S. Fish and Wildlife Service of Ahsahka, Idaho, proved extremely effective in the shallow areas around Carrington Island without harming cutthroat trout. On the nights of September 21 and 22, 975 additional mature lake trout were removed from Yellowstone Lake by electrofishing. In the following week, only 88 were captured, indicating the spawn was likely over. On nights we electrofished, we surrounded the area with gillnets in hopes of catching any lake trout fleeing from the electric current. No increase in gillnet catch due to the electrofishing was observed.

Although the overall increase in CPUE for lake trout in 2004 was somewhat disappointing,

the majority of that increase was due to fish killed by spawner sets. CPUE for just control sets (1.29) did increase slightly over that seen in 2003 and 2002 (0.86 and 0.78, respectively), but was very similar to the 2001 level (1.23). Given that we were able to retain a very experienced crew in 2004, this was not a surprising result.

What *is* disturbing is the large increase in the spawning population of lake trout we are seeing in Yellowstone Lake. For the first time since the program began, we noted collapsed gillnets after setting just one night; i.e., nets were so full of fish they had collapsed to the lake bottom and were no longer fishing. Spawner sets removed a new record number of lake trout in 2004: 7,283 (Figure 7b). Combined with electrofishing, 8,346 lake trout were removed from spawning areas in 2004. This immediately followed another record year of 2,373 lake trout caught in spawner sets during 2003: a threefold increase in the number of spawning lake trout removed two years in a row. Part of the increase (almost 20% of the catch in both years) can be attributed to the identification of a new spawning area near West Thumb Geyser Basin.

The size of lake trout caught in gillnets near spawning areas continued to decrease in 2004 (Figure 7b). Mean total length (528.4 mm) decreased more than 12 mm from 2003. Females were larger than males (mean total lengths of 536.2 and 522.3 mm, respectively) and the male-to-female ratio was 1:0.77. Lake trout removed via electrofishing were considerably smaller, and had a greater male-to-female ratio: 504 mm mean total length, and 1:0.22 ratio of males to females. However, electrofishing was used only briefly, and late in the spawning season; differences in size and sex ratio are likely due to the specific time period during which sampling occurred. Use of this technique throughout the entire spawning season in future years will provide interesting results regarding numbers, timing, and maturity of lake trout congregating at spawning areas.

Given the large increase in numbers of lake trout found at spawning areas, the relatively low mean length, and the preponderance of males (males typically mature earlier than females), we suspect that a substantial portion of these fish were first-time spawners, and the result of strong year classes produced prior to increased gillnet operations beginning in 2001. High CPUE observed in 1998 through 2000 (5.51, 3.54, and 3.81) likely indicated higher densities of lake trout in the past. Although the current increase in numbers of lake trout spawners is discouraging, it is not completely unexpected, given the past high rates of CPUE. Lake trout can mature as early as age 4 and as late as age 10, but more typically mature at age 6 to 7.[24] Offspring from 1998 would have been age 6 this last season. If this is the case, due to the large numbers of lake trout noted that year, we should expect to see

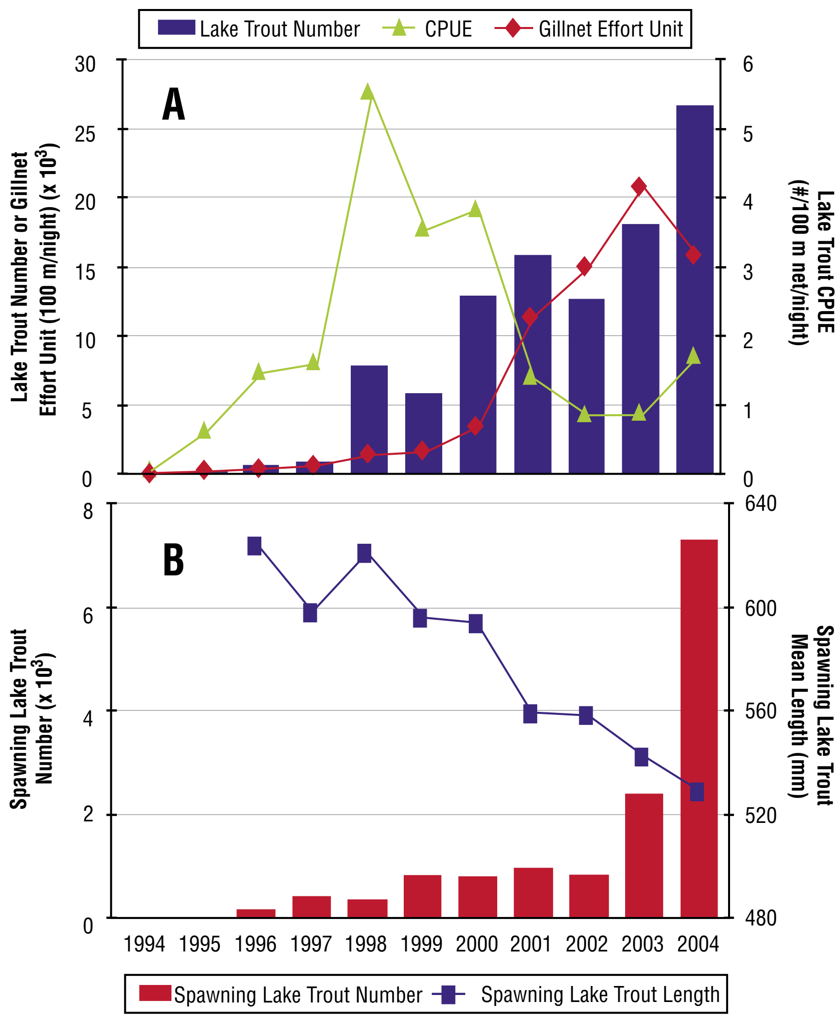
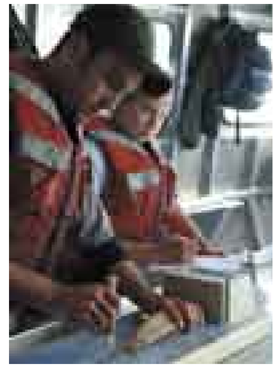


Figure 7. Number of lake trout removed, gillnet effort units (100 m net/night) used, and lake trout catch per unit of effort (CPUE) (#/100 m net/night) obtained by the lake trout removal program on Yellowstone Lake during the entire gillnetting season, 1994–2004 (A). Number and mean length of mature lake trout removed near spawning locations (Breeze Channel, Carrington Island, West Thumb Geyser Basin, and Solution Creek) on Yellowstone Lake during late August–early October, 1996–2004 (B).






PHOTOS BY ZAC SEXTON

More than 100,000 lake trout have been eradicated from Yellowstone Lake.

NPS/TODD KOEL

NPS/PHIL DOEPKE


PHOTOS BY NPS/PAT BIGELOW

Top: *Yellowstone National Park fisheries technicians Stacey Sigler, Brad Olszewski, and Joe Facendola prepare gillnets on board the* Freedom; *fisheries technician Stacey Sigler and Student Conservation Association (SCA) volunteer Anna Varian work with a lake trout gillnet on board the* Freedom; *fisheries technician Brad Olszewski and SCA volunteer Anna Varian measure the length of a lake trout; fisheries technicians Brad Olszewski and Stacey Sigler set a gillnet out the stern of the* Freedom.

Middle: *The Yellowstone Center for Resources lake trout gillnetting boat* Freedom *on Yellowstone Lake in 2004; fisheries technicians Krisi Anderson (L) and Stacey Sigler (R), with SCA volunteer Anna Varian, process gillnets on board the Munson* Hammerhead.

Bottom: *Fisheries technicians Brad Olszewski and Barb Rowdon with lake trout removed from a Yellowstone Lake spawning area.*

continued high numbers of spawning fish over the next three to five years.

Despite the recent increase in numbers of spawning fish, results of the lake trout suppression program are encouraging. Overall CPUE remains low, and more than 100,000 lake trout have been eradicated from Yellowstone Lake by our removal efforts. Bioenergetics modeling (estimates of how many cutthroat trout a lake trout potentially consumes) suggests that an average mature lake trout will consume 41 cutthroat trout per year.[25] Thus, the removal project has saved a large number of cutthroat trout from lake trout predation. Continued decline in mean total length of lake trout caught near spawning areas indicates removal of the older, larger, and therefore most detrimental lake trout. Low CPUE, continued decrease in spawner size, and the large number of lake trout removed from the system are positive indications that gillnetting operations are exerting significant lake trout mortality in this system. However, the increase in numbers of spawning fish underscores the importance of maintaining the effort to keep this non-native predatory population in check. Lake trout densities in the West Thumb area remain high, and a serious threat to the Yellowstone cutthroat trout.

Lake Trout Growth Potential

Park fishery personnel continue to extract as much information about this introduced population of lake trout while vigorously removing as many as possible. All fish captured in the suppression program are counted and measured. An arbitrary sample of these fish, stratified by length, is sexed, stage of maturity is recorded, and aging structures (scales and otoliths) are collected. Data analyzed from the 2004 catch indicated that lake trout in Yellowstone Lake grow relatively quickly during their first two years; age 1 mean length was 189 mm, and age 2 mean length was 277 mm. After the first two years, the average annual growth rates decreased slightly each year, from 61 mm growth per year at age three to 21 mm growth per year at age 12 (Figure 8). The longest lake trout removed from Yellowstone Lake in 2004 was a 940-mm, 12-year-old adult male, caught in a gillnet set in 47 m of water on June 14 in the West Thumb. The oldest lake trout recently aged from Yellowstone lake was a 21-year-old, 765-mm mature male. It was caught on September 24, 2003, in 10 m of water near the West Thumb Geyser Basin spawning area. The age of this fish suggests it may be one of the original fish illegally introduced into Yellowstone Lake.[26] Considering that lake trout can live for more than 60 years, few old lake trout have been caught in Yellowstone Lake. Seven lake trout aged at 12 years, one at 13 years, and one at 15 years were removed from Yellowstone Lake in 2004.

Age-at-maturation of lake trout in Yellowstone Lake is gender-dependent, with males maturing younger and at smaller sizes than females. During the August–October 2004 spawning season, mature males captured in spawning areas ranged in age from 4 to 15 years old; females ranged from 5 to 12. Of the stratified sample of lake trout aged, a decided majority of both genders were 7–9 years old. Fifty percent (50%) of the four- and five-year-old male lake trout were mature. One hundred percent (100%) of six-year-old males were mature, whereas only 50% of the six-year-old, 78% of the seven-year-old, and all (100%) of the eight-year-old female lake trout were mature. The smallest mature male caught in 2004 was 308 mm; the smallest mature female was 357 mm. Practically all lake trout sampled


NPS/BARB ROWDON

Bioenergetics research suggests that each lake trout in Yellowstone Lake has the potential to consume 41 cutthroat trout or more each year.

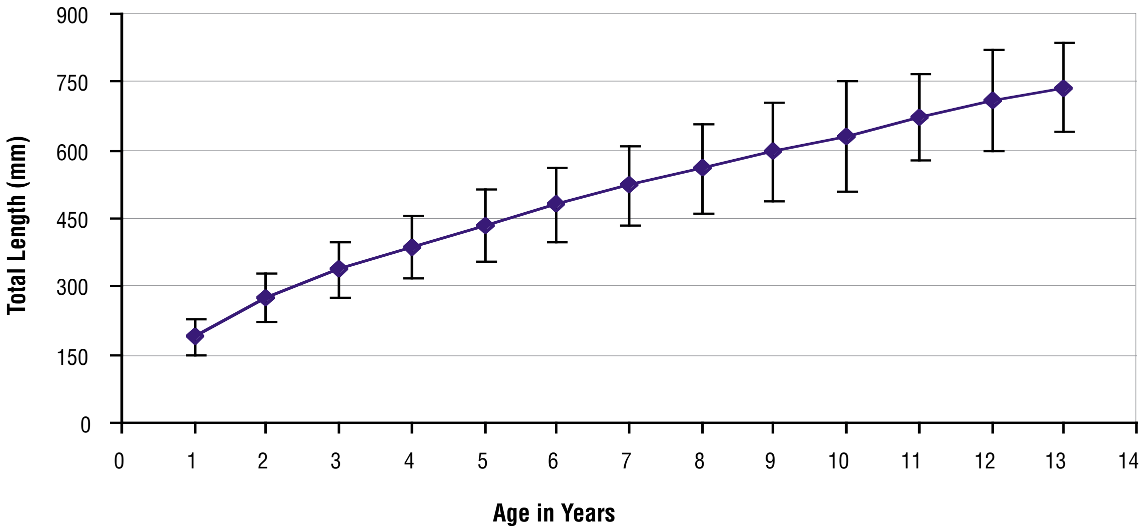


Figure 8. Lake trout mean total length (and standard deviation) at age, back-calculated from otoliths collected from Yellowstone Lake in 2004.

at more than 500 mm have been adults. Adult male lake trout (mean total length 519 mm) were smaller on average than adult females (mean total length 536 mm) caught on or near spawning areas in 2004. Only two of the 307 lake trout aged in 2004 were more than 13 years old. Because otoliths were taken from a stratified sample of fish, almost all of the longer fish (>700 mm) were aged. It is very likely that only two fish of the total 27,770 lake trout removed (gillnetting and electrofishing methods combined) from Yellowstone Lake in 2004 were that old. Low ratios of older to younger lake trout provide a basis for judging the relative effectiveness of the removal program.

Goals to Improve Suppression Efficiency

Results of the 2004 lake trout suppression program clearly emphasized the importance of locating and targeting additional spawning areas in Yellowstone Lake, if they exist. Although less than 5% of our total effort was expended on spawner sets, they accounted for 27% of the total catch. (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, lake trout caught in spawner sets are larger, and therefore, likely more detrimental to cutthroat trout than those caught in control nets. If we can interrupt or even prevent spawning, the suppression effort will potentially remove many thousands more lake trout than accounted for in our control nets.

Given the importance of spawning areas, we have begun a research project to identify other potential spawning areas throughout Yellowstone Lake. Using geomorphologic data of Yellowstone Lake and known lake trout spawning habitat preferences from other areas, and describing habitat preferences observed in Yellowstone Lake, we will predict areas with the highest potential for spawning habitat. Substrate size and distribution data will be collected using our underwater video system. This set-up allows collection of substrate

NPS/PHIL DOEPKE

Example of a cross-section of an otolith from an eight-year-old, 468-mm Yellowstone cutthroat trout captured in Yellowstone Lake.

PHIL DOEPKE

An evening on Yellowstone Lake in 2004.

Results of the 2004 lake trout suppression program clearly emphasized the importance of locating and targeting additional spawning areas in Yellowstone Lake, if they exist.

measurements along a transect while simultaneously recording water depth, surface water temperature, and location via onboard Global Positioning System equipment. It will also enable us to obtain exact timing of lake trout spawning (sometime after dark), and delineate boundaries of known spawning areas. By combining predicted potential spawning areas, seasonal changes in lake trout density, and variation in gillnet catches, we will predict which areas have the highest likelihood of being "colonized" first. We can then develop a monitoring program, and if detection occurs, add these as target areas to our removal program.

Surveys using hydroacoustic equipment for estimating fish densities were conducted throughout Yellowstone Lake twice during the 2004 field season. Partial surveys were completed three additional times to compare seasonal distribution of lake trout. Although analyses to determine the statistical strength of these data are yet to be completed, this technology should allow us to evaluate the effectiveness of our lake trout suppression efforts by estimating lake trout and cutthroat trout population densities annually. Hydroacoustic information should allow us to identify areas with high fish density, size ranges of fish in given areas, and depths at which fish are residing.

The lake trout suppression program is continually searching for ways to improve efficiency and increase lake trout mortality with reduced staff time and funding. The Aquatics Section has recently been assisted by students from the Montana State University College of Engineering, as several have taken the issue of lake trout spawning and egg eradication as a senior design topic. To date, the students have investigated the potential of 40 different solution ideas, including an egg vacuum, termination by resonance, egg and fry traps, fish toxicants, ultrasonics, microwaves, and egg smothering by biodegradable polymers. The ultimate goal for the senior design students is to present the park with new and innovative ways to help reduce the lake trout population in the future.

Restoration of Fluvial Populations of Native Trout

Westslope Cutthroat Trout Status

For much of the past ten years, we have increased our efforts to preserve all remaining populations of westslope cutthroat trout, one of the rarer native aquatic species in the park. Similar to other salmonids in the western U.S., many populations of westslope cutthroat trout have been substantially reduced as a result of interbreeding with other trout, particularly Yellowstone cutthroat trout and non-native rainbow trout. Genetic analyses from early surveys suggested that few, if any, pure populations remain in the Gallatin and Madison river basins, which comprise the historical range of westslope cutthroat trout in the park. Such laboratory analyses are often preferred over field classifications, because they provide a more accurate determination of an individual trout's genetic makeup when compared to classifications based on phenotypic characteristics such as spotting patterns and presence or absence of basibranchial teeth.

Additional genetic analyses in the late 1990s indicated that the park's only pure population of westslope cutthroat trout resided in North Fork Fan Creek, a tributary of the Gallatin River. Consequently, sampling and monitoring of population abundance and life history patterns were focused on that stream.[27] However, analysis of more recent genetic samples taken from this population has suggested that this suspected pure population has become hybridized with rainbow trout. We have now collected another completely new set of genetics samples from the North Fork Fan Creek population, in order to resolve this issue.

When analyses of the additional tissue samples (175 total) recently collected from the Fan Creek drainage are completed, resolution of the equivocal genetic status of the westslope cutthroat trout population there should be achieved. In the interim, the Aquatics Section has concentrated on expanding genetic inventories in the historical westslope cutthroat range in the park. Although we suspect that the Specimen Creek population remains a hybrid swarm, with Yellowstone cutthroat trout and rainbow trout genes commonly found in most of the westslope cutthroat trout there, we collected samples from the majority of fish this year for genetic analyses. Because these samples were collected from a variety of locations, it is hoped that the new genetic analyses will verify whether the amount of hybridization has increased in this watershed since the survey was last done in 1994, and if there are fish within the population that are only minimally hybridized.

Specimen Creek as the Initial Restoration Site

Faced with uncertainty about the continued existence of any genetically pure westslope cutthroat trout populations, the Aquatics Section began surveying other streams in the historical westslope cutthroat trout range within the park in 2004, concentrating on Specimen Creek. This watershed lies immediately north of Fan Creek, and is similar in size. A previous survey in 1994 indicated that the Specimen Creek trout population is highly hybridized with rainbow trout. Before this stream could be considered or rejected as a potential site for westslope cutthroat trout

NPS/DAN MAHONY

East Fork Specimen Creek is currently home to hybridized cutthroat trout and is a good location for future westslope cutthroat trout restoration within Yellowstone National Park.

restoration, updated, detailed information about the existing population needed to be collected. In 2004, three 100-m sections in East Fork Specimen Creek, two sections from North Fork Specimen Creek, and one mainstem site downstream from the confluence of the forks were sampled with backpack electroshockers. Westslope cutthroat trout or their hybrid forms were captured at all six sites, but mottled sculpins (*Cottus bairdi*) were only collected upstream as far as the low gradient (downstream) areas of each fork. This suggests that distribution of mottled sculpins may be limited by their inability to migrate through steep, higher velocity, upstream reaches of the watershed.

Estimated abundance of trout was low in all sections of the North Fork Specimen Creek, and only two were captured during the three-pass removal effort at the upper site. Characteristic of other headwater stream populations in the area, most of the cutthroat trout we sampled from Specimen Creek were not very long (<200 mm); the largest fish were captured in the middle section of the East Fork (Figure 9). The low abundance and small size of the cutthroat trout in Specimen Creek suggests that productivity in this stream is relatively low. Conductivity (an indirect measure of productivity) never exceeded 50 micromhos/cm, and water temperature was rarely higher than 10ºC. The largest fish we sampled were two rainbow trout and a brown trout at the mainstem site. This section was also fished on numerous occasions in 2004, in conjunction with the Volunteer Flyfishing Program. This group of directed anglers fished for a total of about 850 hours, and caught 28 cutthroat trout and 12 rainbow trout. Lengths of the angler-caught trout in the mainstem section were similar to those from the electrofishing survey.

A genetically pure population of westslope cutthroat trout may no longer be present in the park.

Unlike many other areas within its historical range, habitat degradation and excessive harvest rates by anglers do not appear to be the primary reason for the decline of westslope cutthroat trout in Yellowstone National Park. Rather, the extensive stocking and subsequent establishment of populations of non-native competing species (brown trout [*Salmo trutta*], and interbreeding rainbow trout and Yellowstone cutthroat trout) during the first half of the twentieth century has led to a serious reduction in the park's resident westslope cutthroat trout. Our electrofishing, genetic, and radio-telemetry surveys during the past five years have revealed that a genetically pure population of westslope cutthroat trout may no longer be present in the park. Complete protection of any remaining westslope cutthroat trout populations will require that they be permanently protected from sympatric non-native species. The preferred method for perpetuating a native population consists of barrier construction (or use of an existing, natural barrier) to prevent upstream migration of competing species into westslope cutthroat trout habitats.[28] Removal of all fish from the restoration area is needed before

genetically pure fish can be reintroduced.

There are several sites in the Specimen Creek watershed that are highly suitable for barrier construction. The typical site is in a high gradient area of narrowly confined stream channel. Large cobble and boulder substrate and dense wooded riparian areas would provide natural construction materials. In the East Fork, in particular, potential barrier sites are far enough apart to facilitate a sequential downstream restoration project. The cold temperatures and small size of the fish captured in Specimen Creek suggest that only a limited number of cutthroat trout could be expected to persist in this stream when they are reintroduced. However, the fact that this watershed contains some of the most hybridized cutthroat trout found in the park is good reason for restoration to begin there.

An additional consideration for restoration of the Specimen Creek watershed relates to the presence of Yellowstone cutthroat trout in a headwater lake. In 1937, 16,000 Yellowstone cutthroat trout were stocked into High Lake, whose outlet forms the beginning of East Fork Specimen Creek. This lake supports a small local fishery, which, in a typical year, has an estimated 35–50 anglers. Catch rates for Yellowstone cutthroat trout are consistently higher than one fish per hour. An on-site examination of the lake's outlet verified that there are no barriers preventing High Lake fish from migrating downstream. Because of this, complete protection of the westslope cutthroat trout in Specimen Creek will require chemical treatment of High Lake prior to any serious reintroduction efforts. An antimycin treatment of this lake was actually recommended for a restoration project by the park in 1970, but was not undertaken. None of the headwater lakes in the North Fork Specimen Creek basin contain fish, so lake treatments would not be required there. Much of that drainage is low gradient, and the greatest ongoing hybridization threat is continued interaction with non-native species from the mainstem of Specimen Creek and the Gallatin River.

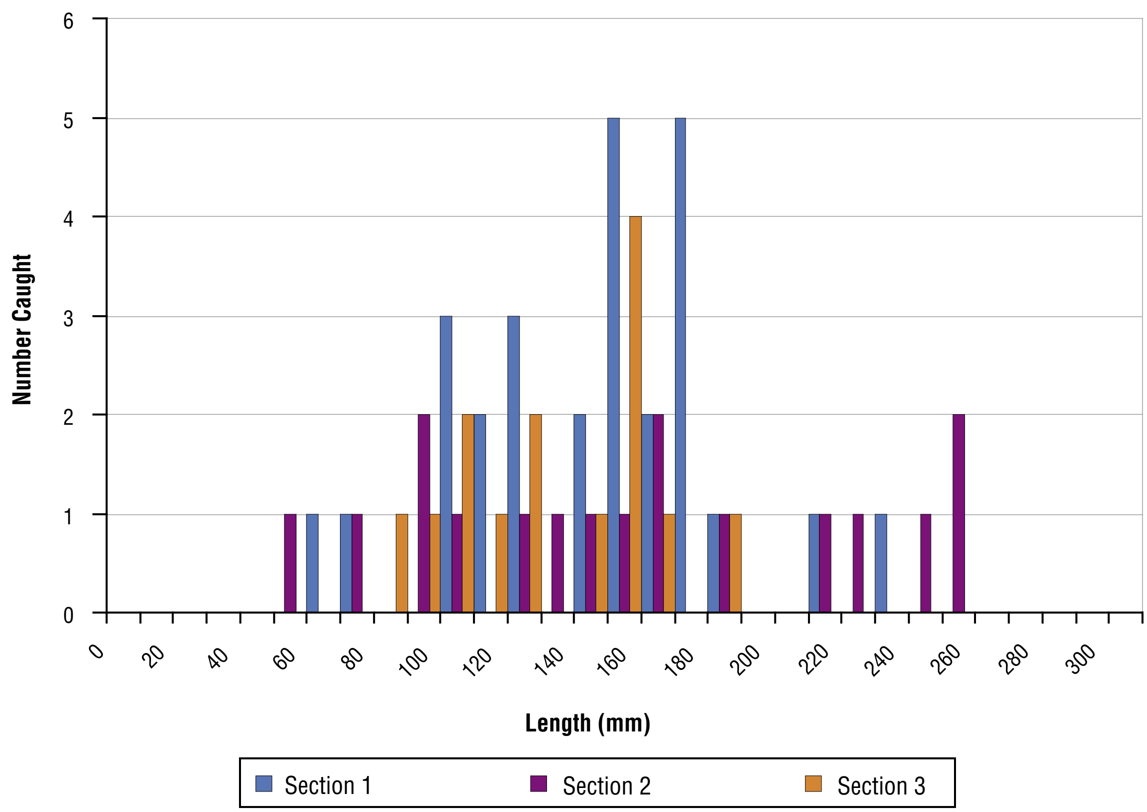


Figure 9. Length-frequency distribution of westslope cutthroat trout (hybrids) captured during electrofishing surveys at the East Fork of Specimen Creek, 2004.

Westslope Cutthroat Trout Restoration Goals

Our overall goal for westslope cutthroat trout restoration within Yellowstone National Park is to reverse the further loss of genetic integrity and establish new, genetically pure populations. Because of its close proximity to North Fork Fan Creek, and the fact that its trout population is highly hybridized, Specimen Creek, especially the East Fork, will be our focus for westslope cutthroat trout restoration in the short term. To do this, the objectives for our work planned for 2005–2006 include:

1. Examine potential for the establishment of a temporary refugia (including laboratory isolation) of westslope cutthroat trout from North Fork Fan Creek (which may still be genetically pure).

2. Complete field surveys for trout, macroinvertebrates, amphibians, and stream morphology in East Fork Specimen Creek.

3. Complete planning documents to examine alternatives for the required restoration (removal of non-native fish species and restocking with genetically pure westslope cutthroat trout) within East Fork Specimen Creek.

Our long-term goals include the construction of a series of temporary log barriers, followed by removal of non-native and hybridized trout in a stepwise manner from upstream to downstream along the East Fork Specimen Creek. Removal will initially be accomplished by using angling (fish rescue and movement downstream and out of the restoration area), followed by complete depopulation using antimycin. The depopulated reach will then be restocked with genetically pure westslope cutthroat trout from an upper Missouri River strain brood source and/or from the nearest neighbor, which is North Fork Fan Creek.

PHOTOS BY NPS/BILL VOIGT

Hybridization with non-native rainbow trout is a significant threat to the persistence of cutthroat trout within Yellowstone National Park.

Specimen Creek will be our focus for westslope cutthroat trout restoration in the short term.

Yellowstone Cutthroat Trout Restoration Goals

Recently, a multi-agency, rangewide status assessment was completed for Yellowstone cutthroat trout, which included all the waters within the range of this subspecies in Yellowstone National Park.[29] In addition, the Aquatics Section has been systematically completing surveys of stream systems within the historical range of this subspecies within the park. Results of this work have revealed that genetically pure fish exist only in a fraction of their historical range in rivers and streams outside the Yellowstone Lake basin (Figure 10). Invasion of stream systems by non-native species is continuing in the park, and remaining genetically pure Yellowstone cutthroat trout populations are being lost, with the most recent example being the loss of the world-class genetically pure fishery of Slough Creek.[30] Although

Genetically pure fish exist only in a fraction of their historical range in rivers and streams outside the Yellowstone Lake basin.

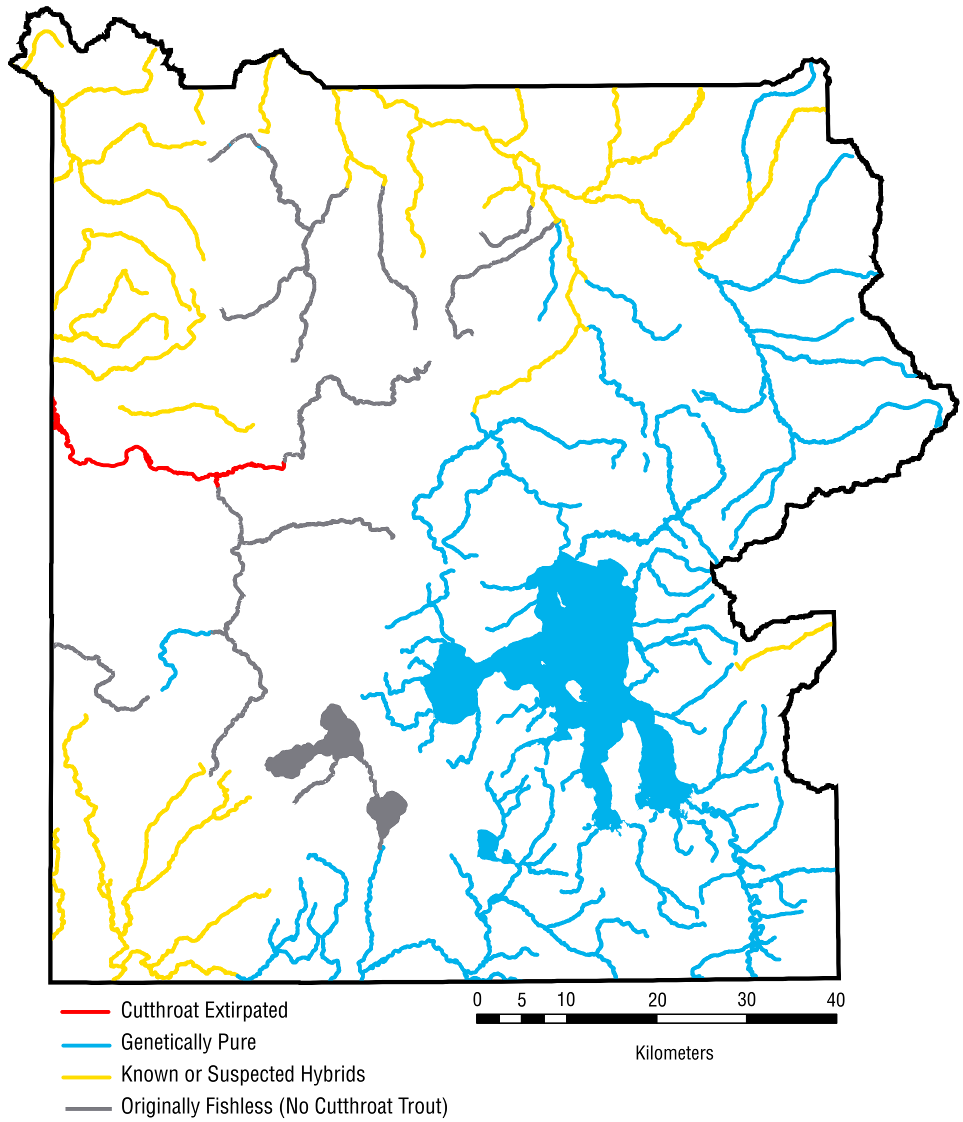


Figure 10. Genetic integrity of cutthroat trout within Yellowstone National Park. Streams tributary to Yellowstone Lake represent the lake's adfluvial cutthroat trout; most do not support stream resident populations.

broodstocks for Yellowstone cutthroat trout are being developed by partner agencies, these stocks have been very difficult (at best) to produce, and their stability should not be assumed.[31] Because of this, the Aquatics Section continues to take steps to ensure the long-term persistence of genetically pure, wild Yellowstone cutthroat trout populations. Reversing the loss of these populations within Yellowstone National Park streams must occur now, while genetically pure fish still exist for reintroduction efforts; fluvial populations may soon be reduced to the point that they cannot effectively be used for sustaining a broodstock or for reintroduction efforts of restored streams.

Given the declining probabilities for persistence of existing populations, the overall goal for fluvial Yellowstone cutthroat trout restoration within Yellowstone National Park is to focus on watersheds within the park's northern range, and identify those that have the highest probability of success for stream restoration. Streams of the northern range were chosen for initial focus because of their accessibility; the logistics for completing stream restorations in this region are very good. Our specific objectives for 2005 to 2007 are to:

1. Review existing, historical information on fishes and habitat characteristics for all northern range watersheds.

2. Use geographic information systems to develop a tool for identifying data gaps and information needs.

3. Conduct intensive field investigations of northern range watersheds to determine the current, uppermost extent of fish distribution, species composition (native vs. non-native), and habitat characteristics, including the presence of any existing barriers to fish movement.

4. Prioritize watersheds and specifically identify those that provide the greatest likelihood of success for restoration.

5. Complete required planning documents (EA or EIS), using information compiled as described above, and complete the NEPA process that will lead to on-the-ground restoration of Yellowstone cutthroat trout within Yellowstone National Park.

After the watershed prioritization and environmental planning is completed, it is our goal to begin on-the-ground work for the restoration of watersheds. The newly created Yellowstone cutthroat trout populations will then be available for other, future restoration efforts within Yellowstone National Park and elsewhere.

Conservation of Arctic grayling requires retention of their innate ability to exist as fluvial populations.

Arctic Grayling Status within the Gibbon River

In 2004, the U.S. Fish and Wildlife Service increased the Endangered Species Act status of the fluvial Arctic grayling in the upper Missouri River drainage from a 9 to a 3.[32] Its range once

NPS/TIM BYWATER

The Gibbon River below Gibbon Falls is an area where Arctic grayling have been consistently found by anglers and electrofishing gear.

In recent years, both anglers and electrofishing surveys have consistently found Arctic grayling throughout the Gibbon River.

Arctic grayling have been collected by flyfishing volunteers from many reaches of the Gibbon River.

Arctic grayling from the Gibbon River.

included much of this drainage, but now the only known remnant population is restricted to the upper Big Hole River in Montana, in an area estimated to be less than 5% of its historical range. In contrast to the still-common lacustrine/adfluvial (lake) populations of Arctic grayling in Montana and Wyoming, the fluvial form of Arctic grayling is adapted to inhabiting riverine environments year-round.[33] Conservation of Arctic grayling requires retention of their innate ability to exist as fluvial populations. In Yellowstone National Park, fluvial Arctic grayling originally existed in the Madison River, and in the Gibbon and Firehole rivers below the falls of these streams.[34] 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.

Recent occurrences have led us to seriously re-evaluate the status of fluvial Arctic grayling within Yellowstone National Park. In recent years, both anglers and electrofishing surveys have consistently found Arctic grayling throughout the Gibbon River (Figure 11). In fact, anglers have reported catching grayling in the Gibbon River in all but one year since 1979. Our ability to interpret whether or not a viable population of fluvial Arctic grayling exists, however, is somewhat confounded by the fact that in the 1920s, adfluvial (lake-dwelling) Arctic grayling were intentionally

stocked into historically fishless Grebe and Wolf lakes, located in the headwaters of the Gibbon River. Although grayling are now regularly found in the Gibbon River above and below all three of its barriers, including Gibbon Falls, it is not known if these fish are truly fluvial in their life history strategies (including successful reproduction and recruitment within the Gibbon River), or if they are merely strays moving downstream from headwater lake populations. Because of this, 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. The work is planned for 2005–2006, and our specific objectives are to:

1. Tag grayling (using visible implant tags) and track movement of juvenile/adult fish at Grebe and Wolf lakes in the Gibbon River headwaters and in the mainstem Gibbon River above and below Gibbon Falls.

2. Conduct intensive surveys for spawning grayling during late May, June, and early July in the Gibbon River and suitable tributary streams.

3. Conduct intensive surveys for young-of-the-year (YOY) grayling using fry traps from June to October in the Gibbon River.

4. Relate 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 will be 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 exist here.

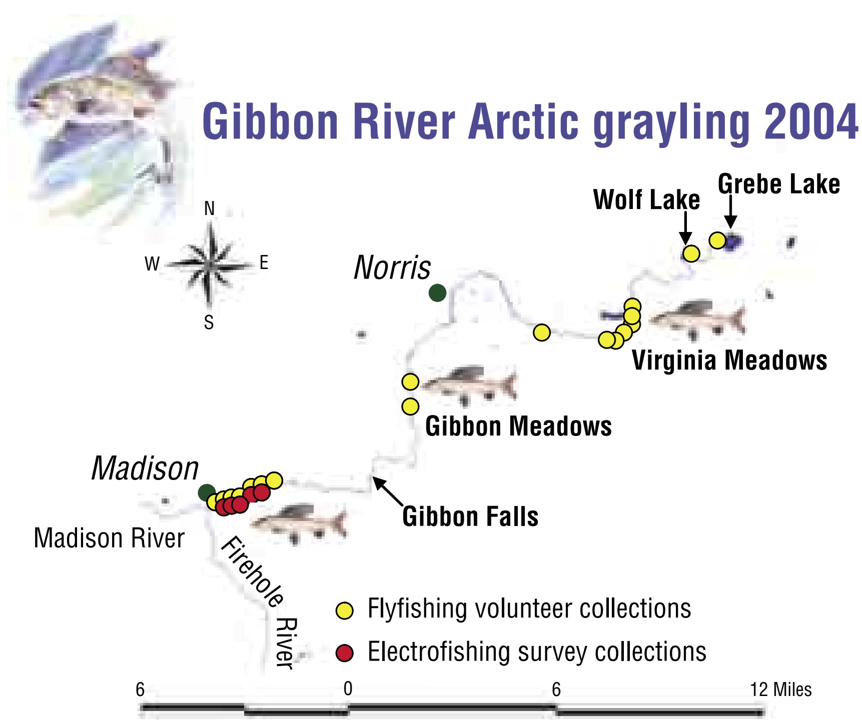


Figure 11. Sites where Gibbon River Arctic grayling were collected by flyfishing volunteers and electrofishing surveys during 2004.

Antimycin as a Native Fish Restoration Tool

Non-native fish species have been introduced into Yellowstone and many other national parks throughout the United States, resulting in the degradation (through hybridization) and displacement of native species. In such cases, ensuring the survival of native species often requires restoration. Although historically fishless waters might seem like possible restoration sites, these aquatic environments actually support unique invertebrate communities and amphibian species, and so to use them for fish restoration would mean introducing a non-native species, thereby exacerbating the very problem we would be trying to fix.

Instead, fish restoration projects are often accomplished by removing non-native and/or hybridized fish that are present in particular streams or lakes, and then restocking the waterway with genetically pure native fish. When fish removal is conducted, it is imperative that all non-native fish are removed, because if any remain, the aggressive, prolific nature of these species that out-competed the native fish in the first place will eventually allow them to return to pre-project population levels, resulting in a failure of the restoration. To be successful, the stream reach to be restored and restocked with genetically pure fish must be isolated either by an existing natural barrier (waterfall) or by the construction of an artificial log (beaver-dam style) structure. The barrier is required to prevent future invasion of the restoration area by non-native fish species existing downstream.

The only sure way to achieve complete removal of non-native fish from Yellowstone's streams or lakes is through chemical treatment by approved piscicides (fish toxins). The two chemicals that have been safely used most commonly are rotenone and antimycin. For several reasons, antimycin is generally recognized as being more effective than rotenone, especially for treatment of streams. Antimycin is a fungal antibiotic produced by certain members of the genus Streptomyces, a bacterium, found naturally in forest soils. The most widely accepted explanation as to why this bacteria produces antibiotics is that the antibiotics are an evolutionary adaptation that helps Streptomyces to reduce competition with other fungi in the soil environment.

DR. MARK BUKTENICA
CRATER LAKE NATIONAL PARK

Example of a log-style barrier used to prevent invasion of restoration areas from downstream non-native fish.

Antimycin has been applied successfully in a wide variety of both marine and freshwater fish habitats. It is absorbed into the piscine bloodstream from the water across the gills, and affects fishes at the molecular level by disrupting the process of cellular respiration. Antimycin is also effective because fish cannot sense its presence in the water and survive the treatment by avoiding and seeking refuge from the toxin, as is the case with rotenone and other piscicides. Antimycin is approved for use in many states, including Montana and Wyoming.

In streams, spring seeps, and lakes, antimycin is normally applied using drip cans, backpack sprayers, and boats, respectively. Antimycin effectively kills trout when applied at an extremely low volume per area treated, typically 5–10 parts per billion (ppb), which is 5–10 parts antimycin to every billion parts water. An antimycin concentration of 10 ppb is about 1,750 times lower than the level determined by the Montana Department of Environmental Quality to be safe for long-term human consumption, and 175,000 times lower than the safe level for short-term consumption. In addition, antimycin naturally degrades rapidly in the stream by hydrolysis, temperature, exposure to sunlight, stream turbulence, and pH. After being added to a stream, the antimycin dose loses much of its toxicity over a drop in stream elevation of about 200 feet. Because of this rapid breakdown, it is necessary to add antimycin to streams at drip stations located every 100–120 feet in vertical drop or at locations separated by the distance it takes the water in the stream to flow in one-half hour. At the downstream end of the restoration reach, typically just below the natural or artificial barrier, the antimycin is stopped/detoxified by adding potassium permanganate ($KMnO4$) to the stream at concentrations of 1–4 parts per million. $KMnO4$ is a strong oxidizer commonly used in drinking water supplies to oxidize metals, kill bacteria and viruses, and remove unpleasant tastes. The effectiveness of the detoxification is monitored using sentinel fish held in small cages both upstream and downstream of the $KMnO4$ station.

Some facts about antimycin:

- Antimycin has been shown to be a safe and effective tool for the removal of non-native fish in the Intermountain West.

- Antimycin does not affect birds or mammals, including humans and livestock, and will not affect downstream drinking water.

- It is not necessary to remove animals that may exist adjacent to streams treated with antimycin, because the water is not toxic to them, and fish killed by antimycin, if consumed, will not harm them.

- Stream and lake invertebrate communities are slightly impacted by antimycin, but studies have shown that the impacts are only short-term, and the invertebrates return within a few months of the treatment.

- Because antimycin enters through gills, amphibian tadpoles are susceptible to antimycin, but conducting treatment during the fall, when tadpoles are not present, mitigates any potential impacts to amphibian populations.

- Antimycin naturally breaks down so quickly in streams that in most cases, native fish can safely be restocked to a treated stream after only 48 hours.

Antimycin was first suggested as a fish toxicant by researchers in 1963, with initial laboratory and field studies in lakes and streams completed by 1969. Since then, antimycin has been used safely and successfully throughout the United States, including in many national parks, such as Yellowstone. When Arnica Creek, a cutthroat trout spawning tributary to Yellowstone Lake, was invaded by brook trout, antimycin was used to remove them in 1985–1986. More recently, successful use of antimycin has occurred at Crater Lake, Great Basin, Great Smoky Mountains, and Rocky Mountain national parks. The experience and knowledge gained during the past three decades of use of this piscicide in our national park system and elsewhere will be used to ensure project safety and success as Yellowstone moves forward with aggressive cutthroat trout restoration projects in the coming years.

DR. MARK BUKTENICA
CRATER LAKE NATIONAL PARK

Example of an antimycin drip station used to remove non-native fish.

Adapted from the following publications:

Cerreto, K.M. 2004. Antimycin and rotenone: short term effects on invertebrates in first order, high elevation streams. Master of Science thesis. University of Wyoming, Laramie, Wyo.

Derse, P.H., and F.M. Strong. 1963. Toxicity of antimycin to fish. *Nature* 200:600–601.

Finlayson, B.J., R.A. Schnick, R.L. Cailteux, L. DeMong, W.D. Horton, W. McClay, and C.W. Thompson. 2002. Assessment of antimycin A use in fisheries and its potential for reregistration. *Fisheries* 27(6):10–18.

Finlayson, B., and 11 co-authors. 2003. Native inland trout restoration on national forests in the western United States: time for improvement? *Fisheries* 30(5):10–19.

Gresswell, R.E. 1991. Use of antimycin for removal of brook trout from a tributary of Yellowstone Lake. *North American Journal of Fisheries Management* 11:83–90.

Hubert, T.D., and L.J. Schmidt. 2001. Antimycin A use in fisheries: issues concerning EPA reregistration. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin.

Schnick, R.A. 1974. A review of the literature on the use of antimycin in fisheries. U.S. Fish and Wildlife Service, Fish Control Laboratory, La Crosse, Wisconsin.

Shepard, B.B. In press. Removal of nonnative fish stocks to conserve or restore native fish stocks. *In* P. Ferreri, L. Neilsen, and R. Gresswell, eds., Conservation of native aquatic fauna: strategies and cases (Bethesda, Md.: American Fisheries Society).

Tiffan, K.F., and E.P. Bergerson. 1996. Performance of antimycin in high-gradient streams. *North American Journal of Fisheries Management* 16:465–468.

Frontcountry Fishery Inventories

Stream Population Surveys

Stream surveys have traditionally been long-term monitoring projects that describe the responses of a fish population to a particular type of angler impact (e.g., minimum size, reduced creel, or catch and release regulations). As the number of threats to the park's fish populations has increased, however, these studies have become shorter-term (i.e., 3–5 years) as park management attempts to respond to impacts in a timely manner. In 2004, our surveys of fish populations included ongoing monitoring of road-impacted streams in many locations of the park.

The high density of brook trout indicates that Middle Creek is productive, but the small number of cutthroat is cause for concern.

Monitoring Associated with Road Reconstruction

Reconstruction of the Grand Loop Road continues to be an important management objective in Yellowstone National Park. Because a significant portion of many roads parallel stream corridors to enhance park visitors' scenic experience, road projects can potentially impact fish populations if excessive sediment is generated during construction, or improperly designed or placed road culverts impede fish passage after project completion. Several streams used by spawning and resident Yellowstone cutthroat trout are located within these construction areas. In June 2004, electrofishing surveys were conducted at several sites in the Hayden Valley portion of the road-resurfacing project between Fishing Bridge and Canyon Junction (begun in 2003). Unlike in 2003, no large cutthroat trout of spawning size were captured at these sites; only juvenile Yellowstone cutthroat trout and introduced red side shiners (*Richardsonius balteatus*) were found.

In 2003, Phase 1 (Canyon-to-Chittenden Road) of the Dunraven Pass road reconstruction was initiated. A small tributary of Cascade Creek that flows under the road here has the potential to be directly affected by construction activities. This stream is of concern because numerous cutthroat trout encompassing several age classes, including fry, were captured there in 2003 and 2004. Few of these fish are longer than 250 mm, suggesting they are juveniles. It is unknown whether larger cutthroat trout from Cascade Lake use this stream for spawning or if the trout we have captured are a stream-resident form that exhibits small size due to diminished growth rates.

Since 1999, the Aquatics Section has monitored fish populations at four locations in the Gibbon River between Gibbon Meadows and Madison Junction to assess possible road construction impacts to resident fish there. A secondary objective of our study is to document the responses of any Arctic grayling that may reside in the downstream areas to road construction activities. Most of the Gibbon River was originally barren of fish, but the sections below Gibbon Falls (Tuff Cliffs and Canyon Creek sample areas) historically contained westslope cutthroat trout and fluvial Arctic grayling. Westslope cutthroat trout have apparently been eliminated from the Gibbon River, but Arctic grayling are occasionally captured (Figure 11). The Madison-to-Norris road reconstruction project is one of the most ambitious ever undertaken in the park. After the existing road is widened to meet current federal highway standards, a new re-route and bridge over the Gibbon River will be built, and several kilometers of road will be removed. Thus, the potential for increased sediment input into the stream and associated habitat degradation is very high. More importantly, the road removal portion of the project represents one of the first attempts by the park to physically restore a section of stream channel that has been previously altered by road building.

Each year, brown trout were the most common fish collected at each sample area of the Gibbon River, and the only species captured in the Tanker Curve section. During the past several low water years, estimated brown trout abundance averaged from 400 to 800 fish per km. As in 2003, rainbow trout were only captured downstream from Gibbon Falls (but large rainbow trout longer than 450 mm were not encountered in 2004). If the rainbow trout life history in the Gibbon River involves summer migration, this observed difference in size distributions between the two years may partially be explained by different sampling periods (early September 2003 vs. late July 2004). In 2004, six different grayling were captured in the Tuff Cliffs reach. Although

this represents the second-highest number of Arctic grayling captured since monitoring began, abundance of grayling in the Gibbon River remains extremely low when compared to non-native brown trout and rainbow trout.

In 1992, Yellowstone National Park released an environmental assessment detailing plans for the reconstruction of the East Entrance Road over Sylvan Pass. The first two phases were completed within the past few years, but initial work on the technically more challenging portion from Avalanche Peak to the East Entrance Station did not begin until this year. Most of the road is located along steep, avalanche-prone slopes, and the last several kilometers near the entrance station are in proximity to the Middle Fork of the Shoshone River (Middle Creek). For the fourth consecutive year, fish populations were monitored by three-pass electrofishing removal estimates at two 100-m sample sites. The lower site is entirely adjacent to the existing road, and about half of the reach length contains riprap on the outside channel bend as a form of road protection. The upper site is in proximity to the former, historic road in the valley bottom, but the channel is not constricted, and woody debris is abundant in the sample section.

Brook trout (*Salvelinus fontinalis*) were the most abundant fish caught at both Middle Creek sites in all years. Yellowstone cutthroat trout and their hybrids with rainbow trout were less abundant. Many size classes of brook trout were captured, but the cutthroat trout were typically small; young-of-the-year individuals often composed the bulk of the cutthroat trout catch. Abundance of cutthroat trout varied only slightly between the two sites and between years. In contrast, brook trout were significantly more abundant at the upper site (Figure 12). The high density of brook trout indicates that Middle Creek is productive, but the small number of cutthroat is cause for concern. Several factors may affect the reduced numbers of cutthroat trout in this stream. Brook trout are typically a superior competitor with cutthroat trout, which could explain the lack of cutthroat trout dominance in the higher-quality, upper section habitat.[35] The presence of rainbow trout suggests that the population there may be hybridized. Often, cutthroat–rainbow hybrids are not as fit as pure strain fish, and may be less able to adapt to changing environmental conditions.[36]

Road erosion also became an urgent concern this past spring, when the mainstem channel of Soda Butte Creek migrated close to the Northeast Entrance Road. At the area of concern, Soda Butte Creek is classified as a C-type channel, which is characterized by low gradient, small cobble and gravel substrate, and a meandering channel pattern. This type of channel is naturally highly erosive, and needs to be unconfined to function properly.[37] Fishery data in the immediate area of concern are limited, so Aquatics Section staff consulted with park managers and recommended that soft-material revetments would be most beneficial for the fisheries in this situation. However, due to time constraints imposed by a possible closure of the road, standard boulder riprap was used as a short-term solution to the erosion of the road base. The long-term effects of this project on the resident cutthroat trout in Soda Butte Creek are presently unknown, but ongoing monitoring will continue. Status of the cutthroat trout is further threatened by the discovery of brook trout in the headwaters of Soda Butte Creek in 2003. Montana Fish, Wildlife and Parks carried out a treatment project upstream of the park boundary in fall 2004 to eliminate the source of these potential competitors, but the treatment was not entirely successful, as a few brook trout were later captured several kilometers downstream from the rehabilitation area. Anglers have also recently reported catching brook trout in a Soda Butte Creek tributary downstream of Ice Box Canyon.

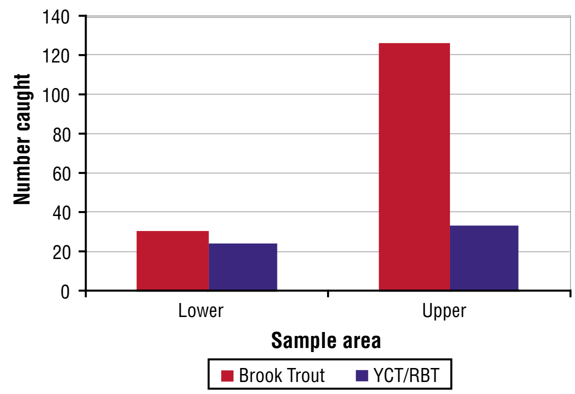


Figure 12. Number of Yellowstone cutthroat trout x rainbow trout hybrids and brook trout caught per 100 m of stream during three-pass depletion population estimates of Middle Creek in 2004.

Wilderness Fisheries of the South

Status of Cutthroat Trout in the Upper Snake River

In Yellowstone National Park, the Snake River finespotted cutthroat trout (*O. c. behnkei)* is one of the least-studied aquatic species. Although the Snake River is one of the park's larger watersheds, much of the stream has never been surveyed because of its remote location. In August 2004, in a cooperative effort with fishery biologists from the Bridger-Teton National Forest, the mainstem of the Snake River and several tributaries were surveyed for native fish species. The survey downstream from the confluence with the Heart River (approximately 30 km of river) was sampled for historical comparison with a survey conducted in 1983. An additional 20 km upstream from the Heart River–Snake River confluence was surveyed for the first time ever. Preliminary results included:

In a cooperative effort, the mainstem of the Snake River and several tributaries were surveyed for native fish species.

• Several waterfalls about halfway between the headwaters and the Heart River presumably function as barriers to upstream fish migration and separate the mainstem Snake River fish into two populations.

• Mountain whitefish (*Prosopium williamsoni*) were the most abundant salmonid downstream from Heart River.

NPS/DAN MAHONY

Yellowstone National Park fisheries technicians electrofish the Snake River.

NPS/DAN MAHONY

The finespotted form of Yellowstone cutthroat trout was found within the Snake River in 2004.

• Young cutthroat trout were found at almost all sites.

• Adult Yellowstone cutthroat trout (large-spotted) were found infrequently, and rarely exceeded 250 mm in length.

• The rare fine-spotted form (Snake River fine-spotted cutthroat trout) was only collected downstream from the confluence with the Heart River.

• Other native species collected included longnose dace (*Rhinichthys cataractae*), speckled dace (*Rhinichthys osculus*), and mottled sculpin.

• In at least two headwater tributaries, waterfalls delimited areas of historically fishless portions of streams.

The Snake River survey will be completed in 2005, with a focus on the stream's many remote, headwater tributaries. Anecdotal angler reports suggest that numerous large cutthroat trout are typically caught in the river earlier in the year, so additional sampling of the mainstem river may also be required earlier in the season to verify the accuracy of these reports. Angling effort in the Snake River comprised less than 1% of the total angling effort in Yellowstone National Park during the 2004 fishing season. Anglers reported catching predominately native cutthroat trout and mountain whitefish.

Status of Cutthroat Trout in the Upper Yellowstone River

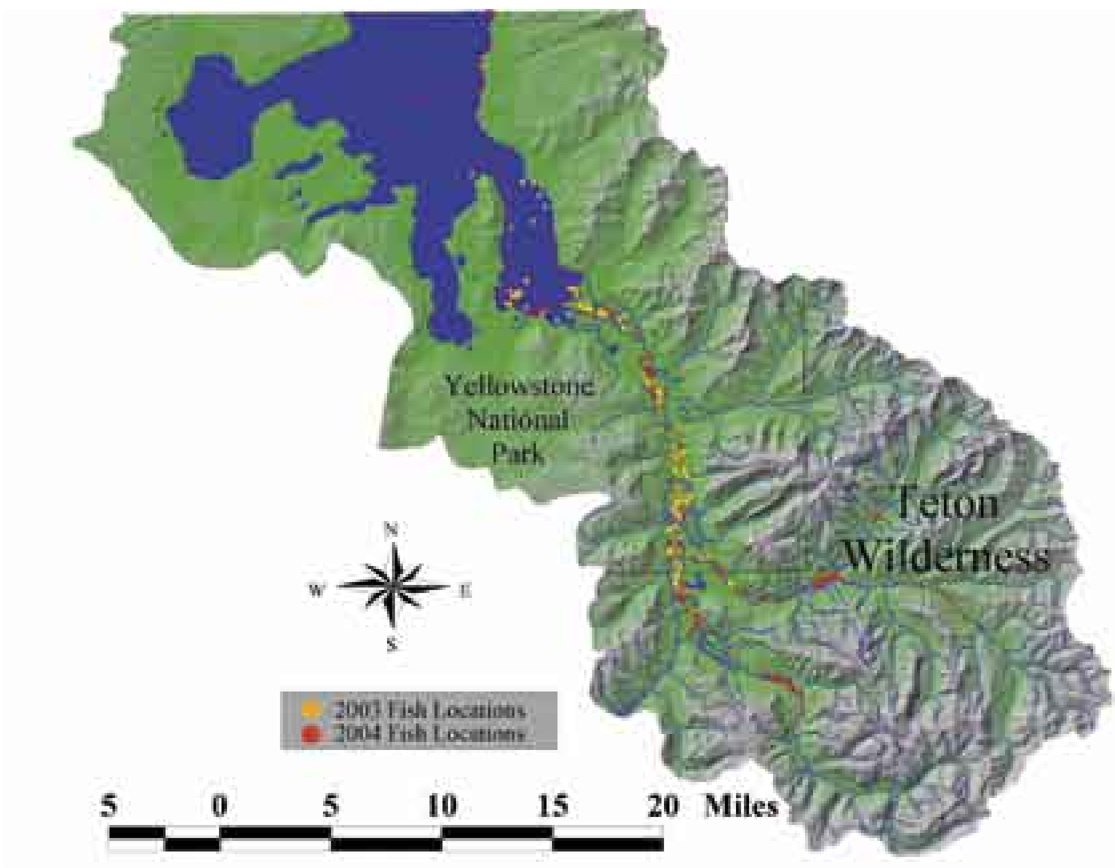
During the park's history, there has never been a comprehensive fishery survey of the Yellowstone River upstream of Yellowstone Lake. Because of this, in 2003, the National Park Service, in cooperation with the Wyoming Game and Fish Department, initiated a fisheries assessment of this remote river. The study will help determine movements of adult Yellowstone cutthroat trout during their spawning migration in the Yellowstone River and several of its tributaries. We also hope to determine if any resident populations exist in the drainage.

Adult Yellowstone cutthroat trout were surgically implanted with radio transmitters in the Yellowstone River and several of its tributaries (Thorofare Creek, Mountain Creek, and Atlantic Creek). Sixty-five cutthroat trout were surgically implanted in 2003. An additional 67 fish were implanted with transmitters in 2004. All fish collected were measured, weighed, sexed, had scale samples taken, and were fin-clipped for genetic testing.

Trips to implant radio transmitters in 2004 began in mid-May, two weeks after ice-off from Yellowstone Lake. Fyke nets and trap nets were set in the mouth of the Yellowstone River. Two gill nets (300 feet long, 25-mm bar measure) were also used in the mouth of the river and delta as a large seine. Eight fish were captured and implanted with tags during this initial session. Our second tagging operation took place from June 21 to July 1, 2004. Sample reaches were located in the Bridger-Teton Wilderness area located just south of the Yellowstone National Park boundary. All sampling was done on the Yellowstone River from three miles south of Atlantic Creek to three miles south of Castle Creek. During this effort, 27 fish were implanted with radio transmitters. All females captured during this period were post-spawn, and males were either post-spawn or ripe, indicating that our tagging occurred after the main spawning period in 2004. Wyoming Game and Fish personnel implanted radio tags in an additional 32 fish in the Thorofare Creek watershed from July 12 to July 21, 2004. Sampling took place from the lower reaches of Open Creek and Dell Creek to the boundary of Yellowstone National Park.

Fish outfitted with radio transmitters were monitored with weekly tracking flights by fixed wing aircraft and several ground-truthing trips from June to November 2004 (Figure 13). Flights then were conducted monthly from December through mid-April 2005. Surveys to locate fish that moved into Yellowstone Lake were conducted via aircraft and boat.

Initial analysis indicates that the majority



JASON BURCKHARDT, WYOMING GAME AND FISH DEPARTMENT

Figure 13. Locations of Yellowstone cutthroat trout in the upper Yellowstone River system, collected and identified through aerial and ground telemetry in 2003 and 2004.


NPS/TODD KOEL

Yellowstone National Park fisheries technician Brian Ertel with a Yellowstone cutthroat trout from the upper Yellowstone River that has been outfitted with a radio-telemetry transmitter.

of adult cutthroat trout tagged in the upper Yellowstone River and its tributaries migrated back to Yellowstone Lake following the spawning period, both in 2003 and 2004. Some cutthroat trout traveled great distances to spawn. For example, several fish migrated from Yellowstone Lake upstream more than 30 miles to the upper reaches of Thorofare Creek. Several male Yellowstone cutthroat trout tagged during 2003 returned to spawn in 2004, indicating that males may spawn in successive seasons. No female fish tagged during 2003 returned during 2004, indicating that females in this system may not spawn in successive seasons.

Several known mortalities of tagged cutthroat trout were noted in 2004. One radio tag was recovered from the Molly Islands of Yellowstone Lake's Southeast Arm (most likely caused by white pelican predation), and two transmitters were retrieved from below standing dead pines in the lower river region in areas where bald eagles were frequently perched. Bald eagles may have captured the fish or may have scavenged the dead fish carcasses with radio transmitters. Monitoring of fish movement patterns is planned for at least two more field seasons, as this information is some of the first ever obtained for these remote waters of the park.

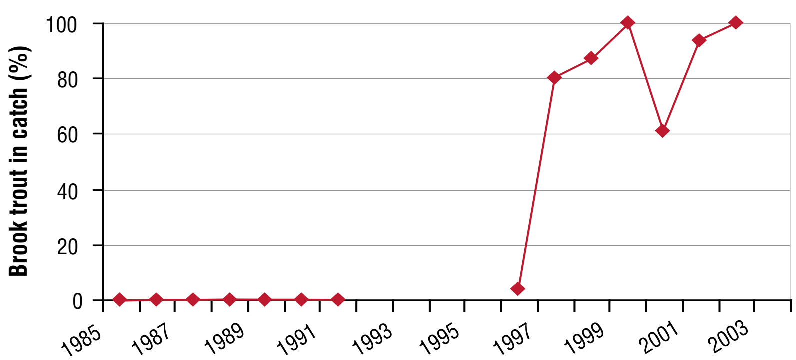


Figure 14. Brook trout reported by anglers from Pocket Lake, 1985–2002.

Pocket Lake Cutthroat Threatened by Brook Trout

From 1963 to 1986, U.S. Fish and Wildlife Service personnel surveyed 112 of Yellowstone National Park's backcountry lakes to obtain baseline data on water quality, aquatic invertebrates and macrophytes, lake bathymetry, and fish species composition and size structure.[38] This data series was meant to provide baseline data for assessing changes over time. Pocket Lake, located in a small basin 1.5 miles northwest of Shoshone Lake, was re-surveyed in 2004. Originally fishless, this lake was stocked with brook trout in 1953–1954. In 1977, the U.S. Fish and Wildlife Service chose Pocket Lake as a refugia for the depleted stock of Heart Lake Yellowstone cutthroat trout.[39] This lake was deemed an excellent refugia site for three reasons: (1) its historical fishless condition meant no native fish species would be impacted, (2) its location in a steep drainage with one small inlet and one outlet with a steep cascade would keep it isolated from other fish populations, and (3) the success of the brook trout stocked in the 1950s demonstrated it had the ability to sustain a fish population. The U.S. Fish and Wildlife Service chemically treated Pocket Lake with antimycin with the intent of eradicating all brook trout. They subsequently stocked 1,800 Yellowstone cutthroat trout from the Heart Lake drainage (900 from Heart Lake and 900 from Beaver Creek, a tributary to Heart Lake) into Pocket Lake in 1977 and 1978. When Pocket Lake was re-surveyed in 1983, four cutthroat trout and zero brook trout were collected.[40] At that time, successful recruitment of cutthroat trout had not been documented, although it was felt that it was occurring. Although Volunteer Angler Reports (VAR) have been sporadic over the years for Pocket Lake, anglers have documented catching cutthroat trout of varying sizes, supporting that at least some recruitment had occurred in the past. Unfortunately, no VAR data exist for Pocket Lake for 1992–1995. By 1996, brook trout had

reappeared in the catch, and by 1997, were reportedly 80% of the catch (Figure 14). From 1997 on, cutthroat trout have been caught infrequently in Pocket Lake; only in four of the seven years since the reappearance of brook trout have anglers reported catching a cutthroat trout.

To ensure our ability to confirm the persistence of the Heart Lake cutthroat trout in Pocket Lake, we sampled the fisheries community by gillnet, angling, and snorkeling methods during August 2004. Two variable-mesh gillnets, 38.1 m long, with 7.6 m mesh panels of 19-, 25-, 32-, 38-, and 51-mm bar mesh were used. These were set overnight, perpendicular to shore—one off a steep drop, and the other in habitat more typical of the lake. Two snorkel surveys of the lake were completed, and personnel sampled by angling as time permitted. No cutthroat trout were caught in the gillnets or by angling. However, one cutthroat trout and a second fish, thought to be a cutthroat trout, were seen during the snorkel surveys. No evidence of young-of-the-year cutthroat trout was observed.

It is not known how brook trout became re-established in Pocket Lake. If the original treatment was not 100% effective, any remaining brook trout would have been able to re-populate the lake along with the introduced cutthroat trout. This is not likely, considering that almost 20 years passed before brook trout began appearing in reported catch. Brook trout do exist in Shoshone Lake, and could have gained access via the Pocket Lake outlet. This outlet passes through a narrow canyon, and although it has a steep cascade that would prevent fish passage for most of the year, it does not appear to be a complete barrier. Regardless of how brook trout became re-established, it is apparent they are now the dominant fish in Pocket Lake, where very few Heart Lake cutthroat trout persist.

The Pocket Lake brook trout population appears healthy. Age classes 1–5 were represented in the sample, and sizes ranged from 158 mm to 357 mm (Figure 15). Mean condition factor of fish sampled was 1.0, considered ideal in a trout population.

NPS/TODD KOEL

NPS/JOE FACENDOLA

NPS/JOE FACENDOLA

Top: *Pocket Lake was stocked with cutthroat trout from Heart Lake during 1977–1978. Surveys in 2004 indicate the cutthroat trout are now largely lost due to invasion of the lake by non-native brook trout.*

Middle: *Yellowstone National Park fisheries technician Brad Olszewski measures brook trout at Pocket Lake.*

Bottom: *Non-native brook trout (shown here) have resulted in the decline of cutthroat trout within Pocket Lake.*

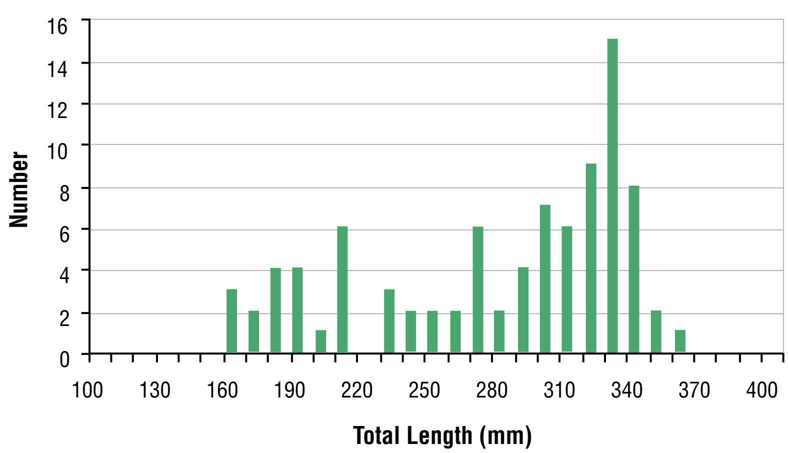


Figure 15. Length–frequency distribution of brook trout captured during gillnetting surveys of Pocket Lake, 2004.

Aquatic Ecosystem Health

Aquatic Invasive Species Program

Yellowstone's world-class fisheries are threatened by introductions of aquatic invasive species (AIS). These harmful, non-native (from elsewhere in North America) and exotic (from another continent) invading species displace precious native species, such as cutthroat trout and many native macroinvertebrates upon which Yellowstone fishes depend for growth and survival. AIS 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 mud snail (*Potamopyrgus antipodarum*) and the parasite that causes whirling disease in trout are examples of exotic AIS that are already present in park waters.[41] The zebra mussel and Eurasian watermilfoil are examples of AIS that are quickly approaching the park, and there are over 300 others now in North America—often so small they are difficult to see.[42] 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.

During 2004, a resource team convened to develop both short-term and long-term goals for the prevention of additional AIS invasions of Yellowstone National Park waters. Prevention is the key, because once introduced and established in park waters, aquatic invasive species are virtually impossible to get rid of. The following measures have been taken:

Once introduced and established in park waters, aquatic invasive species are virtually impossible to get rid of.

- 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/planvisit/todo/fishing/exotics.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 asked to watch a video on how to conduct boat inspections for AIS.

The resource team identified several additional "critical control points" that could be used in the future for the prevention of AIS introductions to park waters. These control methods will require a source of funding both for establishment and for long-term maintenance. The long-term goals for AIS prevention include:

- Enhancing public awareness of AIS issues.
- Establishing mandatory boat inspections by trained personnel.
- Establishing boat washing stations.
- Providing facilities for cleaning waders and other angler gear.
- Collaborating with the National Park Service's Vital Signs Monitoring Program to complete an aquatic invasive species risk assessment, and development of monitoring for waters with highest probability of receiving introduced species.
- Collaborating with partner agencies and non-governmental organizations and developing of an Aquatic Invasive Species Management Plan for the Greater Yellowstone Ecosystem.

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.[43] Whenever possible, images and other educational materials common to the campaign are used for purposes of AIS prevention

STOP AQUATIC HITCHHIKERS!™
Prevent the transport of nuisance species.
Clean all recreational equipment.
www.ProtectYourWaters.net

within the park. Additional information can be obtained at <www.protect yourwaters.net> and several other websites.

Long-Term Water Quality Monitoring

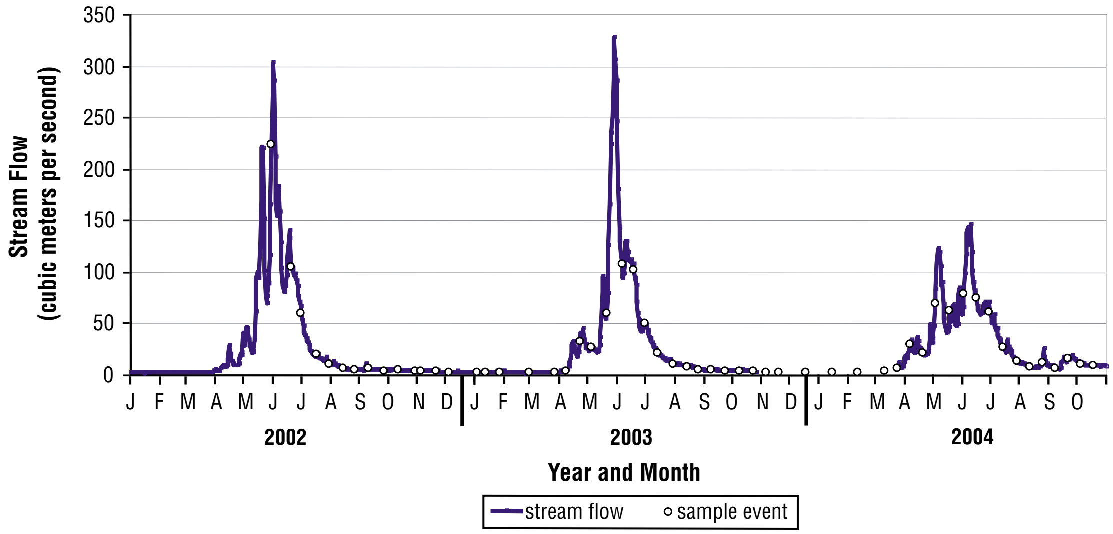


Figure 16. Hydrograph of Lamar River near confluence with Yellowstone River, illustrating mean daily streamflow from 2002 to 2004. Streamflow information was obtained from a U.S. Geological Survey gaging station; open circles represent days when water quality samples were collected.

During 2004, the Aquatics Section continued to conduct water quality monitoring at 12 established sites on major river basins throughout Yellowstone National Park (Figure 1). Each site was sampled once every two weeks (once each month during winter), with sample days being randomly selected within a sample week. This schedule allowed data to be collected during a variety of flow conditions (Figure 16). A multiparameter probe was used to collect water temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. Water samples were also collected at each location for total suspended solids (TSS) and volatile suspended solids analysis. These core water quality parameters are important to monitor because they can determine the presence or absence, as well as regulate the distribution and abundance of aquatic organisms. The primary purpose of the water quality monitoring program is to obtain baseline information regarding the health of major streams and rivers within Yellowstone National Park.

The 2004 sample season was characterized by an unusually wet summer and fall period; however, the additional moisture did not translate into higher runoff or increased stream discharge for any of the established water quality sites. In fact, streamflow conditions from gage stations throughout Yellowstone National Park indicated lower flow conditions than in the previous two years (Figure 16). During 2004, most parameters varied considerably within and between sites (Figure 17). Variations among water quality parameters resulted primarily from diurnal cycles, higher flows during spring snowmelt, rain events, seasonal temperature changes, altitude differences, and the thermal influences that affect many streams. Highest mean water temperature of 15.5 degrees Celsius (°C) occurred on the Firehole River (range 7.8–24.0°C), a thermally influenced stream. Lowest mean water temperature of 4.6°C occurred on upper Soda Butte Creek (range -0.1–13.7°C), which is near the park's northeast boundary.

Highest mean DO concentration of 10.7 milligrams/Liter (mg/L^{-1}) was recorded for the Lamar River (range 8.7–13.4 mg/L^{-1}); lowest mean DO concentration of 8.1 mg/L^{-1} was recorded for Pelican Creek (range 2.4–11.0 mg/L^{-1}) (Figure 17). Typically, DO concentrations of less than 5 mg/L^{-1} are considered stressful to most aquatic organisms. Pelican Creek, a slow-moving tributary that enters the northern part of Yellowstone Lake, is characterized by abundant vegetation in the surrounding floodplain. Decomposition of organic matter, coupled with thick ice and snow cover, could be a factor contributing to the low DO reading of 2.4 mg/L^{-1} recorded on December 16, 2003.

Within-site variation of pH was quite low, with most differences occurring between sites (Figure 17). This is best illustrated in the Madison River drainage. The Madison River receives water from the Firehole and Gibbon rivers, both of which are influenced by thermal activity. Mean

Higher turbidity values usually corresponded to spring runoff or localized precipitation events during summer months.

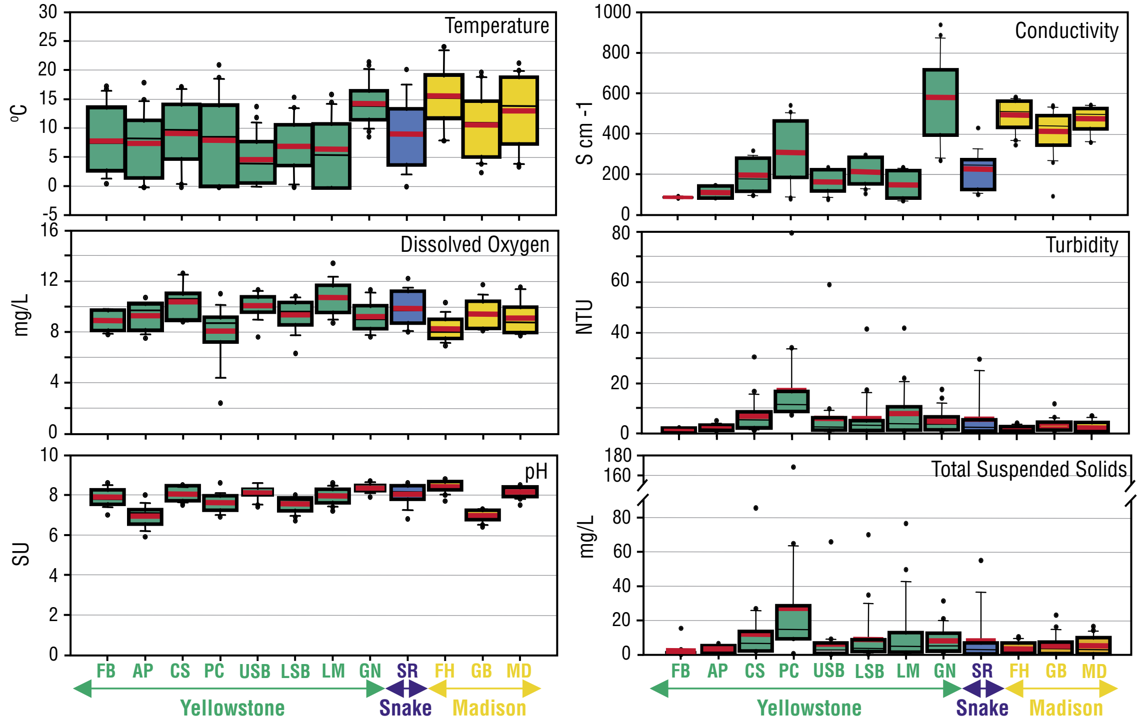


Figure 17. Box and whisker plot illustrating annual variation for selected parameters at each stream water quality location in 2004. Lower and upper portion of boxes represent the 25th and 75th percentile respectively; lower and upper black horizontal bars represent 10th and 90th percentile respectively. Outlining 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).

pH for the Firehole River was 8.4 standard units (SU) (range 7.7–8.8). This was the highest mean value for all sites sampled, with the exception of Gardner River, which also had a mean pH value of 8.4 (range 7.9–8.7). Conversely, the Gibbon River had a mean pH value of 7.0 (range 6.4–7.3). This river drainage receives considerable runoff 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 6.9 (range 5.9–8.0).

Values for specific conductance, turbidity, and TSS were highly seasonal, and appeared to be correlated with river discharge. On average, specific conductivity tended to be lowest during spring runoff and highest during the base flow period of fall and winter months. Additionally, higher specific conductivity values were generally found at sample sites with thermal contributions. For example, the highest mean specific conductivity recorded for all sites sampled were from the Gardner, Firehole, Madison, and Gibbon rivers, with 582.1, 495.3, 475.7, and 413.5 microseimens per centimeter (µS/cm^{-1}) respectively. All of those waterways receive considerable amounts of thermal contributions (Figure 17). Specific conductivity was least variable at the Yellowstone River near Fishing Bridge, and had the lowest mean value of 88.5 µS/cm^{-1} (range 82–94 µS/cm^{-1})(Figure 17). The lowest specific conductivity for all sites sampled was 69 µS/cm^{-1}, recorded at the Lamar River water quality station during a high flow period on June 3, 2004.

Turbidity and TSS are closely linked parameters, both of which evaluate suspended material in the water column. Turbidity is a measure of water clarity, with higher values reflecting a more turbid condition (i.e., less-clear water). It is important to measure because increases in turbidity can negatively affect aquatic plants (reduce photosynthesis) and animals (influence

feeding behavior of visual predators). Turbidity is caused by suspended particles present in the water column such as clay, silt, and plankton. In Yellowstone National Park, higher turbidity values usually corresponded to spring runoff or localized precipitation events during summer months. Most sites had mean turbidity measurements below 10 nephlometric turbidity units (NTU), with the exception of Pelican Creek, which had a mean turbidity measurement of 17.1 NTU (range 7.5–79.5 NTU) (Figure 17). The lowest mean turbidity measurement of 1.4 NTU was recorded for the Yellowstone River at Fishing Bridge, which is located just downstream of Yellowstone Lake.

TSS is important to monitor because it is a quantitative measure of the total fraction of inorganic (i.e., clay, silt, and sand) and organic (i.e., detritus and plankton) 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 the loss of fish habitat. Concentrations of TSS at stream sites mirrored turbidity readings. The highest mean TSS was recorded for Pelican Creek, with a mean of 27.2 mg/L^{-1} (range 0.9–168.6 mg/L^{-1}). The lowest mean TSS was recorded for Fishing Bridge, with a mean concentration of 2.3 mg/L^{-1} (range 0.4–15.5 mg/L^{-1}).

Water Quality Associated with Winter Road Use

During spring 2004, we collected snowmelt runoff from four sample locations within Yellowstone National Park. Snowmelt runoff was sampled for concentrations of volatile organic compounds (VOC). VOCs in snowpack are most likely produced by the incomplete combustion of gasoline from two-stroke snowmobiles. At high enough levels, VOCs can have adverse effects on aquatic organisms.[44] This study was initiated to determine if VOCs were present in snowmelt and, if so, whether there was a possible link to snowmobile use. This was the second year of a two-year study.

Sampling began after the end of the 2003–2004 winter season, March 20–April 3, 2004.

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Ecologist Jeff Arnold samples water quality at Pelican Creek.

Between six and ten water samples were collected from each of the sample locations, which were located in the road corridor between the West Entrance and Old Faithful. Three test sites were established within this area, with one site each in the vicinity of the West Entrance, Madison Junction, and Old Faithful. Each site was selected based on its proximity to the groomed roads used by snowmobiles during the winter season. A fourth site was used as a control located near Madison Junction, on a small, intermittent stream approximately 100 meters from the road.

Sample analysis was conducted by the U.S. Geological Survey's laboratory in Denver, Colorado. Nine compounds within the VOC category were analyzed, including benzene, ethylbenzene, ethyl tert-butyl ether, isopropyl ether, m-xylene/p-xylene, methyl tert-butyl ether, o-xylene, tert-pentyl methyl ether, and toluene. Similar to the 2003 results, only five of these compounds were detectable within any given sample (benzene, ethylbenzene, m-xylene/p-xylene, o-xylene, and toluene). Samples of snowmelt runoff near Old Faithful contained all five compounds during at least one sample event. The maximum concentration for these five compounds detected near Old

Faithful were (units are in µg/L^{-1}): benzene, 0.026 (estimated); ethylbenzene, 0.720; m-xylene/p-xylene, 3.365; o-xylene, 2.183; and toluene, 1.008. Only two VOC compounds (m-xylene/p-xylene, and toluene) were detected from snowmelt runoff near the West Entrance site, which is in contrast to 2003, when all five compounds were identified there. Both m-xylene/p-xylene and toluene were found in very low concentrations, with maximum estimated values of 0.008 and 0.037 µg/L^{-1}, respectively. VOCs were not detected in any test sample from the Madison Junction site. Water samples from the control site did contain trace levels of toluene during three sample visits, which was comparable to the 2003 results. These are similar to results of previous investigators who have also found measurable levels of toluene at off-road locations during spring snowmelt sampling.[45] Currently, the source of toluene at off-road locations is not known. Although VOCs were found at several sample locations, particularly Old Faithful and the West Entrance, the concentrations of these compounds were well below the U.S. Environmental Protection Agency's level of toxicity to aquatic organisms.[46] In addition, once the snowmelt enters a larger body of water, the dilution of the VOCs will be even more pronounced. Thus, given the volatile nature of these compounds and the low concentrations present in the test samples, it is unlikely that these chemicals will adversely affect aquatic organisms.

Although VOCs were found at several sample locations, the concentrations of these compounds were well below the U.S. Environmental Protection Agency's level of toxicity to aquatic organisms.

Water Quality Monitoring Goals

Future goals for the water quality program are to continue monitoring at the 12 established sites on major river basins of the park (Figure 1) to acquire baseline information and determine inter- and intra-annual variation of basic, water quality core parameters. In addition, through collaboration with the National Park Service Vital Signs Monitoring Program, we will begin focused water quality sampling of the park's state 303d-listed streams (Soda Butte Creek and Reese Creek). We are also working on the development of a probabilistic sampling design for macroinvertebrates and water quality at a large spatial scale. The protocols to be used will be consistent among the three parks of the Greater Yellowstone Network, and will allow for the comparability and consistency required for tracking long-term changes (decades or longer) in the health of Yellowstone's aquatic systems.

Yellowstone Lake Limnology

Collection and analysis of physical and chemical parameters is a crucial component in understanding the limnology of Yellowstone Lake. These parameters have a tremendous influence on abundance and distribution of aquatic organisms. In particular, these data will provide park fisheries biologists with important information regarding movement patterns of lake trout while gillnetting operations are underway. For example, during summer months when the thermocline (area in water column of greatest temperature change) becomes established, lake trout generally move into deeper, cooler waters avoiding the warmer water near the lake surface.

The seven long-term water quality monitoring sites on Yellowstone Lake were sampled from May 21 through October 20, 2004 (Figure 3), with data being collected every two weeks. During each sample event, water temperature, DO, pH, specific conductance, and turbidity measurements were made using a multiparameter probe near the lake's surface at a depth of 0.2 m. Surface water was also collected at each location for TSS and volatile suspended solids analysis. To obtain a more comprehensive understanding of Yellowstone Lake limnology, we collected depth profile information from all sites when weather permitted. The multiparameter probe was used to collect water temperature, DO, pH, and specific conductance at various depths throughout the water column from each sample location.

Mean surface water temperature, DO, pH, and specific conductance values were fairly consistent among all seven sample locations. Surface water temperatures reflected seasonal changes, with lower temperatures occurring during the spring and fall, and higher temperatures occurring during the summer months. The highest mean surface water temperature of 11.2°C (range 4.5–17.5°C) was recorded at the Mary Bay site;

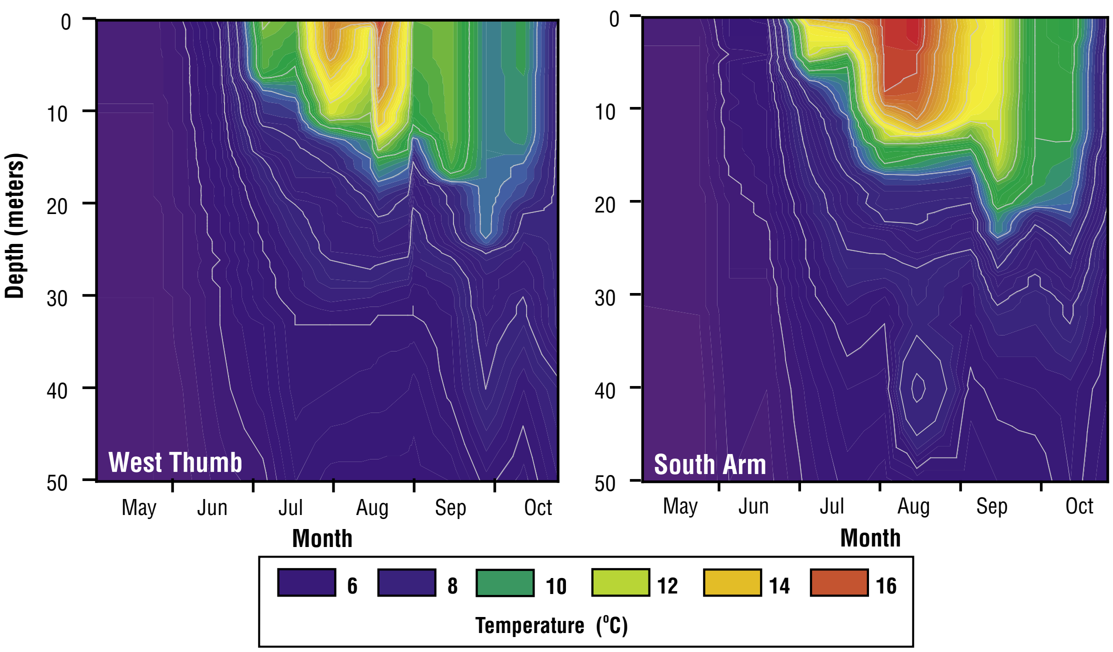

Figure 18. Isopleth of water temperature in West Thumb and South Arm of Yellowstone Lake during summer 2004. Contour lines represent one-degree intervals. For comparison, and greater resolution of surface temperatures, only data from the first 50 meters is displayed for the West Thumb location.

the lowest mean surface water temperature of 9.7°C (range 4.5–15.2°C) was recorded at the West Thumb site (Figure 18). The slightly cooler water temperatures recorded for the West Thumb site are likely the result of its being sampled prior to noon on most sample days. Data from the water temperature depth profiles indicated that the water temperature remained fairly constant throughout the water column, about 4°C, until mid-June, when surface water temperatures began to rise. The lake began to stratify by early July, with the development of the thermocline, which became established at approximately 20 m by mid-September (Figures 18 and 19).

Surface water DO concentrations on Yellowstone Lake, for all sites combined, ranged from 7.4 to 10.7 mg/L^{-1} throughout the 2004 season. Trends in DO concentrations were similar among all sites, with lower values being recorded during the summer months (July and August) when surface water temperatures were warmest, and higher values being recorded during the spring months (May and June) when surface water temperatures were coolest. Mean DO concentrations were similar among all sites, with values ranging between 8.6 and 8.8 mg/L^{-1}. Examination of the depth profile data indicated that DO concentrations remain comparatively consistent throughout the water column for any given sample day (Figure 19).

Surface water pH values were less variable between sites and throughout the season. The highest mean pH value of 8.0 (range 7.5–8.3) was recorded for the South Arm site; the lowest mean pH value of 7.6 (range 7.3–7.9) was recorded for the Mary Bay site. The subtle differences in pH values among and between sites can most likely be attributed to natural variability throughout the lake basin.

Specific conductivity values varied little during the season and between sites. Overall, mean specific conductivity values for all sites ranged from 84 to 94.4 µS/cm^{-1}. The highest mean specific conductivity value of 94.4 (range 92–96 µS/cm^{-1}) was recorded for the West Thumb site; the lowest mean specific conductivity value of 84 µS/cm^{-1} (range 69–91 µS/cm^{-1}) was recorded for the Southeast Arm site. The slightly higher values in the West Thumb area may likely be linked to the large amount of thermal activity within the basin. The lower specific conductivity values recorded for the Southeast Arm are most likely associated to the lower specific conductivity of the upper Yellowstone River, which enters Yellow-

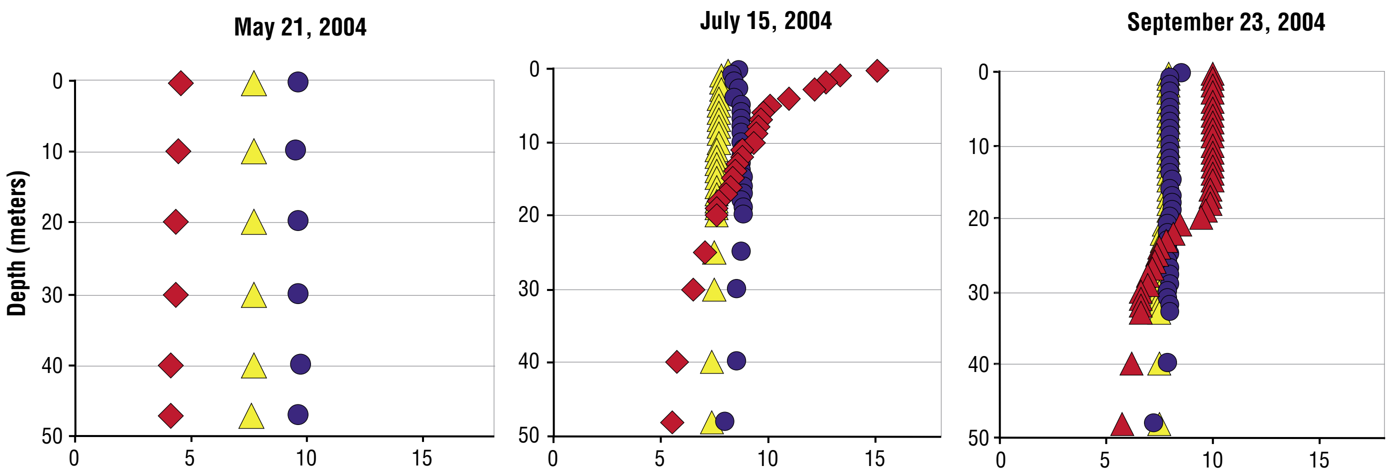

Figure 19. Water temperature (red), pH (yellow), and dissolved oxygen (blue) values in relation to depth and season in South Arm of Yellowstone Lake, 2004.

stone Lake just south of the sample location.

As with stream sampling, turbidity and total suspended solids are closely linked parameters that measure the amount of material present in the water column. Mean turbidity measurements were quite low for all sites. The highest mean turbidity of 1.6 NTU (range 0.4–6.0 NTU) was recorded for the Southeast Arm site; the lowest mean turbidity measurement of 0.5 NTU (range 0.3–1.0 NTU) was recorded at the Stevenson Island site. The slightly higher mean turbidity in the Southeast Arm could be attributed to suspended material entering Yellowstone Lake via the upper Yellowstone River. Measurements of TSS in Yellowstone Lake primarily reflect the organic (plankton) material present in the water column. As with turbidity, TSS measurements for all sites were quite low throughout the season. The highest mean TSS measurement of 0.097 mg/L^{-1} (range 0–0.212 mg/L^{-1}) was recorded for the Mary Bay site; the lowest mean TSS measurement of 0.039 mg/L^{-1} (range 0–0.091 mg/L^{-1}) was recorded for the West Thumb site.

Macroinvertebrates as Health Indicators

Effective water quality monitoring requires a combination of physical, chemical, and biological measurements to efficiently evaluate the health of aquatic systems. Physical and chemical measurements directly measure 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 environment. Sampling aquatic invertebrate communities continues to be a practical method of evaluating stream health in Yellowstone National Park. These organisms are ideal biological indicators because they are sensitive to environmental changes (physical and chemical), relatively immobile (as compared to fish), generally have long life spans (1–2 years), and are easy to sample. Accordingly, by studying aquatic macroinvertebrate communities within a given stream segment, we can assess the current water quality condition of that stream. Additional water quality information that is collected with invertebrate sampling includes a habitat assessment and collection of basic water quality parameters such as water temperature, dissolved oxygen, pH, specific conductance, turbidity, and stream discharge.

During 2004, we continued to collect aquatic macroinvertebrates as part of the Aquatic Section's aquatic ecosystem health program. Macroinvertebrate monitoring was conducted in response to a variety of factors that currently threaten the health of aquatic resources within the park. For example, the ongoing road construction projects are continual concerns 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. As a result, renovation of these roads poses potential risks to aquatic systems through

sedimentation and stream channel alteration. In relation to ongoing or future road construction projects, we sampled 17 sites on 10 stream segments. Streams (and number of sites) selected for sampling were: Antelope Creek (1), Alum Creek (1), Elk Antler Creek (1), Gardner River (1), Gibbon River (4), Middle Creek (2), Obsidian Creek (4), Otter Creek (1), Pelican Creek (1), and Trout Creek (1) (Figure 1). Data collected from these sites will help park resource managers better understand the impacts, if any, that road reconstruction has on water quality, specifically effects on aquatic biota. Additionally, a long-term macroinvertebrate site on upper Soda Butte Creek near the park's northeast boundary was sampled. This site is sampled annually to monitor any possible effects that the McLaren Mine tailings, located upstream of the park boundary near Cooke City, Montana, may have on the water quality of Soda Butte Creek within park boundaries. This is the third consecutive year that aquatic benthic macroinvertebrates have been collected at this location. Samples collected for these projects are currently being analyzed, with results becoming available during spring 2005.

Invertebrate samples were also collected as part of the westslope cutthroat trout restoration project currently underway in the Specimen and Fan creek drainages. During August 2004, we sampled six invertebrate locations throughout the Specimen Creek drainage to evaluate current water quality conditions. These data will also provide necessary background information regarding inventory and distribution patterns of aquatic invertebrate assemblages needed prior to any fish restoration attempt there. Samples collected from the Specimen Creek drainage are being analyzed, with data expected to be available in summer 2005.

In response to an accidental fire retardant drop that occurred in the Bacon Rind Creek drainage during September 2003, we conducted invertebrate sampling to examine potential impacts the spill had on stream water quality. Most fire retardants, as was the case with the Bacon Rind spill, contain high concentrations of ammonia, which is toxic to most plants and animals. The initial site inspection, which occurred during October 2003, concluded that the main volume of fire retardant was dropped approximately 90 m from Bacon Rind Creek. By examining the spray pattern on materials near the stream channel, it was also determined that approximately 33% of the stream surface area within a 20-m reach was affected by the fire retardant. To evaluate the effects of fire retardant on stream water quality and aquatic biota, we collected invertebrates from two stream segments, one downstream and one upstream of the impacted area. Eight surber samples (0.09m^2, 500-µm mesh) were collected from each stream segment. To reduce variability, samples were collected from areas with similar instream habitats, gradients, and steamflow. Preliminary results indicate that the area immediately downstream of the fire retardant drop may have been mildly impacted by the fire retardant. Fifty-six unique taxa were collected from the downstream reach, compared to the 64 taxa collected from the upstream reach. Additionally, the number of intolerant taxa (groups of organisms that are not tolerant of environmental pollutants) was slightly lower at the downstream location (10 taxa) than the upstream location (12 taxa). However, the Hilsenhoff Biotic Index, which evaluates tolerance levels of benthic macroinvertebrates to pollutants, scored both of these stream segments as being in excellent condition. If the fire retardant had any impacts on the water quality of Bacon Rind Creek, they appeared to be short term, with no significant adverse effects on aquatic biota.

If the fire retardant had any impacts on the water quality of Bacon Rind Creek, they appeared to be short-term.


NPS/TODD KOEL

Bacon Rind Creek at the site of an accidental fire retardant drop during September 2003.

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 26 sites within Yellowstone National Park have been examined by the Survey (1995–2004), with many additional sites examined in the Yellowstone Lake drainage as part of the park's whirling disease research program (Figure 20). To date, we have documented the presence of two significant fish pathogens within the park:

- *Renibacterium salmoninarum*, the agent of bacterial kidney disease, and

- *Myxobolus cerebralis*, parasite responsible for salmonid whirling disease

R. salmoninarum was confirmed by DNA polymerase chain reaction (PCR) from 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 the pathogen, 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* 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 native cutthroat trout and other fish species in the intermountain region.

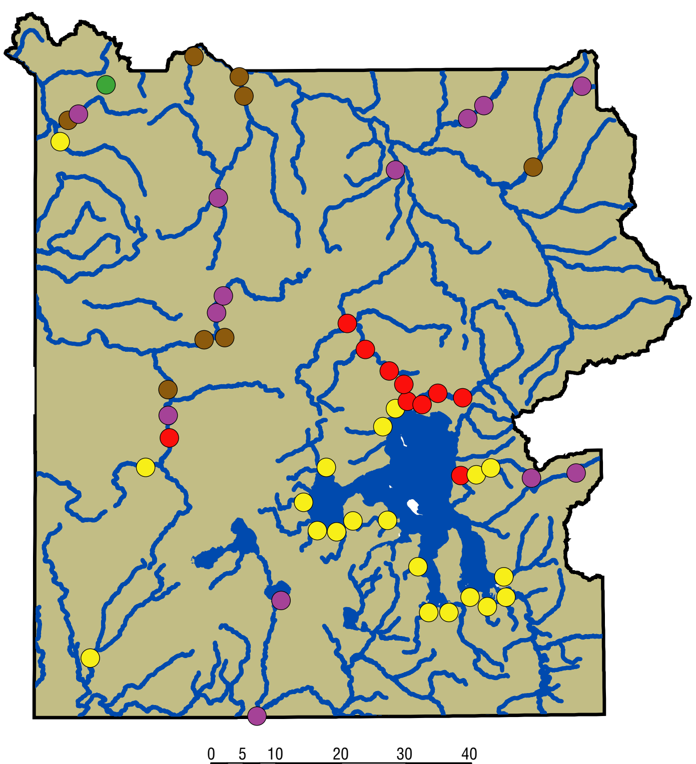

Figure 20. Stream sites examined by the U.S. Fish and Wildlife Service, Wild Fish Health Survey or by sentinel cutthroat trout fry exposures, 1995–2004. Sites that tested positive for the presence of Myxobolus cerebralis (Mc), *the cause of whirling disease, are in red.*

Whirling Disease and its Effects on Cutthroat Trout

In Yellowstone National Park, research on the native Yellowstone cutthroat trout of the Yellowstone Lake basin has provided strong evidence that this subspecies and strain is extremely susceptible to *Myxobolus cerebralis* (*Mc*), the parasite that causes whirling disease. Up to 20% of all juvenile and adult Yellowstone cutthroat trout within the lake are infected. Sentinel exposure studies (in which uninfected fry are held within cages in a stream and later examined for exposure to whirling disease) suggest that risk of infection is highest in the Yellowstone River and Pelican Creek (the second largest tributary to Yellowstone Lake). Average infection grades in this stream have been 4–5 on the MacConnell-Baldwin scale (0 = no infection to 5 = worst possible infection). Additionally, recent studies have examined the genetic composition of *Tubifex tubifex* (Oligochaeta: Tubificidae) in the Yellowstone Lake

basin. Results indicated that at least some of the *T. tubifex* are similar to those from the Madison River in Montana, a clade that is moderately susceptible to the parasite.[47]

The following is a timeline of *Mc* examinations within Yellowstone National Park during the decade following the 1994 discovery of *Mc* (and 70–90% decline) in rainbow trout of the nearby Madison River:[48]

1995–1998 following the discovery of the parasite in the Madison River of Montana, fish from Yellowstone's "boundary area" streams, thought to be most vulnerable, were tested for *Mc.*

1998 (October) *Mc* is unexpectedly confirmed from deep in the interior of the park, in cutthroat trout collected within Yellowstone Lake near the mouth of Clear Creek.

1999 juvenile and adult cutthroat trout are found to have *Mc* at locations throughout Yellowstone Lake.

1999 sentinel exposure studies begin on Yellowstone Lake tributaries, with the Yellowstone River at Fishing Bridge testing positive for *Mc.*

2000 multiple exposure period studies begin on Yellowstone Lake tributaries, with *Mc* detected at Clear Creek (slight, a single fry) and Pelican Creek (severe).

2000 *Mc* confirmed in a single rainbow trout from the Firehole River.

2001 sentinel exposure studies continue, oligocheate surveys are initiated, and actinospore release studies are conducted, as are *T. tubifex* genetics investigations. At least two other myxozoans are also infecting fishes of the Yellowstone Lake basin.

2002 intensive research begins on Pelican Creek, Clear Creek, and the Yellowstone River downstream of Fishing Bridge. *Mc* is confirmed at sites as far upstream on Pelican Creek as the old bridge crossing; no further spread to other tributaries is noted.


NPS/TODD KOEL

Fisheries technician Shane Keep checks a whirling disease sentinel cage in the upper Pelican Creek watershed during 2004.

2003 testing continues on Yellowstone Lake, its tributaries (especially those with characteristics similar to Pelican Creek), and at streams throughout the park. *Mc* confirmed downstream in the Hayden Valley reach of the Yellowstone River.

2004 intensive research begins to examine the tubificids of the Pelican Creek watershed in an effort to look for ways to mitigate the disease. Severe *Mc* infection risk is confirmed at remote, upstream sites within the watershed through sentinel fry exposures and tubificid surveys.

2004 research is undertaken to examine the role of American white pelicans as dispersal vectors for *Mc* in the region.

2004 testing by Montana Department of Fish, Wildlife and Parks locates a severe *Mc* infection in Cougar Creek, an upstream tributary of the Madison River (Hebgen Lake).

By 2001, cutthroat trout sentinel fry exposures confirmed the presence of *M. cerebralis*

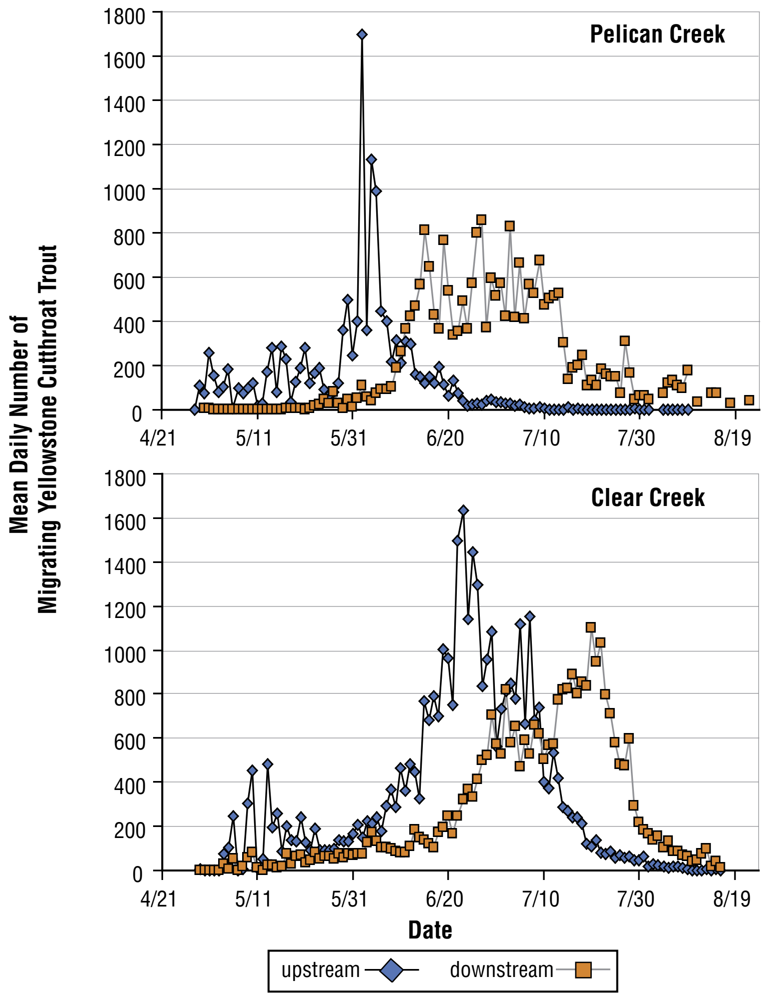

Figure 21. The mean daily number of Yellowstone Lake adfluvial Yellowstone cutthroat trout that were enumerated at migration traps while moving upstream and downstream in Pelican Creek (1964–1983) and Clear Creek (1977–2001).

in three important Yellowstone Lake spawning streams: Pelican Creek, Clear Creek, and the Yellowstone River downstream from the lake outlet (Figure 1).[49] Since then, sentinel exposures in the Yellowstone River upstream of the lake inlet and 13 other spawning tributaries have failed to detect the presence of this exotic parasite. The impacts of *M. cerebralis* were most severe in Pelican Creek, where few wild-reared fry have been observed in recent years (2001–2004). Because of this, we began looking for spawning cutthroat trout each spring. Consistent, annual counts of upstream-migrating adult cutthroat trout were not made in Pelican Creek in recent years, but records exist from a historical weir that was used to enumerate spawning fish through 1981.[50] Historical records indicated that most cutthroat trout migrated up Pelican Creek from mid-May through the third week in June, with peak migration occurring during the first week of June (Figure 21). The spawning migration at Clear Creek, the tributary where *Mc* has only been found one time in a single fry, has generally occurred a few weeks later in the year, with a bimodal spawning peak typically occurring during the third week in June. Downstream movements of adult fish returning to Yellowstone Lake from Pelican Creek occurred from mid-June through mid-July; from Clear Creek, they occurred from late-June through late-July. This variation in timing of cutthroat trout spawning may, to some extent, explain the differences in *Mc* infection we have noted among these tributaries.

Netting near the location of the historical weir on Pelican Creek (near the tributary mouth) for upstream-migrating adults in 2002–2004 indicated that the spawning cutthroat trout population of this tributary, which in 1981 was nearly 30,000 fish, has been essentially lost. With a drainage area of 17,565 ha, Pelican Creek is the second-largest tributary to Yellowstone Lake in terms of discharge (the Yellowstone River upstream of Yellowstone Lake has the largest drainage area). Establishment of *Mc* has likely contributed to the severe decline of cutthroat trout within Pelican Creek, and the overall population decline within the Yellowstone Lake ecosystem. Fry and fingerling cutthroat trout found in remote, upstream tributaries of Pelican Creek during 2004 provide hope, however, that at least some fish in this drainage are avoiding the disease, and may one day give rise to higher numbers of cutthroat there.

Work on *Mc* is now focused on Pelican Creek, where the infection consistently has been most severe. Infection risk of native Yellowstone cutthroat trout is being related to *Tubifex tubifex* (the alternate host for *M. cerebralis*) presence, abundance, and infection, and the environmental characteristics of sites within the Pelican Creek watershed. Prior to 2004, severe infection was documented through exposure of Yellowstone cutthroat trout fry to the trail crossing (near the old bridge site) far upstream on Pelican Creek. In 2004, for the first time, we conducted exposure studies in the upper reaches of the drainage,

including the unnamed tributary that originates on Mount Chittenden (Creek 10851100), Raven Creek, and the mainstem of Pelican Creek just below the confluences with these streams. Ten-day exposures beginning on August 31 and September 10, followed by incubation of the fry in aquaria for three months, indicated some of the highest whirling disease infection risk ever found within the park. All three sites in this area resulted in a mean histological score for infection severity of 5.0. These fry also tested positive for *Mc* by PCR analysis, as did fry exposed experimentally for only 24 hours that were immediately sacrificed. The 24-hour exposures were conducted in an attempt to find a more efficient way of determining *Mc* prevalence in remote streams like Pelican Creek. Analyses of caudal, anal, or pectoral fins, or skin scrapes of these exposed fry, all proved to have potential for use in the future.[51] Because the fry are sacrificed on site, instead of being transported out of the backcountry alive and held for months in laboratory aquaria, the 24-hour technique saves great amounts of time and expense. A trade-off, however, is that the severity of the infection cannot be assessed with this technique, because the parasite is not allowed to develop for histological examination.

A large-scale investigation of *Tubifex tubifex* was launched in 2004, as part of our continued attempts to understand whirling disease in Yellowstone, in close collaboration with the Department of Ecology, Montana State University. Preliminary DNA results of 5,804 oligochaetes collected at 25 sites and examined by PCR in 2004 suggested that the parasite extends far upstream in the watershed.[52]

Additionally, we have been interested in learning about how *Mc* might have originally been introduced to Yellowstone's waters, and ways this parasite might be moving within the park, infecting additional streams in the future. Movement of infected hatchery fish has been blamed for the spread of *Mc* in Colorado, and its introduction to Wyoming, but fish have not been stocked (legally) in the Yellowstone River drainage within Yellowstone National Park since 1955, prior to the first discovery of whirling disease in the United States. The vector for dissemination to many waters of the Intermountain West, including the relatively pristine and highly protected waters of Yellowstone Lake, is unclear. The risk of *Mc* spread to additional waters within the Greater Yellowstone Ecosystem, where fish are not being introduced by humans, is equally unclear. Obvious potential vectors include the movement of myxospores by humans (anglers and their gear) or by fish-eating wildlife, especially those capable of traveling long distances in a short period of time, such as avian piscivores.

The wide spatial extent of *Mc* found within the Pelican Creek watershed suggests that movement of this parasite has occurred, to some extent, by vectors other than anglers. To examine the potential of *Mc* movement by fish-eating birds, we collected 500 white pelican fecal samples from the Molly Islands (in Yellowstone Lake's Southeast Arm) during August 2004, for development of an extraction technique and testing for the presence of *Mc* DNA by PCR. Results from the initial analyses of these fecal samples suggested that *Mc* was not present. However, only a small portion of each fecal sample was examined. We are now working to refine the extraction techniques to include the entire fecal sample and ensure that any *Mc* myxospores that may be present are isolated and analyzed.[53] Our goals for this research in 2005 are to examine the potential of

BETH MACCONNELL

Yellowstone National Park supervisory fisheries biologist Dr. Todd Koel and fisheries biologist Dan Mahony with the fisheries horses Pat, Ethan, Scotty, Sammy, and Mother (L to R) at Pelican Springs cabin in August 2004.

NPS/TODD KOEL

American white pelicans of the Molly Islands colony are being examined to gauge their potential to transport whirling disease.

A better understanding of how *M. cerebralis* is dispersed may help us to prevent introductions to additional Yellowstone waters in the future.

other birds to be *Mc* dispersal vectors, including great blue herons and double crested cormorants. Fish infected by *Mc* will be fed to captive birds, and viability of spores will be assessed following passage through the alimentary canal of these bird species. Companion research is being conducted by Montana State University and the U.S. Geological Survey's Montana Cooperative Fishery Research Unit to examine the possible role of anglers as dispersers of *Mc.* A better understanding of how *Mc* is dispersed may help us to prevent introductions to additional Yellowstone waters in the future.

Amphibian Loss Near Fishing Bridge

Two major infectious diseases were found in Yellowstone National Park amphibians in 2004: one from specimens collected during monitoring, and the other from a mortality event (die-off) of spotted frogs at a small tributary to the Yellowstone River north of Fishing Bridge in 2002. This stream happens to be an outflow of the Fishing Bridge sewage treatment plant. From examination of amphibians found in several areas in the park in 2000–2002, pathologists at the USGS National Wildlife Health Center in Madison, Wisconsin, confirmed the presence of ranavirus and chytridiomycosis.[54] Both diseases were found in dead or moribund adult spotted frogs collected at Chipmunk Creek and Creek 1082, tributaries to Yellowstone Lake. Chytridiomycosis is caused by a fungus parasitizing the skin of adult amphibians, and is a known cause of amphibian population declines elsewhere. Ranavirus typically affects larval amphibian populations. The discovery of lethal outbreaks in adult spotted frog populations was described by the USGS pathologist as extremely rare and noteworthy.

It was also discovered that a parasite of cutthroat trout affects frogs. Encysted metacercaria of trematodes (family *Diplostomatidae,* genus and species not identified) resulted in abnormalities in most of the young-of-the-year spotted frogs inhabiting the mouth of Lodge Creek in August–September 2003. This type of parasite has loose host specificity for the first and second intermediate hosts. Fish kills due to the parasite have been reported in small, young fish. Salmonid and sucker species are heavily infected in some areas, including Yellowstone Lake and the Madison River. In 2004, no abnormal frogs were found at lower Lodge Creek, but young-of-the-year frogs were nearly absent despite abundant egg production in May.

The cause and ability of these disease events to persist is unknown, but this work highlights the fragility of these unique fauna, even within the highly protected environment of Yellowstone National Park.

Trends from the Volunteer Angler Report Cards

Angling remains a popular pastime for those visiting, living near, and working in Yellowstone National Park. An estimated 51,542 people fished in park waters during 2004. 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 since 1973, and provide anglers an opportunity to share their fishing success and opinions about the fisheries with park fisheries managers. There was a response of more than 3,000 angler outings through the VAR program in 2004.

Park fisheries managers use the information provided by VAR cards to get an overview of angler use, fish population dynamics, and attitudes toward the fisheries resources of Yellowstone National Park. Data from 2004 indicated that anglers fished for an average of 2.87 hours per

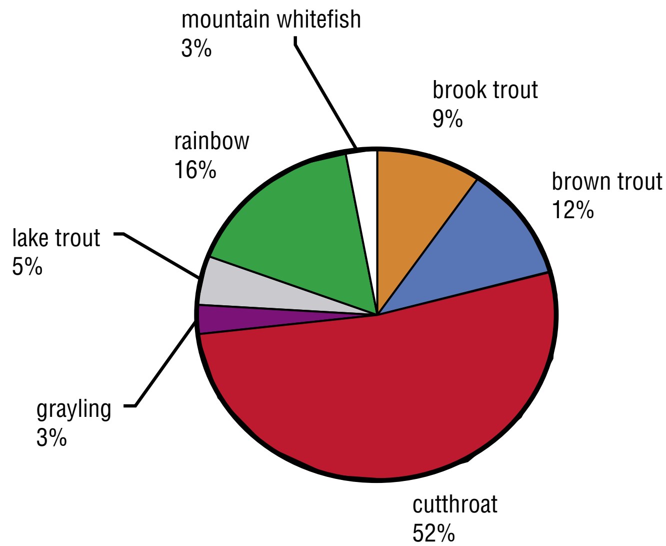

Figure 22. Total angler-reported catch for each fish species in Yellowstone National Park during the 2004 fishing season.

CHARLES WALTON

Yellowstone cutthroat trout is the most highly sought after species by anglers visiting Yellowstone National Park.

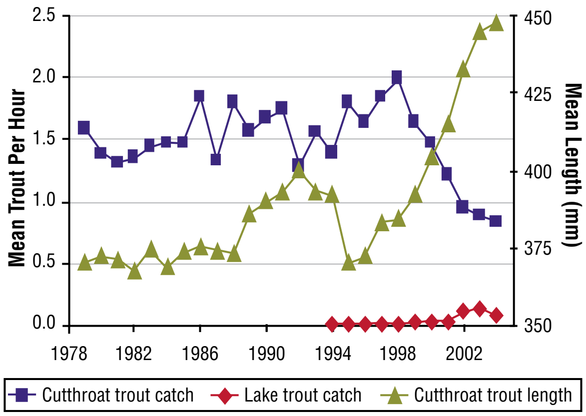

Figure 23. Angler-reported catch rate for cutthroat trout and lake trout, and the average length of cutthroat trout caught by anglers from Yellowstone Lake, 1979–2004.

day during a typical outing, and fished 1.69 days during the season. Sixty-two percent of anglers fished only one day, and accounted for 82% of fish caught. Only 5.1% of these anglers kept fish. Anglers reported being satisfied with the overall fishing experience (76%), with the number of fish caught (62%), and with the size of fish (68%).

Anglers caught an estimated 606,521 fish in Yellowstone National Park during the 2004 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 16%, brown trout 12%, brook trout 9%, lake trout 5%, mountain whitefish 3% and grayling 3% (Figure 22).

Yellowstone Lake remained the most popular destination for anglers; an estimated 10,326 anglers fished Yellowstone Lake in 2004, representing one quarter of all fishing effort in the park. Anglers fishing Yellowstone Lake reported catching 0.83 cutthroat per hour of fishing. This catch rate is less than in recent years, and follows a five-year downward trend since a record high in 1998. The average length of cutthroat caught by anglers increased again in 2004, to 448 mm (17.7 inches), and is at an all-time high (Figure 23).

In the effort to decrease lake trout in Yellowstone Lake, the park encourages anglers to fish for lake trout, without limitations on size or numbers. In fact, anglers are required to kill all lake trout they catch in Yellowstone Lake. An estimated 8,465 lake trout were caught by anglers in Yellowstone Lake during the 2004 angling season. The angler-reported catch rate for lake trout in Yellowstone Lake decreased in 2004, to 0.13 fish per hour. This is the first year since 1998, and the second year since their discovery in Yellowstone Lake that the angler catch per effort has decreased, and is a positive sign that the effort to reduce lake trout is achieving some success.

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

NPS/TODD KOEL

Lake Yellowstone and the upper Yellowstone River.

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 National Park Service staff cannot address all of the park's aquatic issues, a program was established to incorporate flyfishing volunteers to use catch-and-release angling as a capture technique for gathering biological information on fish populations throughout the park. In 2004, 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.

- documentation of the status and movement patterns of grayling originating in Grebe and Wolf lakes of the Gibbon River system. More than 300 grayling are now tagged in the Gibbon River, and much of our current understanding of grayling distribution within the Gibbon River is due to the efforts of the flyfishing volunteers.

Another highlight of the 2004 field season was the initiation of a hook-type study, in which half of the volunteer anglers fished with barbed hooks, and the others with barbless hooks. The study will be continued in 2005, but preliminary results indicated no difference among hook types for injuring fish or causing mortality.

Under this incredibly successful program, 68 volunteer anglers from across the United States 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 assist in our understanding of the park's fisheries.

NPS/BILL VOIGT

JOANN VOIGT

Top: *The Yellowstone Volunteer Flyfishing Program brings anglers from across the country together to address the park's fisheries issues.*

Bottom: *During 2004, 68 anglers participated in the Volunteer Flyfishing Program, and information was obtained from many locations 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 National Park Service seasonal staff. All aspects of the Aquatics Section greatly benefit from both long- and short-term volunteer support. In 2004, a total of 103 volunteers dedicated 4,441 hours to Aquatics Section activities.

NPS/PAT BIGELOW

Smallcraft operator Don Wethington practices water rescue techniques with fisheries staff.

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 provide for training in Motorboat Operator Certification and American Red Cross certification in First Aid and CPR for employees of Yellowstone National Park as well as 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 National Park Service biologists and other regional managers of aquatic systems.

Projects by Graduate Students

Graduate Student: Julie Alexander (Doctor of Philosophy candidate).
Committee Co-Chairs: Dr. Billie Kerans and Dr. 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 lake trout spawning areas in Yellowstone Lake as a part of the native Yellowstone cutthroat trout preservation program in Yellowstone National Park.

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: Dr. Billie Kerans and Dr. 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: Dr. Al Zale, U.S. Geological Survey Cooperative Fisheries Research Unit, and Dr. 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.

Cub Creek in spring 2004 following the East Fire of August 2003.

Other Research and Collaboration

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

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

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

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

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

We would like to extend special thanks to the Yellowstone Park Foundation and the many private individuals that have graciously provided support for our critical fisheries projects in the park.

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.

We also thank the many volunteers who have dedicated their time and also a great deal of other expense to our Aquatics Section. Without them, much of what we do in our programs 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.

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

The Aquatics Section is extremely grateful for the assistance provided by David Weston, Dr. Mike Wells, Dr. Dan Shaffer, and the dedicated students of the Montana State University College of Engineering lake trout crisis senior design project.

Information on annual cutthroat trout spawning migration surveys and bear use of Yellowstone Lake tributaries (Figure 6) was provided by Kerry Gunther of Yellowstone National Park's Bear Management Office and Daniel Reinhart, Patrick Perrotti, and Eric Reinertson of the park's Resource Management and Visitor Protection Division.

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Appendices

Appendix i. Fish Species List

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

Family	Common Name	Scientific Name	Status	Missouri	Snake	Yell R.
Salmonidae	Yellowstone cutthroat trout	*Oncorhynchus clarki bouvieri*	Native	I	I	N
	Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Native	N		
	Finespotted Snake River cutthroat trout	*Oncorhynchus clarki behnkei**	Native		N	
	Rainbow trout	*Oncorhynchus mykiss*	Non-native	I	I	I
	Mountain whitefish	*Prosopium williamsoni*	Native	N	N	N
	Brown trout	*Salmo trutta*	Exotic	I	I	I
	Eastern brook trout	*Salvelinus fontinalis*	Non-native	I	I	I
	Lake trout	*Salvelinus namaycush*	Non-native		I	I
	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


NPS/DAN MAHONY

Snake River.

NPS/TODD KOEL

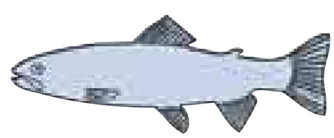
Volunteer Flyfishing Program coordinator Bill Voigt examines a fish caught on Slough Creek by Chessie Thacher of the Yellowstone Park Foundation.

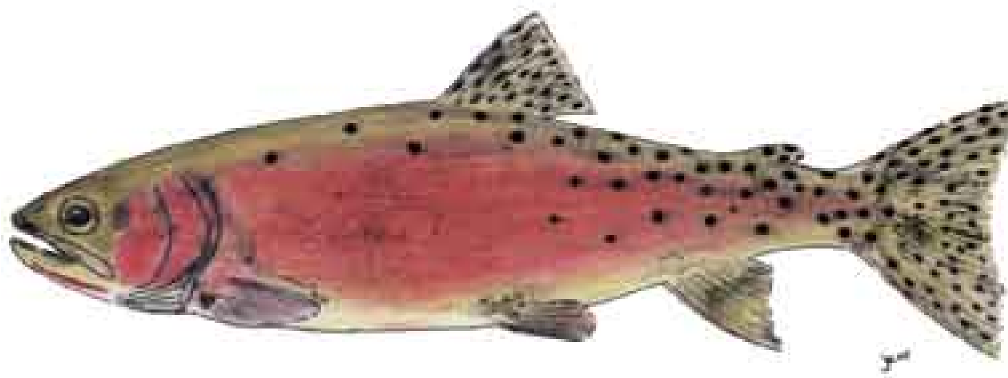
Appendix iii. Long-term Volunteers, 2004

Name	Period of Involvement (mm/dd/2004)	Hours
Allen, Hayley	09/06–11/27	480
Blakney, Jason	08/08–10/30	480
Cook, Michelle	08/23–11/13	480
Dixon, Chris	03/16–04/30	296
Fisher, Christine	06/01–08/02	280
Hutchinson, Hunter	08/27–10/30	360
Merryman, David	05/16–08/07	480
Varian, Anna	05/16–10/30	845
Voigt, JoAnn	05/25–08/21	149

Appendix iv. Seasonal Staff, 2004

Name	Period of Involvement (mm/dd/2004)
Anacker, Melissa	05/16–08/21
Anderson, Krisi	05/16–11/24
Bywater, Tim	05/25–08/21
Cook, Alice	05/26–08/21
Conley, Steve	05/16–08/31
Dixon, Chris	05/02–10/08
Facendola, Joseph	05/12–11/24
Fisher, Christine	08/03–10/30
Jones, Mike	05/02–10/08
Kavanagh, Maureen	05/09–10/30
Keep, Shane	05/02–10/08
Legere, Nicole	05/27–10/30
Olszewski, Brad	05/19–11/24
Rowdon, Barb	01/01–10/30
Sigler, Stacey	05/12–10/30
Voigt, Bill	05/25–08/21
Wethington, Don	05/02–10/30





JOE FACENDOLA

Yellowstone cutthroat trout.