Yellowstone Fisheries & Aquatic Sciences

Annual Report
2006


NPS/TODD KOEL

The upper Yellowstone River near the south park boundary, where raft electrofishing surveys started and then continued downstream to Yellowstone Lake in September 2006.

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

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

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

The stakes are high, raising the bar for innovative management and fundraising. The increased magnitude of the problems faced by the park's fisheries, and the accelerated rate at which they are occurring, are straining Yellowstone's resources. Despite this, our hope and enthusiasm remains high as within Yellowstone Lake, cutthroat are showing subtle signs of recovery while lake trout are showing signs of suppression. Within the streams, momentum could not be greater as we successfully complete our first cutthroat restoration and the replication of newly discovered, pure-strain westslope cutthroat trout populations.

This annual report describes historical and continuing park aquatics programs with information obtained through 2006 and outlines project goals and objectives for future years. We want to make sure that everyone with an interest has a solid understanding of both our intent and of the direction our efforts are taking to preserve and restore native fishes in the waters of this tremendous park.

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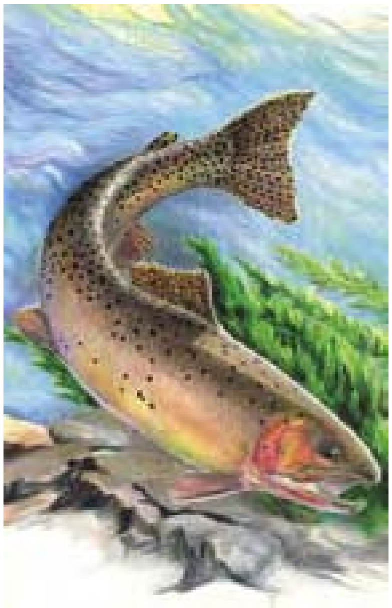
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Yellowstone cutthroat trout

Todd M. Koel, Jeffrey L. Arnold, Patricia E. Bigelow,
Philip D. Doepke, Brian D. Ertel, and Michael E. Ruhl

National Park Service
Yellowstone Center for Resources
Yellowstone National Park, Wyoming
YCR-2007-04

Suggested citation:
Koel, T. M., J. L. Arnold, P. E. Bigelow, P. D. Doepke, B. D. Ertel, and M. E. Ruhl. 2007. Yellowstone Fisheries & Aquatic Sciences: Annual Report, 2006. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, Wyoming, YCR-2007-04.

Title page art courtesy Mimi Matsuda. Inside back cover art courtesy Derek Rupert.

Front cover photo captions (left to right): NPS supervisory fisheries biologist Todd Koel and MSU fisheries restoration biologist Mike Ruhl apply rotenone to High Lake (photo by Jeff Arnold); westslope cutthroat trout from Geode Creek (photo by Derek Rupert); NPS fisheries technician Stacey Sigler on the gillnetting boat *Freedom* (photo by Noelle Tubbs). Back cover photo captions (left to right): NPS fisheries technician Brian Ertel on the upper Yellowstone River (photo by Todd Koel); Yellowstone cutthroat trout from the upper Yellowstone River (photo by Todd Koel); NPS water quality technician Jeremy Erickson and NPS Bighorn Canyon National Recreation Area natural resource program manager Cassity Bromley on the Gibbon River (photo by Jeff Arnold).

Facing page photo: Water quality crew lowers a probe into the Yellowstone River at Chittenden Bridge (photo by Jeff Arnold).

Contents

Background

Established 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 provide park visitors with fresh meals. Fish-eating wildlife, such as bears, ospreys, otters, and pelicans, were regarded as a nuisance, and many were destroyed as a result (Schullery 1997).

To supplement fishing and to counteract "destructive" consumption by wildlife, a fish "planting" program was established in Yellowstone. Early park superintendents noted the vast fishless waters of the park and asked the U.S. Fish Commission to "see that all waters are stocked so that the pleasure seeker can enjoy fine fishing within a few rods of any hotel or camp" (Boutelle 1889). The first fishes from outside the park were planted in 1889–1890, and included brook trout (*Salvelinus fontinalis*) in the upper Firehole River, rainbow trout (*Oncorhynchus mykiss*) in the upper Gibbon River, and brown trout (*Salmo trutta*) and lake trout (*Salvelinus namaycush*) in Lewis and Shoshone lakes (Varley 1981). The harvest-oriented fish management program accounted for the planting of more than 310 million native and non-native fish in Yellowstone between 1881 and 1955. In addition, from 1889 to 1956, 818 million eggs were stripped from the cutthroat trout of Yellowstone Lake and shipped to locations throughout the United States (Varley 1979).

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

Approximately 48% of Yellowstone's waters were once fishless (Jordan 1891), and the stocking of non-native fishes by park managers has had profound ecological consequences. The more serious of these include displacement of intolerant natives such as westslope cutthroat trout (*O. clarkii lewisi*) and Arctic grayling (*Thymallus arcticus*), hybridization of Yellowstone (*O. c. bouvieri*) and westslope cutthroat trout with each other and with non-native rainbow trout, and, most recently, predation of Yellowstone cutthroat trout by non-native lake trout. Over the years, management policies of the National Park Service have drastically changed to reflect new ecological insights (Leopold et al. 1963). Subsistence use and 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. Eighteen fish species or subspecies currently are known to exist in Yellowstone National Park; 13 of these are considered native (they were known to exist in


NPS PHOTO

U.S. Fish and Wildlife Service fisheries staff examining cutthroat trout netted from Yellowstone Lake in 1974.


NPS PHOTO

An estimated 72 million Arctic grayling eggs were shipped from the Grebe Lake Hatchery during 1931–1956.

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).*

...harvest regulations have been liberalized to encourage anglers to keep non-native trout caught in waters where they are causing harm to native cutthroat trout...

park waters prior to Euro-American settlement), and five are introduced (non-native or exotic; see Appendix i) (Varley and Schullery 1998).

A perceived conflict exists in the National Park Service mandate to protect and preserve pristine natural systems and provide for visitor use and enjoyment (NPS 2006). 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 catch-and-release requirement. Because the primary mission of Yellowstone's Fisheries and Aquatic Sciences Section (Aquatics Section) is the preservation of natural ecosystems and ecosystem processes, the program does not emphasize maintenance of established non-native fish stocks. In fact, harvest regulations have been liberalized to encourage anglers to keep non-native trout caught in waters where they are causing harm to native cutthroat trout or Arctic grayling. Aquatics Section activities are focused almost exclusively on the preservation of Yellowstone Lake cutthroat trout, the restoration of fluvial (stream-resident) populations of native trout, and the research and monitoring needed to support these critical activities.

Summary 2006

Preservation of Yellowstone Lake cutthroat trout continued to be one of the Aquatics Section's top priorities in 2006, when 60,116 non-native lake trout were killed, bringing the total killed from 1994 to 2006 to more than 198,000. However, the cutthroat trout population has yet to demonstrate a significant positive response. The number of upstream-migrating cutthroat trout counted at Clear Creek, one of the cutthroats' largest spawning tributaries, was only 489 during 2006 compared to 917 in 2005; 1,438 in 2004; 3,432 in 2003; and 6,613 in 2002. It was the lowest count at Clear Creek since annual counts were first recorded in 1945.

The number of upstream-migrating cutthroat trout counted at Clear Creek was only 489 during 2006...the lowest count at Clear Creek since annual counts were first recorded in 1945.

Cutthroat trout abundance within Yellowstone Lake has been monitored by an annual fall netting assessment since 1969. An average of 6.0 cutthroat trout were caught per net in 2006, the lowest cutthroat catch rate on record for this assessment. These data suggest only very limited survival of juvenile cutthroat trout (total length; TL <330 mm) in the lake from 1998 through 2002. That would explain the observed decline from 2002 to 2006 in young adult cutthroat trout (TL 330 to 420 mm), which normally make up the bulk of the spawning population. The reproductive potential and resiliency of this population is currently very low and, given the persistence of lake trout and other stressors, it is likely to remain that way for several more years.

The generous support of the Fisheries Fund Initiative of the Yellowstone Park Foundation has enabled us to move forward quickly on restoration of fluvial native trout populations. National Environmental Policy Act (NEPA) compliance was completed to initiate westslope cutthroat trout restoration in the East Fork Specimen Creek watershed, where a piscicide was used in Yellowstone for the first time in two decades. Although a treasured, native species outside the Madison/Gallatin drainage, Yellowstone cutthroat trout is considered non-native in High Lake, and genetic analysis has revealed that this subspecies has been interbreeding with and degrading downstream populations of westslope cutthroat trout. For this reason, the first phase of the restoration plan called for their chemical removal from High Lake, its inlet streams, and its outlet channel. The removal of the introduced Yellowstone cutthroat trout from High Lake was completed as planned. Our intention is to restock High Lake with pure-strain westslope cutthroat trout in July 2007 from two genetically pure westslope cutthroat trout populations that were verified in 2006.


NPS/NOELLE TUBBS

NPS fisheries technicians Phil Doepke and Ryan Kreiner on board the fisheries Freedom *removing lake trout from gillnets.*

We also finished prioritizing the watersheds in the park's northern range based on probability of success for Yellowstone cutthroat trout stream restoration. Reese Creek, Rose Creek, the Elk Creek complex, and Blacktail Deer Creek all provide excellent opportunities for re-establishment of genetically pure Yellowstone cutthroat trout populations. Rose Creek, given its proximity to the Lamar Buffalo Ranch, would also provide opportunities for public education and awareness activities regarding native trout issues in the park. Initiation of a NEPA process for restoring Yellowstone cutthroat trout to northern range stream systems is planned for late 2007 or early 2008.

The ecological health of the park's aquatic systems continues to be monitored intensively. The quality of the surface waters is monitored monthly at 12 fixed sites 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. A new emphasis is the assessment of potential impacts of piscicides on non-target species during native fish restorations. We monitored amphibians and aquatic invertebrates at High Lake during and after piscicide treatment in 2006. Additional post-treatment surveys in 2007 will allow for a much more complete understanding of rotenone's potential impacts. Several other watersheds with high probability of restoration success have also been surveyed, primarily on the park's northern range.

The Fly Fishing Volunteer Program, funded by the Yellowstone Park Foundation, continues to be an integral mechanism for communicating information and raising public awareness of issues facing Yellowstone's native fishes. This year 78 anglers from across the United States contributed over 1,400 hours to fisheries projects throughout the park. Data were gathered on Arctic grayling population dynamics, the genetic integrity of native cutthroat trout, and the presence/abundance of non-native brook trout.


NPS/JEFF ARNOLD

Transport of rafts, outboards, and other heavy equipment to High Lake by helicopter for restoration of westslope cutthroat trout.

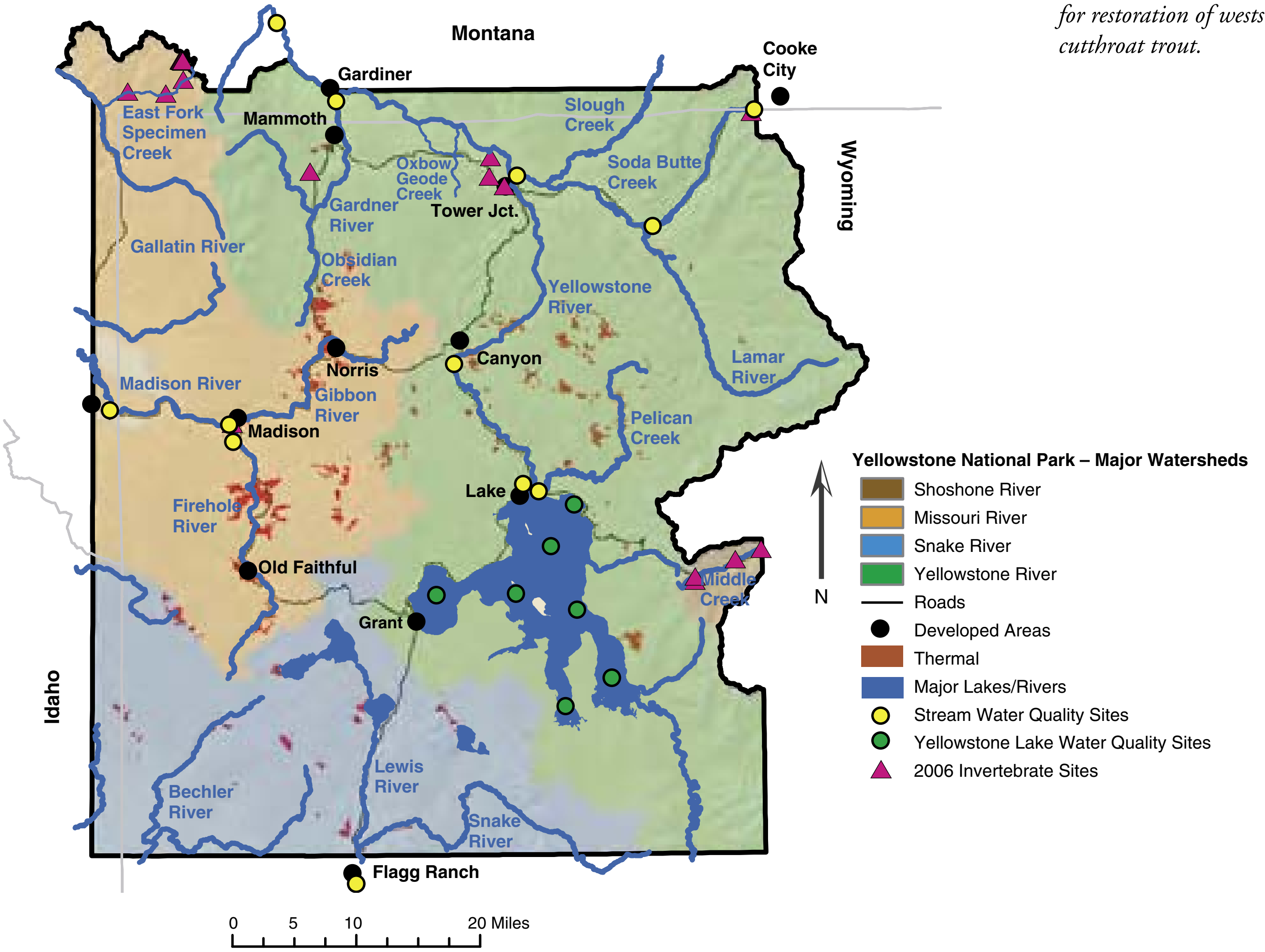


Figure 1. Major watersheds and surface waters of Yellowstone National Park, with sites established for long-term water quality monitoring on streams (12 sites–yellow circles) and Yellowstone Lake (7 sites–green circles). Areas sampled for aquatic invertebrates in 2006 (16 sites–purple triangles) are also shown.

The Fisheries Program

Primary Emphasis Areas

...the Aquatics Section will focus the greatest effort on its two main priorities: (1) preservation of cutthroat trout in Yellowstone Lake...and (2) restoration of fluvial populations of native trout...

Over the last decade, the aquatic resources of Yellowstone National Park and the ecosystems they support have been threatened by the presence of non-native (from elsewhere in North America) and exotic (from another continent) species. For the foreseeable future, the Aquatics Section will focus the greatest effort on its two main priorities: (1) preservation of cutthroat trout in Yellowstone Lake, which is the largest remaining concentration of genetically pure inland cutthroat trout in the world; and (2) restoration of fluvial populations of native trout, many of which have been lost because of non-native species introductions.

The lake trout suppression effort to preserve Yellowstone Lake cutthroat trout is one of the largest non-native fish removal programs occurring in the United States. Activities related to fluvial populations of native trout include westslope cutthroat trout restoration in the East Fork Specimen Creek watershed and prioritization of northern range streams based on their potential for Yellowstone cutthroat trout restoration.

NPS/TODD KOEL

Amphibians are now intensely studied due to the sensitivity of their larvae to piscicides used for cutthroat trout restoration. This boreal toad was one of a pair found near the High Lake outlet stream, at 8,500 feet elevation.

NPS/NOELLE TUBBS

NPS/TODD KOEL

The lake trout suppression (left) and the northern range restoration (right) programs are large efforts aimed at Yellowstone cutthroat trout conservation. These programs involve NPS staff, Montana State University staff, and Student Conservation Association and many other volunteers.

Preservation of Yellowstone Lake Cutthroat Trout

Yellowstone Cutthroat Trout Long-term Monitoring

Contemporary data suggest that a significant decline has occurred in the Yellowstone Lake cutthroat trout population. The number of upstream-migrating cutthroat trout counted at Clear Creek (Figure 2) was only 489 during 2006 (Figure 3) compared to 917 in 2005; 1,438 in 2004; 3,432 in 2003; and 6,613 in 2002. It was the lowest count at Clear Creek since annual counts were first recorded there in 1945. Fewer than 20 fish were counted on a daily basis and the migration peaked in mid-May. All of the captured cutthroat trout were longer than 400 mm and 56% were longer than 500 mm. Whether the large sizes observed represent very old cutthroat trout or rapidly growing younger fish will not be known until the scale samples have been analyzed. Although females outnumbered males by 3.7 to 1, less than 30% of them were ready to spawn. In contrast, all but one of the sampled males were classified as ripe spawners. Males were longer than females and typically weighed about 200 grams more.

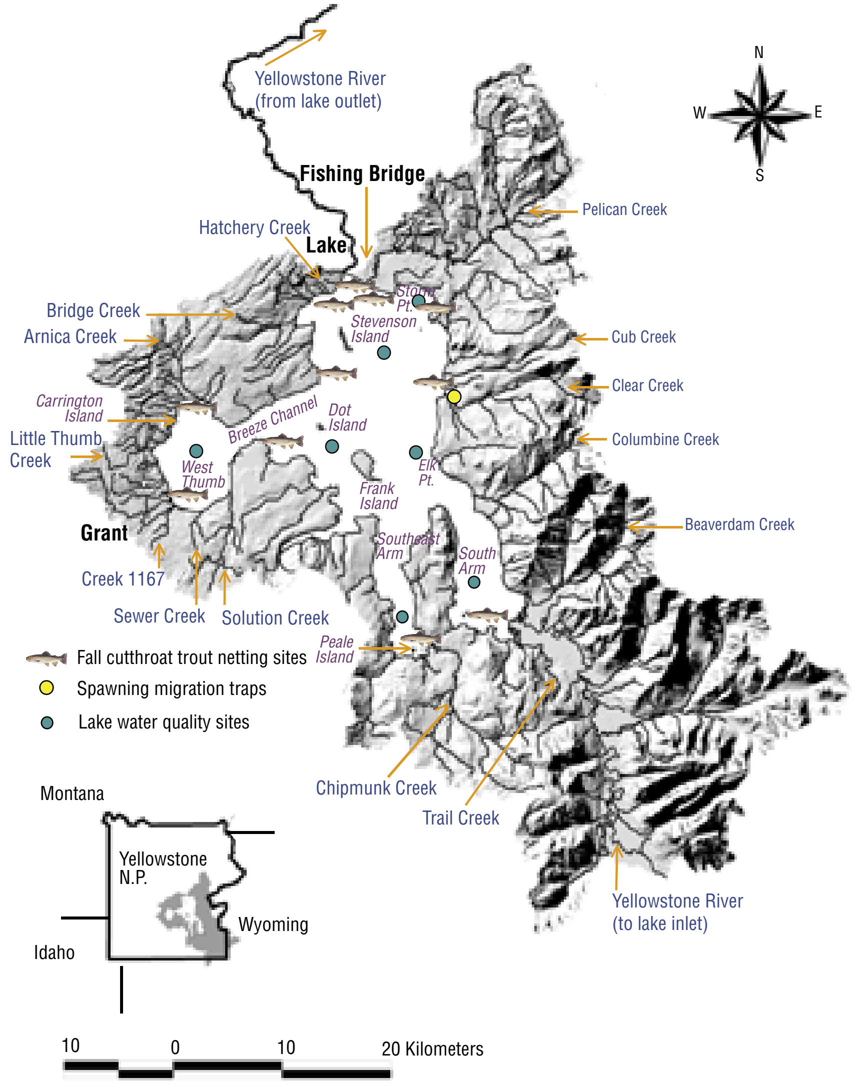


Figure 2. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

Yellowstone Lake's cutthroat trout population is also monitored by a fall netting assessment. Since 1969, multi-mesh-size gillnets have been set in shallow water at 11 sites throughout the lake. Typically, sampling has occurred during the third week in September; however, our 2006 assessment was delayed by two weeks and two of the sites were not sampled: Peale Island (in the South Arm) and Sand Point. The average number of cutthroat trout caught from the nine sites we sampled in 2006 was 6.0 per net, slightly lower than in previous years (Figure 3). These data suggest only limited survival of juvenile cutthroat trout from 1998 through 2002 (total length <330 mm; Figure 4).

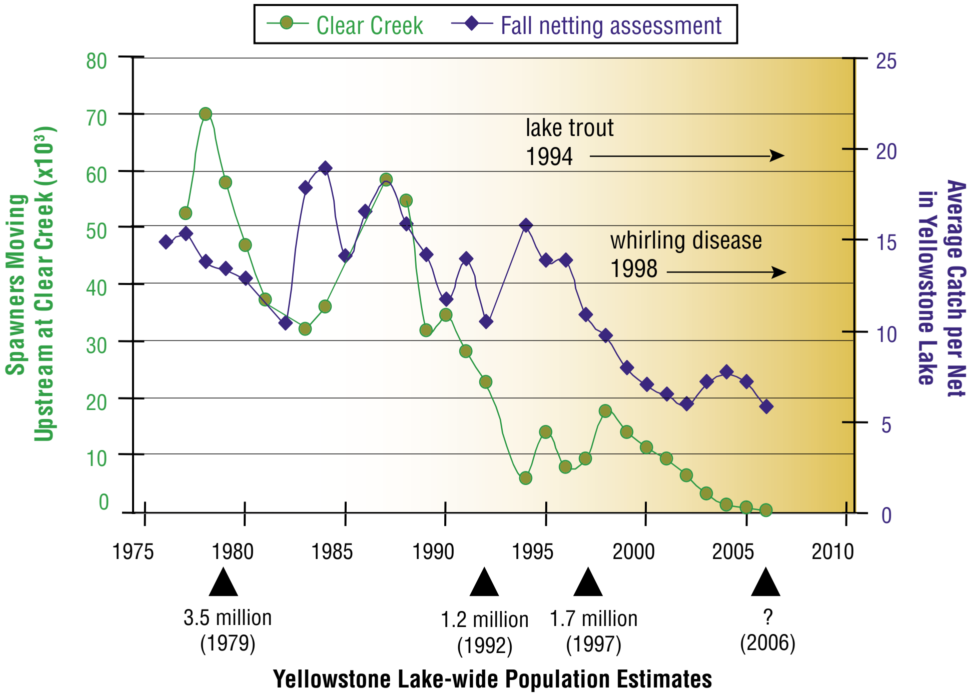


Figure 3. Total number of upstream-migrating cutthroat trout counted at the Clear Creek spawning migration trap and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake (1976–2006).

...evidence suggests that in terms of abundance, the loss of Yellowstone Lake cutthroat would be greater than a loss of all Yellowstone cutthroat trout from Idaho, Nevada, and Utah.

A subsequent decline has been observed from 2002 to 2006 in young adult cutthroat trout (TL 330 to 420 mm), which normally make up the bulk of the system's spawning population. Reproductive potential, and hence resiliency, of this population is currently very low, and it is likely to remain this way for at least several more years.

The loss of cutthroat trout from Yellowstone Lake is highly significant from both a park and range-wide perspective. Recently, Meyer et al. (2006) provided an estimate of 2.2 million Yellowstone cutthroat trout (all sizes) persisting in southeastern Idaho and the small portion of the subspecies' range in Nevada and Utah. On Yellowstone Lake, population estimates were made using mark-recapture during 1979 (Jones et al. 1980) and sonar technology during 1992 and 1997 (McClain and Thorne 1993; Ruzycki et al. 2003). Cutthroat trout abundance within the lake was approximately 3.5 million in 1979 (>350 mm length), but fell to 1.2 and 1.7 million (>100 mm length) in 1992 and 1997, respectively. No lake-wide estimates are available for the current population, but evidence suggests that in terms of abundance, the loss of Yellowstone Lake cutthroat trout over the past two decades would be equivalent to or greater than a loss of all Yellowstone cutthroat trout currently existing in Idaho, Nevada, and Utah.


NPS/STACEY SIGLER

NPS/DAN MAHONY

Clear Creek, a Yellowstone Lake tributary, on April 28 when the (historic) cutthroat trout spawning migration weir and trap was set up (left) and during peak runoff on May 23 (right).

Lake Trout and Whirling Disease Impacts Continue

In streams throughout the park and elsewhere in the Yellowstone cutthroat trout's natural range, populations have been compromised by introgression with non-native rainbow trout or other cutthroat trout subspecies (Kruse et al. 2000; Behnke 2002). The cutthroat trout of Yellowstone Lake and its associated drainage have remained genetically pure because of isolation provided by the Lower and Upper Falls of the Yellowstone River, located 25 km downstream from the lake outlet. The genetic purity of these fish makes them extremely valuable; however, the population has been exposed to three other stressors, including non-native lake trout (Kaeding et al. 1996), the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease; Koel et al. 2006b), and effects of a drought that recently persisted in the Intermountain West (Cook et al. 2004).

The presence of lake trout in Yellowstone National Park is the result of intentional stocking of the historically fishless Lewis and Shoshone lakes in 1890. Lake trout were illegally moved from Lewis Lake to Yellowstone Lake in the mid-1980s (Munroe et al. 2005; Stott 2004). Contemporary research points to non-native fish as the greatest threat to cutthroat trout of the Intermountain West (Dunham et al. 2004; Peterson et al. 2004a). 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 (Schullery and Varley 1995). In fact, bear activity has declined at Yellowstone Lake spawning streams since 1989 along with the loss of spawning cutthroat trout, revealing the cascading effects of lake trout and whirling disease (Figure 5; Koel et al. 2005).

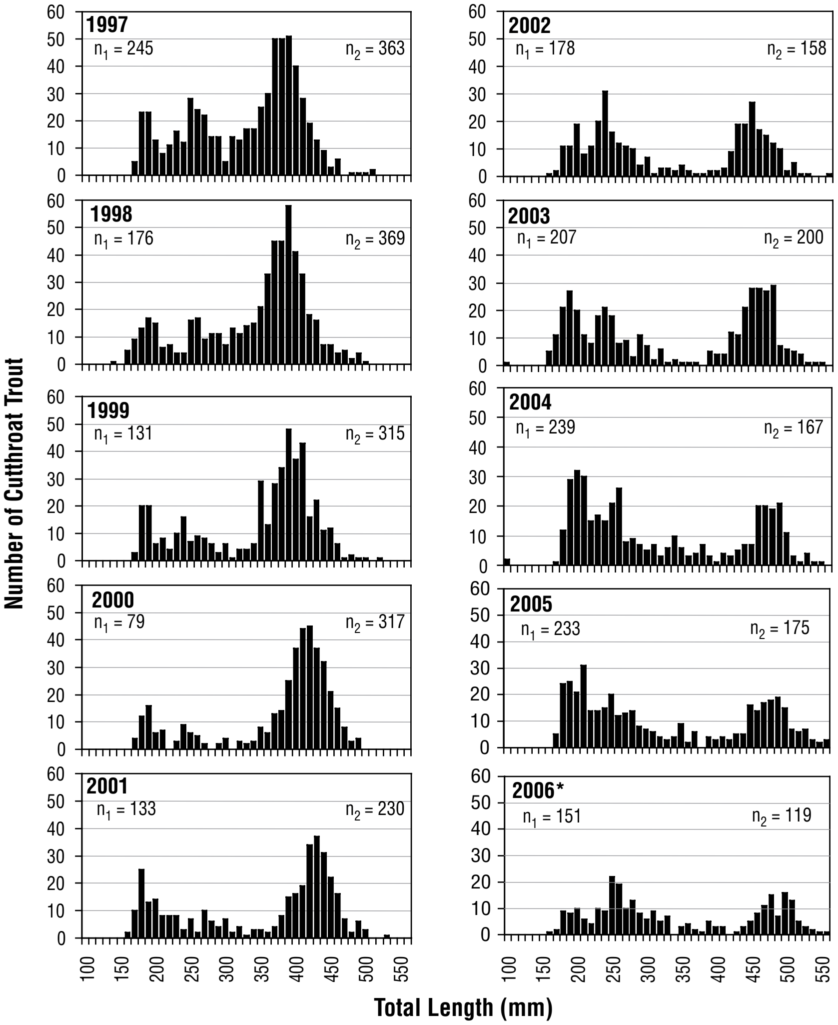


*Figure 4. Length-frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake with total number of trout <325 mm (n_1) and >325 mm (n_2), 1997–2006. * The 2006 assessment was delayed by two weeks and two of the sites were not sampled: Peale Island (in the South Arm) and Sand Point.*

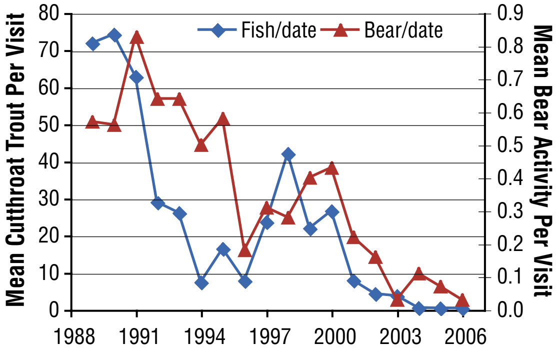


Figure 5. Mean number of cutthroat trout and mean activity by black bears and grizzly bears observed during weekly spawning visual surveys of 9–11 tributaries along the west side of Yellowstone Lake between Lake and Grant, 1989–2006.

Lake Trout Suppression Program

Lake trout suppression efforts on Yellowstone Lake have been ongoing for the past 12 years. A total of 60,116 lake trout were removed from Yellowstone Lake in 2006, which is more than during any previous year (Figure 6a); 59,035 by gillnetting and 1,075 by electrofishing. In 2006, the male-to-female ratio of the catch was 1.54:1 and females tended to be larger than males, with mean total lengths of 514.0 and 502.1 mm, respectively. Gillnetting effort continued at a high rate with a more than eight-fold increase over that conducted in 2000. As in past years, most of our effort occurred in the West Thumb area (Figure 7).

On a typical day between June and September, 8 to 14 miles of gillnet were set on Yellowstone Lake. Most of the effort was targeted at young lake trout residing at lower depths than those occupied by most cutthroat trout (control netting; Figure 6a). Small mesh (25–38 mm bar) gillnets were placed along the lake bottom in water typically 40–65 m deep. Lake trout carcasses are returned to the lake to avoid removing nutrients from the system and increase handling efficiency. The control netting removed 52,593 lake trout (87% of the total catch), and, for the second year in a row, the majority of this catch was in 25 mm bar mesh gillnets, the smallest size used (Figure 8). Lake trout catch also increased dramatically in the 32 mm mesh nets, but remained low in the 38 mm mesh. These increases in small mesh nets are likely indicators of successful spawning during 2003–05, when we noted large numbers of spawning-age lake trout (Koel et al. 2006a). Given the continued high numbers of spawning lake trout in our annual catch, high catch rates of young fish by control nets are expected during future years as well. Although steadily increasing over the last five years and a cause for concern, catch per unit effort (CPUE) for lake trout removed in 2006 (2.38) was still less than half that in 1998 (5.24).

Occasional bycatch of cutthroat trout is unavoidable but minimized by paying careful attention to net locations, mesh sizes, and depths. The majority of our nets (control) are set deeper than the cutthroat trout tend to reside. When we do need to set nets shallow, such as

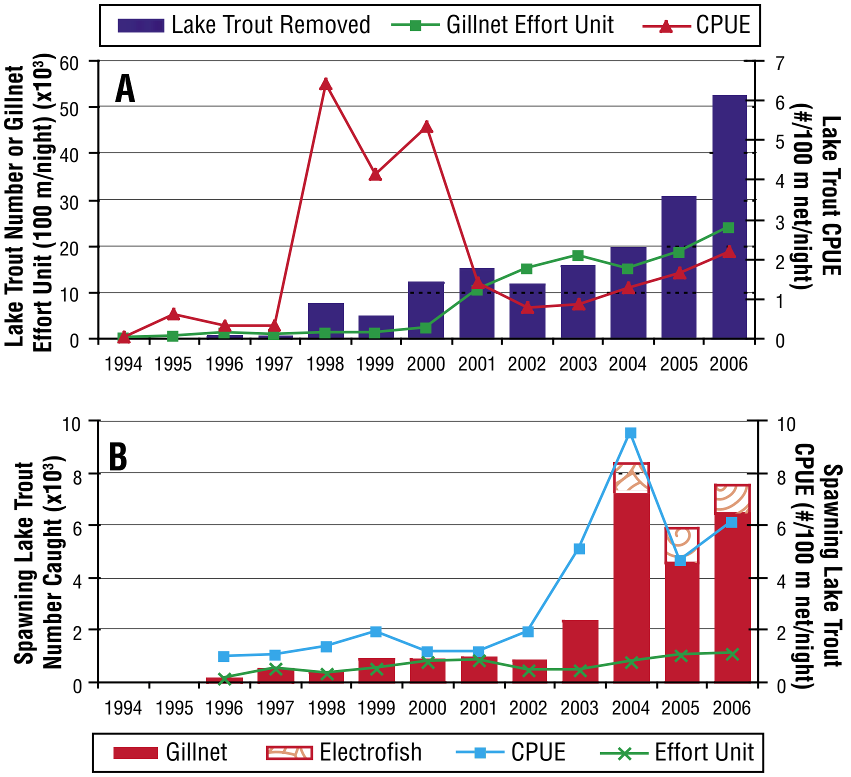


Figure 6. (A) Number of lake trout removed, gillnet units of effort (1 unit = 100 m of net/night), and lake trout catch per unit of effort obtained during the gillnetting season, 1994–2006. (B) Number and mean length of mature lake trout removed by gillnetting and boat-mounted electrofishing near Yellowstone Lake spawning locations (Breeze Channel, Carrington Island, Geyser Basin, and Solution Creek) late August–early October, 1996–2006.

NPS/JOE FACENDOLA

The NPS fisheries gillnetting boat Freedom *on Yellowstone Lake.*


NPS/PHIL DOEPKE

NPS fisheries technicians Stacey Sigler (left) and Rebecca Adams (right) setting gillnets from the fisheries munson Hammerhead *on May 18 due to early loss of ice from Yellowstone Lake in spring 2006.*

during the lake trout spawning season, we strive to tend them daily rather than weekly, so any cutthroat trout caught are more likely to survive. In 2006, for 38 and 32 mm gillnets, only 0.04 and 0.10 cutthroat trout were lost for every lake trout killed, respectively. However, the bycatch for 25 mm mesh gillnets was significantly higher at 0.33. This increase in the number of cutthroat trout caught in small mesh control nets is an indication that the subspecies may be on the rebound in this system.

Spawning Lake Trout

Lake trout in Yellowstone Lake congregate from late August until early October to spawn. Focusing on these larger lake trout is important to reduce both predation on cutthroat trout and the reproductive potential and recruitment of the lake trout population. Approximate locations of four spawning areas were targeted near Carrington Island, west of the mouth of Solution Creek, northeast of West Thumb Geyser Basin, and in Breeze Channel (Figure 9). An area just outside the Grant Village marina in West Thumb has proven productive as well. These areas were intensely netted during the spawning season using 38–76 mm bar mesh. Nets deployed in other areas throughout West Thumb and in a few areas in the main basin of the lake caught 6,442 lake trout (Figure 6b). Despite the greatest effort to date directed at these spawning areas, CPUE increased in 2006. The majority (76.6%) of lake trout caught by gillnets were in spawning (ripe) condition.

Electrofishing was used to remove lake trout from Yellowstone Lake for the third consecutive year. The shallow spawning area surrounding Carrington Island was electrofished during 14 nights in September and early October. In addition, we also located a previously unknown spawning site just north of Snipe Point, the first site to be documented in the main basin of the lake. Approximately 99% of the 1,075 lake trout

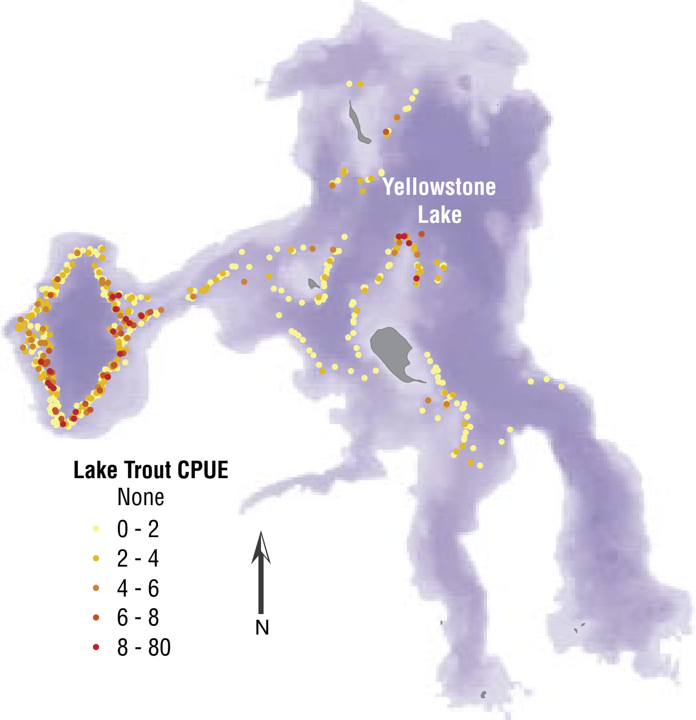


Figure 7. Catch per unit of effort (1 unit = 100 m of net set per night) for gillnets set on Yellowstone Lake, 2006.

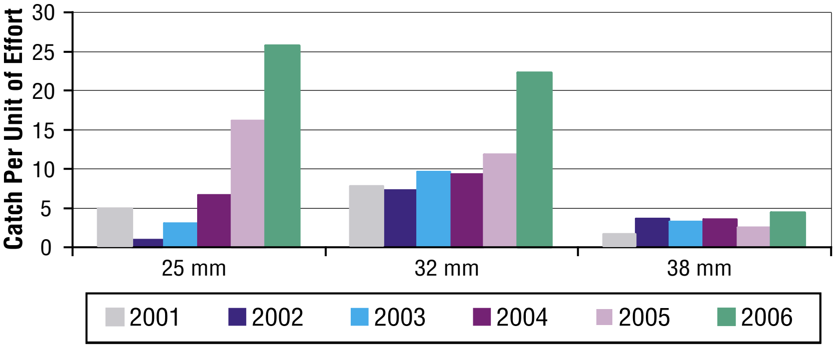


Figure 8. Catch per unit of effort (1 unit = 100 m of net set per night) by bar mesh size for control nets in Yellowstone Lake, 2006. The increase in catch for the smallest mesh used correlates well with recent increases seen in numbers of mature lake trout during spawning season, indicating strong recruitment.

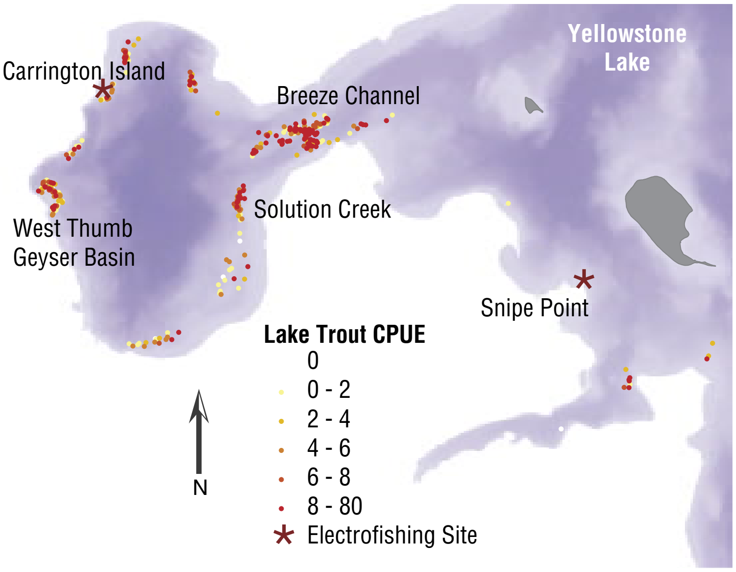


Figure 9. Catch per unit of effort (1 unit = 100 m of net set per night) for gillnets and locations of sites electrofished during the spawning season, 2006.

killed in shallow spawning areas by electrofishing were in spawning condition.

Lake Trout Growth Potential

Analysis of 370 otoliths (ear bones) from lake trout killed during the 2006 season indicates that the fish were 2 to 17 years old and ranged from 220 to 962 mm total length. Based on this information, an age-length key was applied to all 7,517 lake trout collected near spawning areas. Males accounted for 60.7% of this catch and ranged in age from 4 to 14 years; 68% were age 7 or less. Females ranged from 5 to 17 years; 70% were age 8 or less. Most lake trout caught near spawning areas were mature (86.3% of the males and 70.0% of the females).

The mean lengths of mature lake trout caught near spawning areas were similar to those in 2005: 554 mm for females (range 312–962 mm) and 520 mm for males (range 338–962 mm; Figure 10). Of the mature lake trout caught in the fall of 2006, a majority (59%) were "green," meaning they were captured before actually spawning, 39% were "ripe" (or gravid), and 2% were "spent" (had already spawned). Thus, 98% of these lake trout were removed before being able to spawn.

The oldest lake trout caught in 2006 was a 17-year-old female from Breeze Channel on September 19 in 20 m of water. The heaviest lake trout (ever removed from Yellowstone Lake) was a 24.25 lb female just short of a meter in total length (957 mm) from Breeze Channel on September 11 in 20 m of water. Lake trout are a long-lived species, yet less than 2% of the spawning lake trout population in Yellowstone Lake are more than 13 years old. Our age structure information indicates the population is a relatively young, exploited population, showing positive effects of the suppression effort. Many of the captured adults were likely attempting to spawn for the first time.

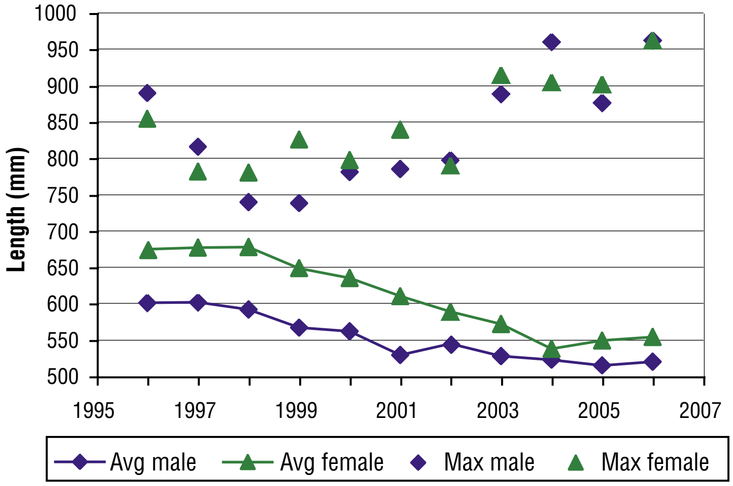


Figure 10. Average (Avg) and maximum (Max) length of mature male and female lake trout caught near spawning areas in Yellowstone Lake, 1996–2006.

WYOMING GAME AND FISH DEPT/MARK SMITH

Beth Bear, former NPS fisheries technician now Wyoming Game and Fish Department fisheries biologist, returned to Yellowstone Lake in September 2006 to assist with night electrofishing of spawning lake trout.

Restoration of Fluvial Populations of Native Trout

Specimen Creek Westslope Cutthroat Trout Restoration

This year marked an exciting milestone in native fish restoration in Yellowstone National Park. Plans to restore westslope cutthroat trout to the East Fork Specimen Creek (Figure 1) watershed received final approval through a National Environmental Policy Act (NEPA) process that resulted in a Finding of No Significant Impact (FONSI) on June 29, 2006 (Koel and York 2006; York and Koel 2006). The FONSI, coupled with other state and federal permits, authorized us to begin on-the-ground restoration activities during the summer of 2006. The multi-year plan calls for

NPS/TROY DAVIS

High Lake (7.1 surface acres) at the headwaters of East Fork Specimen Creek on June 5, 2006, showing locations of inlet streams (left), spring seeps (bottom center), and the outlet stream (right).

Plans to restore westslope cutthroat trout to the East Fork Specimen Creek watershed received final approval through a National Environmental Policy Act (NEPA) process...


NPS/TODD KOEL

Mike Ruhl (left), MSU fisheries restoration biologist, and Don Skaar, Fish Management Bureau Chief, Montana Fish, Wildlife and Parks, discuss logistics of rotenone treatment at High Lake.

the removal of all non-native and hybridized fishes from the East Fork Specimen Creek watershed, construction of a barrier to upstream fish movement in the lower reaches of East Fork Specimen Creek, and restocking the system with genetically pure westslope cutthroat trout.

High Lake, a 7.1-acre historically fishless lake, has supported a naturally reproducing population of Yellowstone cutthroat trout since it was stocked in 1937. Although a treasured, native species outside the Madison/Gallatin drainage, this subspecies is considered non-native in High Lake, and genetic analysis has revealed that these Yellowstone cutthroat trout have been interbreeding with and degrading downstream populations of westslope cutthroat trout. For this reason, the first phase of the restoration plan called for their chemical removal from High Lake, its inlet streams, and its outlet channel. An existing waterfall immediately downstream of the lake serves as a barrier to invasion by non-native and hybridized fish in East Fork Specimen Creek.


NPS/JEFF ARNOLD


NPS/JEFF ARNOLD

The rotenone treatment at High Lake, due to its remote location, required a large amount of logistical support provided by NPS staff from corral operations (top) and wildland fire (bottom).

Concerns regarding the efficacy of antimycin led us to choose two formulations of the EPA-approved piscicide rotenone for the High Lake treatments, a decision that proved to be fortuitous given that the high pH (9.4) in the lake at the time of treatment would have rendered antimycin totally ineffective. In total, 17.5 gallons of CFT Legumine and approximately 2 pounds of Prentox powder were applied to the lake and its associated waters between 0700 and 1500 hours on treatment days. Two 14-foot rafts equipped with 25 hp outboard motors applied the bulk of the liquid rotenone using Venturi boat bailer pumps and 80 gallon collapsible tanks. Liquid rotenone was also applied to the littoral portions of the lake and inlet streams using backpack sprayers and drip buckets. Powdered rotenone was mixed with sand and unflavored gelatin and applied to springs and seeps. Based on bathymetric measurements and the amount of rotenone applied, we estimated the active rotenone concentration in the lake to be 50 parts per billion (ppb). Fish collections on the treatment day and the two weeks following yielded 699 mortalities (Figure 11). Following the first treatment, daily visual surveys of the lake and its inlet streams did not detect any live fish, nor were any observed after an identical treatment

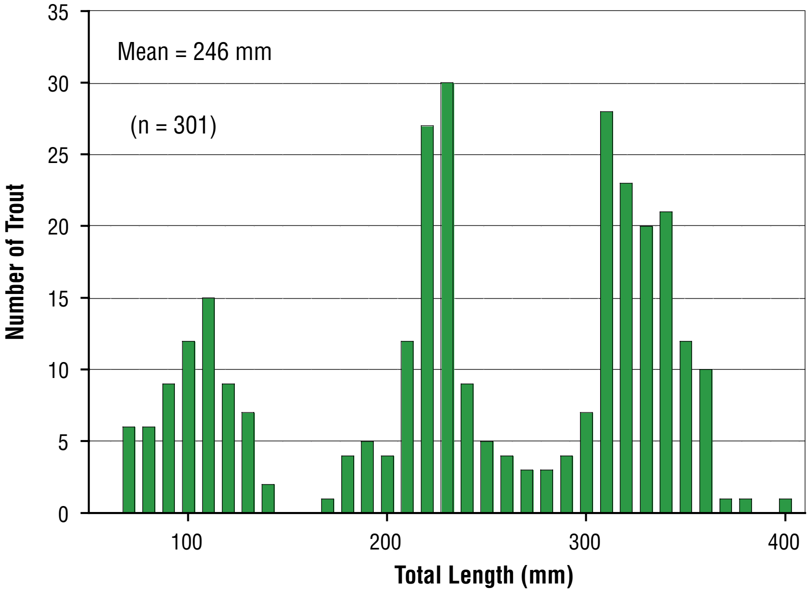


Figure 11. Length-frequency distributions of Yellowstone cutthroat trout collected from High Lake following treatment with rotenone during August 2006.


NPS/MIKE RUHL


NPS/JEFF ARNOLD


NPS/JEFF ARNOLD


NPS/JEFF ARNOLD


NPS/TODD KOEL


NPS/TODD KOEL


NPS/TODD KOEL


NPS/TODD KOEL

At High Lake during 2006. Top: Student Conservation Association (SCA) volunteer Derek Rupert (left) and NPS water quality technician Hunter Hutchinson (right) conduct piscicide bioassays; SCA volunteer Derek Rupert (left) and MSU fisheries restoration biologist Mike Ruhl (right) prepare a raft for applying rotenone. Middle: NPS supervisory fisheries biologist Todd Koel (left) and MSU fisheries restoration biologist Mike Ruhl (right) apply rotenone; potassium permanganate ($KMnO_4$) detoxification station at waterfall downstream of the lake outlet. Bottom: Camp set up during the month of August; mixing to create rotenone sand on the evening prior to first treatment; NPS fisheries technician Brian Ertel applying rotenone to vegetated areas using a backpack sprayer; NPS aquatic ecologist Jeff Arnold examining stream invertebrates between High Lake and the $KMnO_4$ detoxification station.

was conducted two weeks later. Post-treatment placement of gillnets throughout the lake did not capture any fish, indicating complete removal was likely achieved.

A fish barrier constructed mostly of logs and other natural materials will be placed in East Fork Specimen Creek…

To prevent the rotenone from spreading into East Fork Specimen Creek, a neutralization station was set up immediately downstream of the High Lake outlet waterfall that dispensed potassium permanganate ($KMnO_4$) into the water leaving High Lake. Rotenone is readily oxidized by $KMnO_4$, thus neutralizing its toxic effect. Most of the effort expended at High Lake involved maintenance of the neutralization station, which was monitored 24 hours a day for 22 days, from the first day of treatment until the rotenone levels in High Lake were no longer toxic to fish. Fish were placed in cages at locations ½ hour and 1 hour flow travel time downstream of the station and observed to ensure complete neutralization of the toxin. The fish at the 1 hour locations showed no signs of stress throughout the High Lake operations and, after initial adjustments following the first treatment, fish survived at the ½ hour locations as well. High Lake operations ended on September 3, 2006.

Since gillnets left in place over the 2006–07 winter season did not catch any fish, a third treatment tentatively scheduled for summer of 2007 is deemed unnecessary and westslope cutthroat trout introduction efforts to the lake and its inlet streams will begin. A fish barrier constructed mostly of logs and other natural materials will be placed in East Fork Specimen Creek and bioassays will be conducted to determine the background demand for rotenone during August flow and thermal conditions and the amounts of rotenone to be used during full-scale treatment of the creek in 2008.


NPS/TODD KOEL

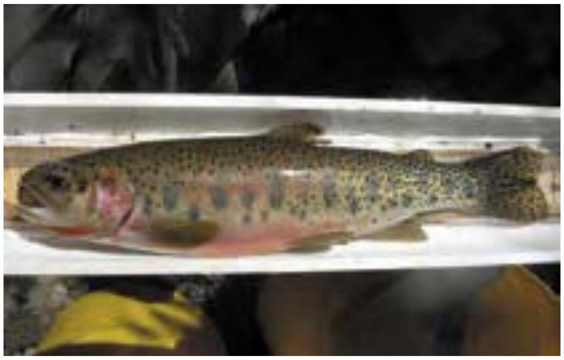
A fish barrier will be constructed at this site on the downstream reach of East Fork Specimen Creek to prevent invasion of the restoration area by non-native rainbow trout located downstream in the mainstem Specimen Creek and the Gallatin River.

Westslope Cutthroat Trout Discovered in Oxbow-Geode Creeks

In August 2005, we located a previously unknown cutthroat trout population in Oxbow Creek upstream of Blacktail Plateau Drive (Figure 1). What made our discovery noteworthy was the phenotypic appearance of the fish, as they did not have color patterns typical of the native Yellowstone cutthroat trout. Instead, the fish more closely resembled westslope cutthroat trout, an observation that was corroborated through analysis of photographs by Dr. Robert Behnke.

Following review of historical records, it was clear that further investigations into Oxbow Creek were necessary. The creek enters a large wetland complex prior to diverging into two distinct streams above (south of) the Grand Loop Road: Oxbow Creek, which exits the wetland complex flowing west toward Phantom Lake carrying only a fraction of its original flow; and Geode Creek, which flows north out of the wetland complex and carries a majority of Oxbow Creek's flow. Because of their hydrologic connectivity, we consider the two streams a single unit upstream of the Grand Loop Road and refer to this portion of the system as the Oxbow/Geode Creek complex.

The Oxbow/Geode Creek complex appears to be isolated from the Yellowstone River by a road culvert on Geode Creek and by the subterminal nature of Oxbow Creek in the vicinity of Phantom Lake. According to published stocking records, Geode Creek was



Genetically pure westslope cutthroat trout from Geode Creek, a tributary of the Yellowstone River.

stocked with “cutthroat trout” for three years starting in 1922 (Varley 1981). The records do not provide information concerning the hatchery or brood source of the fish, or the exact locations of the stockings, but it appears that these introductions were the source of the fish now found in the system. Surveys conducted in 2006 on two stream reaches upstream of Blacktail Plateau Drive yielded estimates of 121 and 176 fish/100 m, with an overall mean length of 118 mm (Figure 12). Given the streams’ small sizes and high fish densities, the system appears to be highly biologically productive. The cutthroat trout downstream of Grand Loop Road on Geode Creek appeared to have similar phenotypic characteristics, but were larger on average (mean TL = 156 mm; Figure 12).

Geode Creek continues downstream of the Grand Loop Road to its confluence with the Yellowstone River, but it is suspected that a definitive barrier to fish immigration from the river exists in its lower reaches where the stream rapidly descends through bedrock cascades. Little is known about the reaches of Oxbow Creek downstream of the Grand Loop Road except that no surface flow has been evident within several hundred meters of the road. This indicates that the small amount of water entering Phantom Lake from the upper reaches of the system either becomes subterranean or evaporates. Further study of Oxbow and Geode creeks’ downstream reaches will be completed in 2007.

Independent analyses by fish genetics laboratories in Idaho and Montana have confirmed the genetic purity of the westslope cutthroat trout in the Oxbow/Geode Creek complex. The discovery of this pure population in a location with quick and easy access has exciting implications for westslope cutthroat restoration. The abundance and spatial extent of fishes here will enable us to move large numbers of fish or gametes to restored habitats elsewhere; densities of westslope cutthroat trout in the Oxbow/Geode Creek complex are far greater than those in any other known population in the vicinity of the park.

Sampling efforts in 2007 on the Oxbow/Geode Creek complex will focus on delineating

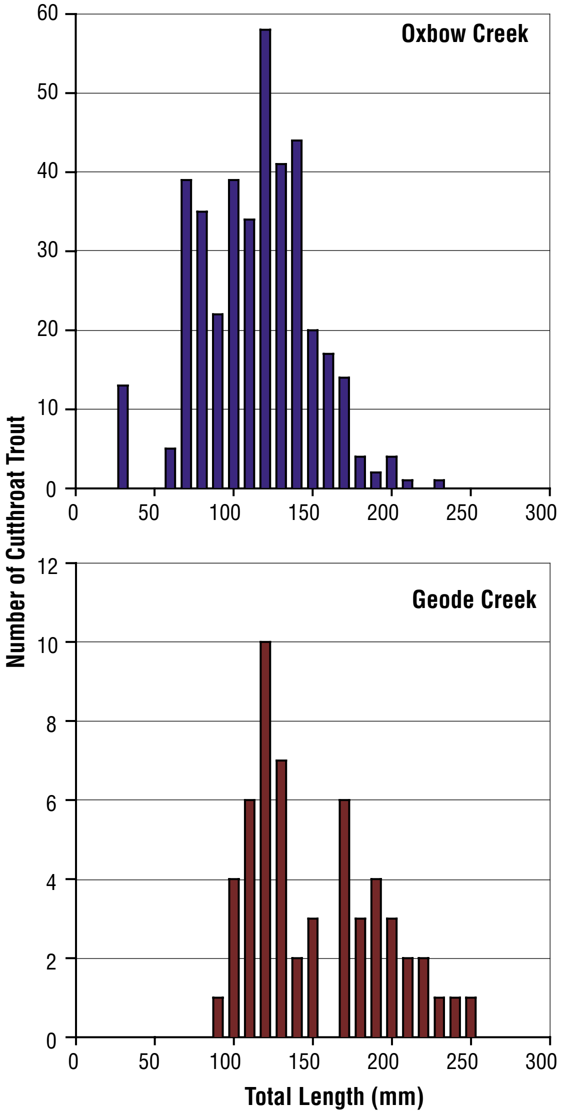


Figure 12. Length-frequency distributions of westslope cutthroat trout from Oxbow and Geode creeks, 2006.

Independent analyses by fish genetics laboratories in Idaho and Montana have confirmed the genetic purity of the westslope cutthroat trout in the Oxbow/Geode Creek complex.


NPS/MIKE RUHL

Genetically pure westslope cutthroat trout from Last Chance Creek, a tributary of Grayling Creek and the Madison River (Hebgen Reservoir) drainage.

physical barriers to upstream fish movement into the system from the Yellowstone River, finalizing population estimates, and documenting the uppermost extent of westslope cutthroat trout in the system. Plans are also being made to move juvenile and adult fish from this population into High Lake in July 2007 for the rapid establishment of a westslope cutthroat fishery.

The Last Chance Creek genetically pure westslope cutthroat trout have great potential as a source population for restoration projects…

Westslope Cutthroat Trout Persist in Last Chance Creek

During the summer of 2005, we received information about a previously undocumented westslope cutthroat trout population in a tributary of Grayling Creek (Koel et al. 2006a) that was subsequently named *Last Chance Creek* (Figure 13). It was visited on several occasions in 2006 to collect fish for health and genetic analysis and observe and document spawning activity. Analyses by fish genetics laboratories in Idaho and Montana have concluded that these westslope cutthroat trout are genetically pure. In addition, no pathogens were detected in these fish.

The Last Chance Creek genetically pure westslope cutthroat trout have great potential as a source population for restoration projects, especially for our current project at High Lake and East Fork Specimen Creek. Plans also include the incorporation of gametes from these fish into the upper Missouri River westslope cutthroat trout broodstock at the Sun Ranch near Ennis, Montana.


NPS/TODD KOEL


NPS/TODD KOEL

A series of steep cascades located on lower Elk Creek (top) were found by electrofishing (bottom) to have both brook trout and cutthroat trout downstream of them, but only brook trout upstream of them. This feature is thought to preclude access of fish to the system from the Yellowstone River.

Yellowstone Cutthroat Trout Restoration on the Northern Range

Analyses completed during 2005 and 2006 indicated that Rose Creek and the Elk Creek complex of streams (Elk, Lost, and Yancey creeks) offer the highest probability of Yellowstone cutthroat trout restoration success (Ruhl and Koel 2007). These streams (Figure 13) were further investigated in 2006 to gain additional insight into fish distribution and the locations and effectiveness of existing barriers. Sampling was conducted above and below a series of steep cascades on lower Elk Creek. Both brook trout and cutthroat trout were captured downstream of the cascades, but only brook trout were captured above it. This indicates that the cascades may preclude upstream movement of fish into the system from the Yellowstone River. Future work in the area will focus on tagging fish below the cascades and then sampling above it to determine if fish can move through this feature.


NPS/TODD KOEL

The lower Elk Creek watershed (near), Yellowstone River canyon (middle), and Hellroaring Creek region (distant).

An advantage of initiating cutthroat trout restoration on Rose Creek is its proximity to the Lamar Buffalo Ranch. Investigations conducted in 2006 located four culverts under the highway at the ranch, only three of which carried water from Rose Creek. Most of the flow passes through the most eastern channel of the creek, which contains a concrete structure that appears to be an old irrigation diversion. The presence of spawning trout from the Lamar River in Rose Creek upstream of the culverts indicates that they are passable by fish.

Assessing the genetic status of streams across the northern range is one of the most important aspects of this restoration initiative.

Analyses completed during 2005 and 2006 indicated that the Rose Creek and the Elk Creek complex of streams (Elk, Lost, and Yancey creeks) offer the highest probability of Yellowstone cutthroat trout restoration success.

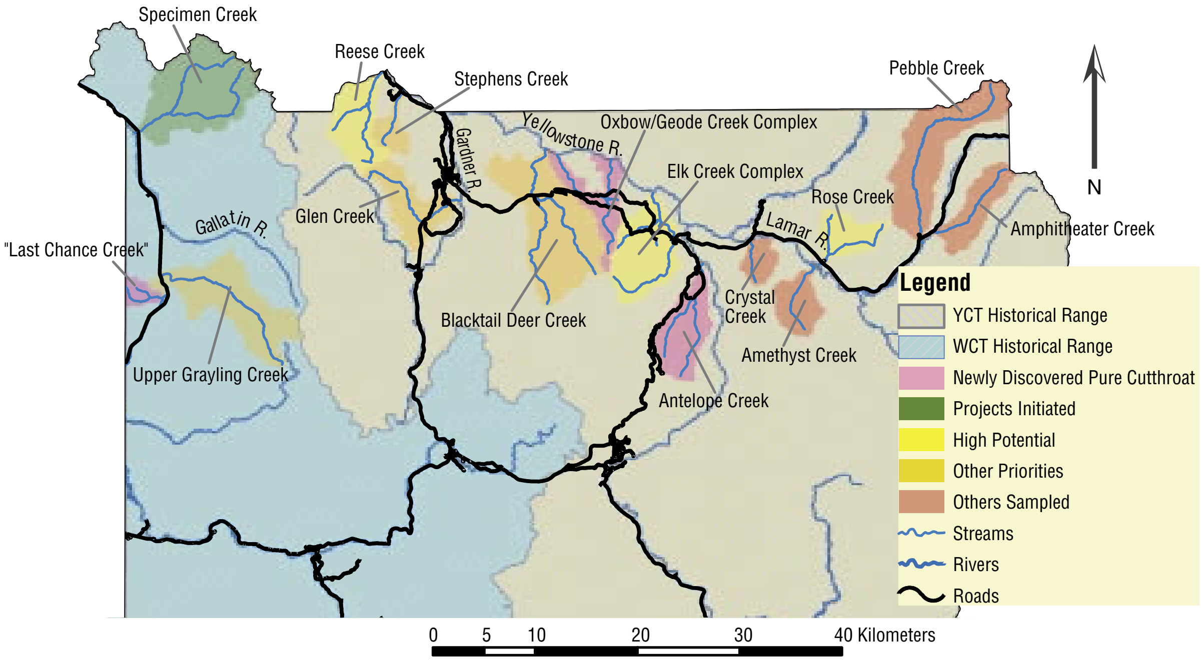


Figure 13. Watersheds in the northern regions of the park that are within the historical range of westslope cutthroat trout (WCT) and Yellowstone cutthroat trout (YCT). Locations with a high probability for successful cutthroat trout restoration and watersheds where genetically pure cutthroat trout have recently been found are also indicated.

Analysis of samples collected in 2005 and 2006 have contributed significantly to our knowledge of the genetic status of Yellowstone cutthroat trout in northern range streams. This includes confirmation of genetically pure Yellowstone cutthroat trout in Antelope Creek, identification of Rose Creek as a site of ongoing hybridization between rainbow trout and Yellowstone cutthroat trout, and discovery of a pure population of westslope cutthroat trout in the Oxbow/Geode Creek complex. Amphitheater Creek, Crystal Creek, Reese Creek, and Stephens Creek were also shown to support hybridized populations of Yellowstone cutthroat trout.

History of Fluvial Grayling Restoration in Yellowstone

Fluvial Arctic grayling, along with westslope cutthroat trout and mountain whitefish, are native fish that once thrived in the Gibbon River below Gibbon Falls and the lower Firehole and Madison rivers of Yellowstone National Park (Jordan 1891). However, construction of Hebgen Reservoir and introduction of non-native brown trout resulted in the apparent extirpation of both grayling and westslope cutthroat trout from the Firehole and Madison rivers (Kaya 2000). The Gibbon River, Grebe and Wolf lakes, and Cascade Lake (in the Yellowstone River drainage near Canyon), are the only park waters that currently support Arctic grayling. We know from historical records that lacustrine (lake-dwelling) grayling were first stocked in Grebe Lake in 1921 as fry from the Montana State Fish Hatchery in Anaconda. These fish originated from fluvial grayling then found in two Madison River tributaries near Ennis Lake, via Georgetown Lake (Kruse 1959; Varley 1981; Varley and Schullery 1998). The introduced Grebe Lake grayling flourished, and a hatchery established there shipped out an estimated 72 million eggs from 1931 to 1956, which were the source of most stocks found today in the western United States (Varley 1979).


BILL VOIGT

Remaining Arctic grayling of the Gibbon River system were found to have a lacustrine (lake-dwelling) ancestry.

Efforts to restore fluvial Arctic grayling in the region began in 1975 (Varley et al. 1976). Following construction of an artificial barrier and chemical removal of introduced brown trout, attempts were made to reintroduce grayling to Canyon Creek, a tributary of the Gibbon River below the falls, using a variety of methods, including: (1) the 1976 stocking of age-1 fish of Grebe Lake origin; (2) the 1976 direct transplant of adults/juveniles from the Big Hole River; (3) the 1977 placement of eyed-eggs from an outlet stream of Deer Lake, Montana, into tributary springs using "Vibert-type" boxes; (4) the 1978 stocking of age-0 fry from Red Rocks Lake, Montana; and (5) the 1980 stocking of age-0 fry from Meadow Lake, Wyoming.

The grayling eventually disappeared from the Canyon Creek restoration area, likely through downstream drift into the Gibbon and Madison rivers, but the pioneering restoration work provided some insights into the fluvial grayling's habitat requirements, and many questions were raised regarding the most useful stocks and methods for successful reestablishment of this species.

Another restoration attempt began in 1993 on Cougar Creek, a tributary to Duck Creek (Madison River drainage; Kaeding et al. 1994), which was chosen because of its physical isolation from adjacent streams by subsurface flows at its downstream end (Jones et al. 1979). Using progeny of fish from the Big Hole River, Cougar Creek was stocked with approximately 800 age-0 and age-1 fluvial Arctic grayling each year, 1993–1995, at densities of 50 fish per stream kilometer (Kaeding et al. 1995). However, no grayling could be found in Cougar Creek by electrofishing crews in 1998.


NPS/COLLEEN BLAINE

Montana State University graduate research assistant Amber Steed (right), NPS fisheries technician Chris Romankiewicz (left) and crew using raft-mounted electrofishing gear to search for fluvial (river-dwelling) Arctic grayling in the Gibbon River.

...we have no reason to believe that a truly fluvial Arctic grayling population remains in Yellowstone National Park.

Results of Grayling Research on the Gibbon River System

Although adult grayling are occasionally caught by anglers in several reaches of the Gibbon River proper (Koel et al. 2005), the 1970s introductions in Canyon Creek and the continued persistence of lacustrine grayling in headwater lakes have confounded our ability to determine whether a viable fluvial population persists in the Gibbon River system. To address this question, the park initiated research in 2005 with the U.S. Geological Survey's Montana Cooperative Fishery Research Unit (Koel et al. 2006a). Methods used in 2006 to assess the status of fluvial grayling included (1) tagging adult grayling; (2) surveying for spawning grayling during May, June, and July; (3) trapping fry from May through September; (4) estimating grayling densities; and (5) relating grayling spatial dynamics to thermal and flow characteristics (Steed 2007). Sampling techniques included backpack and raft electrofishing, snorkeling, fry trapping, and fly fishing. Twelve grayling were collected by fly fishing and electrofishing in 2006 compared to sixteen in 2005. Grayling were also observed on three occasions during snorkel surveys conducted July through September. Similar to 2005, no grayling were caught in fry traps set at locations spanning the length of the Gibbon River. Spawning by grayling within the river itself, which would strongly suggest a fluvial life history strategy, was not documented by this study.

Molecular techniques provide another way to clarify the origin and possible uniqueness of grayling in the Gibbon River. The Big Hole River population, one of the few extant fluvial grayling populations in southwest Montana, has been shown to be genetically distinguishable from other lacustrine populations in the region, including the fish of Grebe Lake (Everett and Allendorf 1985; Kaya 1991, 1992). High resolution genetic analyses conducted in 2006 suggest that the grayling below Gibbon Falls are genetically similar to those from the Grebe and Wolf lakes area at the system's headwaters (Steed 2007). Because of this, and the lack of any other physical or behavioral evidence to suggest that grayling reproduce within the Gibbon River proper, we have no reason to believe that a truly fluvial Arctic grayling population remains in Yellowstone National Park.

Wilderness Fisheries of the South

Status of Cutthroat Trout in the Upper Yellowstone River

Yellowstone cutthroat trout in the upper Yellowstone River (mainstem), were surveyed in September 2006. We selected 42 sample sites by dividing the river into 1 km sections starting at the park's south boundary and working downstream to Yellowstone Lake. Each 1 km section was subdivided into two 500 m sections, and we then randomly chose one of the two sections to sample (Figure 14). Fish in each section were sampled using both underwater census and electrofishing. For the underwater census, three snorklers spaced to cover the entire stream width as best as possible drifted downstream, identifying and counting fish, and assigning cutthroat trout to one of five categories based on total length. Electrofishing surveys were conducted using a 16-foot raft that followed the snorklers by a minimum of 30 minutes to allow fish to redistribute if displaced by the snorklers. Fish were marked with one of four clips depending on capture location and each section was electrofished again approximately 10 days later to provide recapture data for abundance estimates.

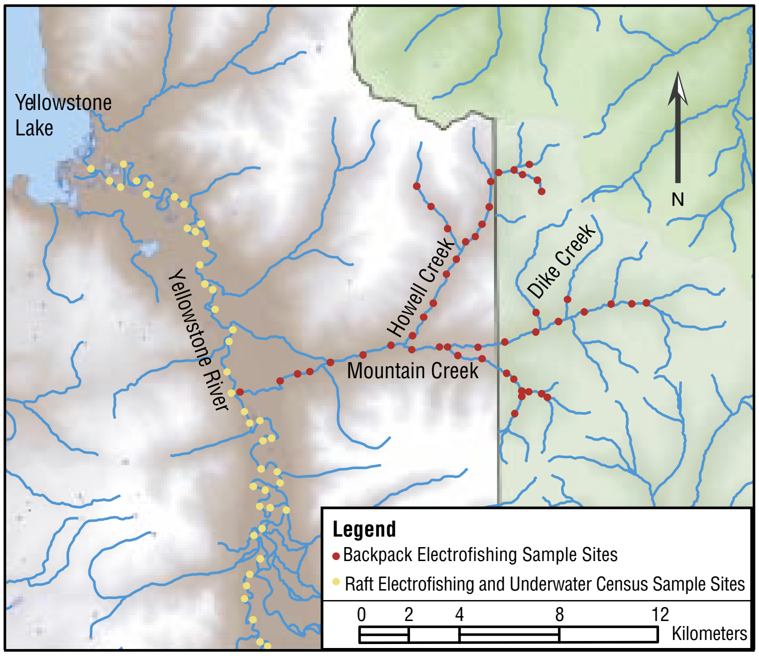


Figure 14. Sites in the upper Yellowstone River drainage surveyed for cutthroat trout by electrofishing and/or snorkeling (underwater census) in 2006.

NPS/HALI KIRBY-ERTEL

NPS/BRIAN ERTEL

NPS fisheries technician Brian Ertel and crew surveyed the upper Yellowstone River in September 2006 using raft-mounted electrofishing gear (shown above) and underwater census (snorkeling).

We located few fish during underwater census and electrofishing surveys. Adult fish were found in low numbers throughout the river except for the last 5 km above the mouth at Yellowstone Lake, where only a few juveniles were captured. Adults were mainly captured in deep water areas often associated with tributary entry points to the mainstem. Juveniles were located in stream margins and macrophyte (vegetation) beds. Similar data on total cutthroat trout sampled and size class distribution were obtained from the electrofishing and snorkel surveys conducted during the mark run (Figure 15). A total of 125 cutthroat trout were counted during the underwater census surveys and 130 fish were captured in the 42 sampling sites during our initial electrofishing run. During the second electrofishing survey, 71 fish were captured in 39 sites; none were marked.

Surveys using a battery-powered backpack unit to make a single electrofishing pass took place in Mountain and Howell creeks and their

NPS/TODD KOEL

View looking east across the upper Yellowstone River valley (foreground) and into the Mountain and Howell creek watersheds (distant).

tributaries in 2006. We divided each creek into 1 km sections and each km into ten 100 m sections, and randomly selected one of the 10 sections to sample (Figure 14). All fish collected were measured and weighed, and scales for aging and fin clips for genetic analysis were collected from a sub-sample of cutthroat trout in each stream. Similar surveys had been performed in previous field seasons in Trappers, Cliff, and Phlox creeks and an unnamed tributary to the Yellowstone River, as well as in portions of Mountain and Howell creeks (Koel et al. 2006a). In 2006 a total of 421 cutthroat trout were sampled in 49 study sections of the Mountain Creek drainage. Fish ranged from 30 mm to 305 mm in total length (Figure 15), but larger fish were found only in the upper reaches of the drainage. The wide range of size and age classes suggests that stream-resident Yellowstone cutthroat trout populations persist in the upper Yellowstone River drainage and that the river is also used as a spawning stream by cutthroat trout migrating from Yellowstone Lake. Further analyses of the age structure of the larger headwater fish collected will help to confirm if this area contains a self-sustaining resident population.

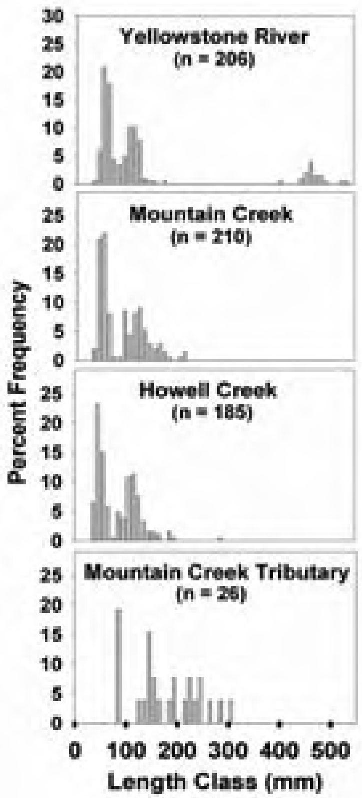


Figure 15. Length-frequency distributions of Yellowstone cutthroat trout collected from the upper Yellowstone River between the park's south boundary and Yellowstone Lake, Mountain Creek, and two major tributaries to Mountain Creek.

Stream-resident Yellowstone cutthroat trout populations persist in the upper Yellowstone River drainage...

Analysis indicates that cutthroat trout in the upper Yellowstone River are very similar to those that spawn in other tributaries of Yellowstone Lake. This being the case, the upper Yellowstone River most likely makes a large contribution to the overall Yellowstone Lake population. Possible resident fish located in the upper Mountain Creek watershed could be important to the long-term survival of the subspecies within the Yellowstone Lake ecosystem. They are isolated from the lake trout that plague the cutthroat trout returning to Yellowstone Lake and they may be less affected by the drought conditions impacting other spawning tributaries, especially the smaller ones.

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 and exotic invading species displace precious native species, such as cutthroat trout and many native macroinvertebrates upon which Yellowstone fishes depend for growth and survival. AIS also have the potential to impact important trout consumers such as eagles, ospreys, and grizzly bears, causing a disruption of the Greater Yellowstone Ecosystem.

The New Zealand mud snail (*Potamopyrgus antipodarum*; Richards 2002; Hall et al. 2003; Kerans et al. 2005) and the parasite that causes whirling disease (*M. cerebralis*) in trout (Koel et al. 2006b; Koel et al. 2007) are already present in park waters. The zebra mussel and Eurasian watermilfoil are quickly approaching the park from elsewhere in the United States, and there are more than 300 other AIS now in North America—often so small they are difficult to see (<http://nas.er.usgs.gov>). AIS frequently "hitchhike" unnoticed from one lake or stream to another in the water of a boat bilge or live well, or in mud, dirt, sand, and plant fragments attached to boats, fishing equipment, or clothing. Prevention is key because, once introduced and established in park waters, AIS are virtually impossible to remove.

The park placed high priority on AIS prevention in 2006. Staff were assigned to contact boaters and anglers to increase awareness of the issue (Fey et al. 2006). While many of the 828 visitors contacted had boats and equipment that were cleaned prior to coming to the park, 387 (47%) had equipment considered unclean.

The purpose of the long-term water quality program is to acquire baseline information for Yellowstone's surface waters that can be used to evaluate overall ecosystem health...

NPS/CATHY JEAN

NPS aquatic ecologist Jeff Arnold (right) checks stream discharge while NPS water quality technician Jeremy Erickson (left) and NPS Bighorn Canyon NRA natural resource program manager Cassity Bromley sample invertebrates from the Gibbon River.

NPS/JEFF ARNOLD

NPS water quality technician Hunter Hutchinson takes a sample from the Vital Signs Monitoring Program water quality site on the Lamar River.

Long-term Water Quality Monitoring

Monitoring water quality continues to be a high priority for Yellowstone, with consistent information dating back to May 2002 now available for 17 sites. The monitoring is conducted in cooperation with the Vital Signs Monitoring Program of the Greater Yellowstone Network (GRYN), which includes Yellowstone National Park, Grand Teton National Park (including John D. Rockefeller Memorial Parkway), and Bighorn Canyon National Recreation Area (NRA). In Yellowstone, 12 of the sites are on major rivers and 7 are on Yellowstone Lake, including two sites added to the program in 2003 (Figure 1). Most of the stream water quality sites are located near U.S. Geological Survey discharge gaging stations. Stream discharge strongly influences limnological processes and flow-weighted measurements can be calculated for chemical parameters when they are collected near gage stations.

The purpose of the long-term water quality program is to acquire baseline information for Yellowstone's surface waters that can be used to evaluate overall ecosystem health, ascertain impacts of potential stressors (e.g., road construction activities and accidental sewage spills), identify any changes that may be associated with water quality degradation, and guide resource management decisions related to water quality. Initially, monitoring consisted of visiting each site once every two weeks to collect data on water temperature, dissolved oxygen, pH, specific conductance, and turbidity. Water samples were brought back to the laboratory for total suspended solid (TSS) and volatile suspended solid analysis. Analysis of data collected from 2002 to 2005 suggested that sampling frequency could be reduced to one visit per month while still capturing statistically significant within- and among-year trends in parameters. Changing to monthly site visits in 2006 allowed more time for other projects yet continues to provide data on a variety of flow regimes (Figure 16).

In June 2006, monthly monitoring was expanded to include a variety of chemical parameters such as anions (sulfate, chloride, and alkalinity [bicarbonate and carbonate]), cations (calcium, magnesium, sodium, and potassium) and nutrients (total phosphorus, orthophosphate, nitrate-nitrogen, nitrite-nitrogen, and ammonia-nitrogen). Dissolved and total metals (arsenic, copper, iron, and selenium) in water and sediment are measured twice annually during high and low flow periods on upper Soda Butte Creek at the park boundary near Silver Gate, Montana (Figure 1).

Core Water Quality Parameters

Descriptive statistics for core water quality parameters indicate spatial trends very similar to those observed from 2002 to 2005. In general, physical and chemical characteristics of water quality were related to seasonal changes, elevation, precipitation events, and presence or absence of thermal features. Water temperature and dissolved oxygen (DO) are closely tied because as water temperature declines, the solubility of oxygen in water increases (i.e., colder water holds more oxygen); conversely, as water temperature increases the solubility of oxygen in water decreases (i.e., warmer water holds less oxygen). Summer months typically bring warmer water temperatures and lower DO concentrations while winter months result in lower water temperatures and higher DO concentrations. Similarly, small streams located at high elevations are colder in summer because of snowmelt and elevation than are larger streams at lower elevations.

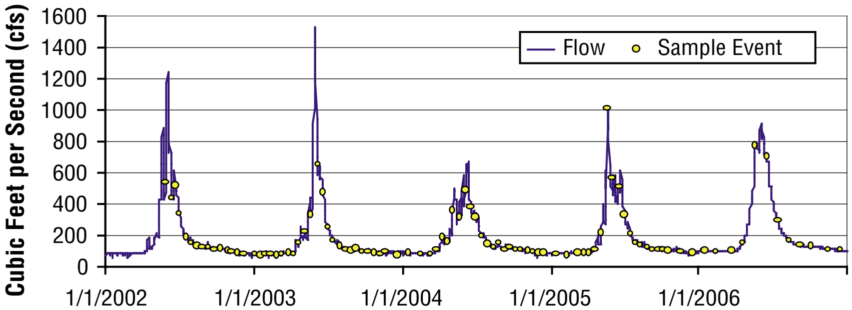


Figure 16. Mean daily streamflow (discharge) of the Gardner River near its confluence with the Yellowstone River, with frequency of water quality sampling events (yellow circles), 2002 to 2006. Note reduced sampling frequency during calendar year 2006.

Water temperatures ranged between -0.2 and 23 degrees Celsius (°C) in 2006. The lowest mean annual temperatures were recorded for the Lamar River and upper and lower Soda Butte Creek. The coldest temperatures on a single day were recorded for the Yellowstone River at Canyon, Lamar River, Pelican Creek, and upper Soda Butte Creek (Figure 17a), which were ice covered during the winter. The highest mean water temperatures were recorded for the Gardner, Firehole, Gibbon, and Madison rivers (Figure 17a), which are located within basins having considerable geothermal activity (Figure 1).

The acidity of surface water in Yellowstone, which is measured in pH, commonly ranges from 2.0 to 9.0 standard units (SU), with most waters having a pH near neutral (6.5–7.5) to slightly basic (7.5–8.5). The pH is influenced by water source, local geology, atmospheric

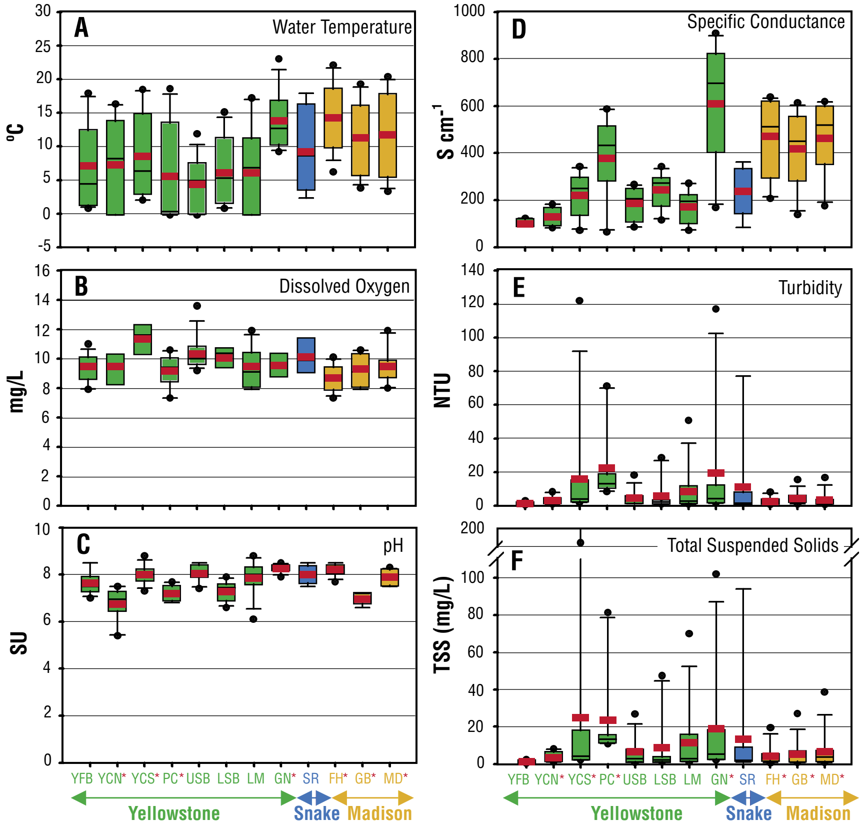


Figure 17. Box and whisker plot illustrating annual variation for selected parameters at each water quality location. Lower and upper portion of boxes represent the 25th and 75th percentile respectively; lower and upper black horizontal bars represent 10th and 90th percentile respectively. Outlying values are represented by black dots; means are indicated by solid red lines. Green, blue, and orange represent the Yellowstone, Snake, and Madison river basins, respectively (YFB = Yellowstone River at Fishing Bridge, YCN = Yellowstone River at Canyon, YCS = Yellowstone River at Corwin Springs, PC = Pelican Creek, USB = upper Soda Butte Creek, LSB = lower Soda Butte Creek, LM = Lamar River, GN = Gardner River, SR = Snake River, FH = Firehole River, GB = Gibbon River, and MD = Madison River). (*) = indicates sites with geothermal contributions.

deposition, geothermal contributions, and biological factors. Within site variation of pH was quite low; most differences occurred spatially across the park and among sites (Figure 17c). The Madison River, for example, receives water from the Firehole and Gibbon rivers, both of which are influenced by geothermal activity. The mean pH at the Firehole River was 8.22 SU (range 7.7–8.5). In contrast, the Gibbon River had a mean of 6.96 (range 6.6–7.2). Very acidic geothermal water that flows into the Gibbon River contributes to the lower pH values at this site.

Specific conductance, turbidity, and total suspended solids (TSS) are directly related to stream flow. Specific conductance is a measure of resistance of a solution to conduct electricity. The ability of water to conduct electrical current increases with an increase in ion content (i.e., anions and cations). Hence, the purer the water, the lower the specific conductance (Wetzel 2001). Specific conductance at all sites was lower during high flow periods of May and June, and higher during low flow periods of late summer and winter. For example, the Gardner River experienced its highest flow from mid-May to mid-June, which coincides with the lowest specific conductivity readings for the entire year (Figure 18). During high flow, snow melt and spring rains increase the volume of water, which dilutes dissolved material and reduces conductivity. During low flow periods of late summer and winter, the dissolved material is more concentrated, resulting in higher conductivity readings. The lowest mean specific conductance was 98 µSiemens cm^{-1} (µS cm^{-1}), recorded at Fishing Bridge (range 87–123 µScm^{-1}). The highest mean specific conductance, was 598 µS cm^{-1} (range 168–909 µS cm^{-1}), recorded at the Gardner River (Figures 17d and 18).

Trends in turbidity and TSS are also related to stream flow, but the effect is opposite from that observed for specific conductivity. Faster flowing water tends to carry more suspended solid materials (i.e., sand, silt, clay) than slower moving water does, which results in more turbid (cloudy) conditions during high flow periods than during low flow periods. Turbidity and TSS concentrations tend to mirror each other through the season (Figure 17e; Figure 17f).

For alkalinity, chloride, and sulfate, a spatial pattern among sites was noticed (Figure 19). Dissolved chloride concentrations have generally been associated with streams having geothermal influences (Norton and Friedman 1991). Our initial year of chemical monitoring supports this. On average, the three sites within the Madison River drainage had higher mean chloride concentrations than any of the sites within the Yellowstone River drainage (Figure 19b). In addition, when considering patterns in dissolved chloride going back to 2002, there appears to be a very strong relationship between this constituent and stream flow (Figure 20a; Figure 20b). Laboratory detection limits for all chemical constituents are provided in Appendix v.

NPS/JEFF ARNOLD

NPS water quality technicians Jeremy Erickson (right) and Hunter Hutchinson (left) measure the temperature, dissolved oxygen concentration, and specific conductance of the Gardner River as a part of the Vital Signs Monitoring Program.

Since chloride in park surface waters is magmatic in origin, the more predictable concentrations on the Gardner River may be related to the constant source of geothermal water from the Boiling River feature located two miles upstream from our monitoring site. Conversely, the less predictable concentrations in the Gibbon River may be attributed to the many geothermal features within the basin that have far less consistency in thermal inputs to the river. Mean dissolved sulfate concentrations tended to be lower at the Madison River sites than at the three sites with geothermal contributions in the Yellowstone River drainage (Figure 19c). Similar patterns were observed for cations (calcium, magnesium, sodium, and potassium).

Nutrients regulate growth of the phytoplankton and aquatic macrophytes that serve as primary producers of energy for higher level consumers in aquatic food webs. Monitoring nutrient concentrations may be used to detect impairments of aquatic systems resulting from anthropogenic sources such as

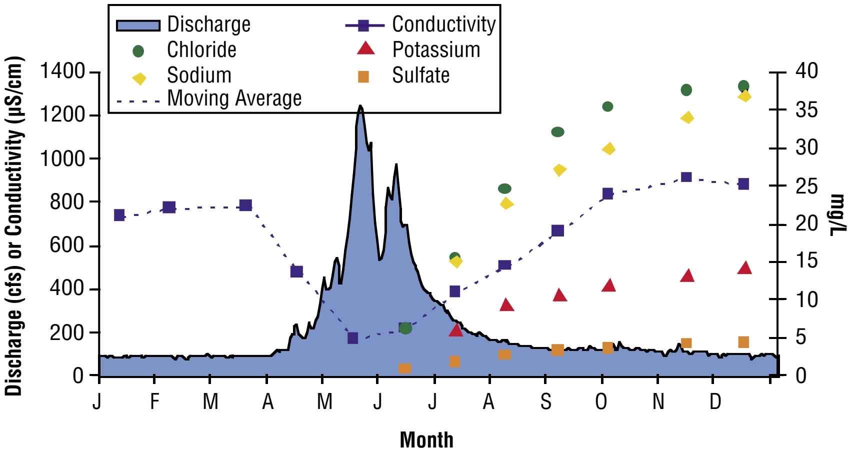


Figure 18. Relationships of conductivity, anions (chloride, sulfate) and cations (potassium, sodium) with mean daily streamflow (discharge) of the Gardner River in 2006.

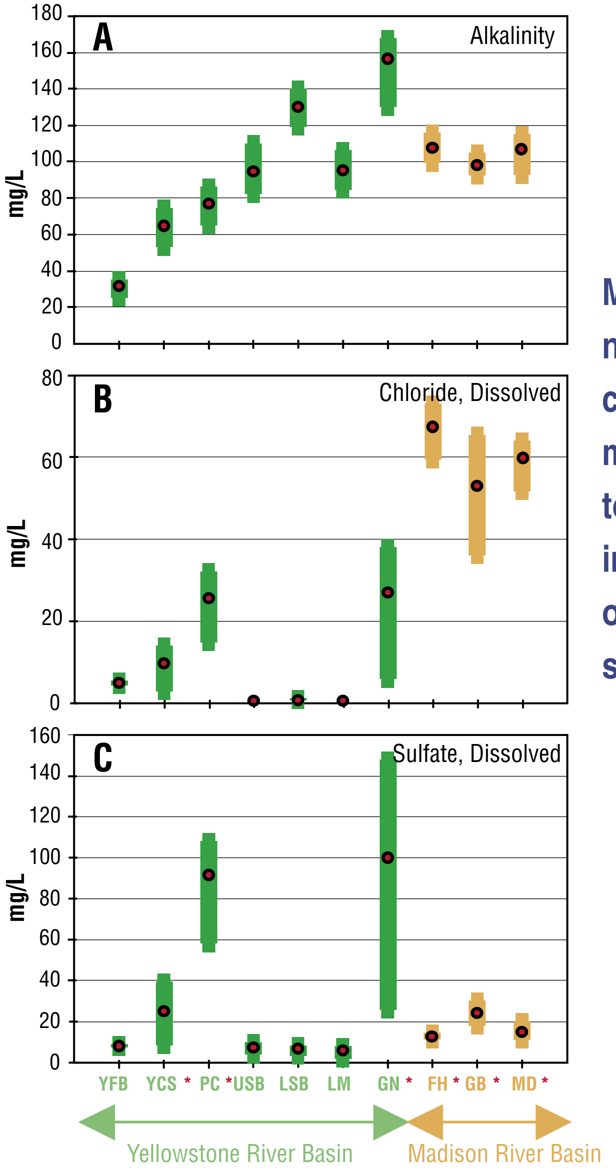


Figure 19. Mean and range of variation of anions (alkalinity, dissolved chloride, and dissolved sulfate) among water quality sites and major river basins. Note different concentrations along Y axis. (*) = indicates sites with geothermal contributions.

Monitoring nutrient concentrations may be used to detect impairments of aquatic systems...

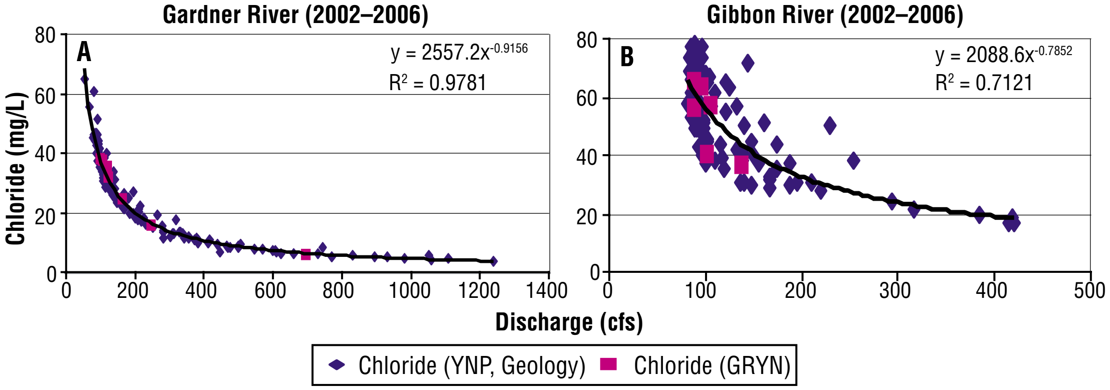


Figure 20. Relationships between dissolved chloride and stream discharge from Gardner and Gibbon rivers. Strong relationship of dissolved chloride in Gardner River may be associated with constant flows from Boiling River area. Higher variability of dissolved chloride in Gibbon River may be contributed to greater number of geothermal features within the watershed and unpredictable eruption intervals. Chloride data are from Yellowstone National Park Geology Section (blue diamond) and from Greater Yellowstone Network (GRYN) long-term water quality monitoring (pink, square).

The state of Montana has listed Soda Butte Creek upstream of the park's Northeast Entrance as "water quality impaired" because of elevated metal concentrations from the McClaren mine tailings...

agricultural runoff or sewage spills. Beginning in June 2006, we began to collect nutrient information including total phosphorus (inorganic and organic), orthophosphate, nitrate, nitrite, and ammonia. Total phosphorus was the only nutrient that was detected at all 10 fixed water quality stations. Orthophosphate, a dissolved inorganic form of phosphorus that is readily utilized by aquatic plants, was only detected once at the Yellowstone River at Corwin Springs and once at the Gardner River during the 7-month sample period.

Three forms of nitrogen were measured: nitrate, nitrite, and ammonia. Nitrites were below the detection limit at all stations during all site visits. Nitrate and ammonia were detected only in the Yellowstone River at Corwin Springs and Pelican Creek. During November and December, ammonia was detected in the Yellowstone River at Corwin Springs (0.1130 and 0.1430 mg/L, respectively) and Pelican Creek (0.5540 and 0.6890 mg/L, respectively). Detection of nitrate and ammonia during late winter and early spring is most likely related to lower flows and reduced uptake by aquatic plants (Miller et al. 2005; Peterson et al. 2004b). Sources of nitrate and ammonia at these two sites are not known; however, ammonia is produced by some geothermal features and oxidization of ammonia produces nitrate (Fournier 1989; Miller et al. 2005). Nitrate and ammonia at Corwin Springs could also be a result of runoff from pastureland, fertilizer, or sewage treatment releases. Regardless of the source, concentrations remain relatively low and are not a cause for concern.

Regulatory Monitoring on Soda Butte Creek

The state of Montana has listed Soda Butte Creek upstream of the park's Northeast Entrance as "water quality impaired" because of elevated metal concentrations from the McClaren mine tailings located near Cooke City and within


NPS/JEFF ARNOLD

NPS water quality technician Jeremy Erickson (right) and Student Conservation Association volunteer Kristy Kollaus, as a part of the Vital Signs Monitoring Program, obtain sediment samples from Soda Butte Creek to be laboratory tested for the presence of metals.

the Soda Butte Creek floodplain. In June and September (periods of high and low stream flow, respectively), we collected water and sediment for analysis of arsenic, copper, iron, and selenium. Samples were obtained in both the morning and evening to capture diurnal variations. Total and dissolved arsenic, copper, and selenium were below analytical detection limits in all water samples (Appendix iv). In June, dissolved iron ranged from <0.1 to 0.115 mg/L and total iron from 0.591 to 0.857 mg/L. In September, dissolved iron was below analytical detection limits and total iron ranged from 0.266 and 0.348 mg/L. In the sediment sample selenium was below detection in both periods. For the other three metals, concentrations tended to be lower in June than in September: arsenic (1.23 and 2.58 mg/kg respectively), copper (21 and 36.9 mg/kg), and iron (19,800 and 25,500 mg/kg).

Yellowstone Lake Limnology

Yellowstone Lake, the largest high elevation lake in North America, is approximately 23 km long and 20 km wide, has a surface area of 36,017 hectares, and is >100 m deep in many areas. The lake's water is derived from hundreds of streams and springs with the majority (approximately 1/3) of the water entering the southeast arm via the upper Yellowstone River. In addition, hundreds of geothermal features around and within the lake contribute to the overall chemical composition of lake water. The lake's seven water quality monitoring sites were sampled monthly from June through October. Water temperature, DO, pH, specific conductance and turbidity were recorded using a multiparameter probe at a depth of 0.2 m. Secchi depth was also recorded from each site and surface water was collected for TSS and volatile suspended solids analysis. To obtain more comprehensive information on temperature changes throughout the water column we deployed 20 temperature loggers at different depths in the West Thumb on May 30, 2006.

Mean surface water temperature, DO, pH, and specific conductance values were relatively consistent among all seven sample locations. Between June and October, Yellowstone Lake surface water ranged between 6.6 and 17.2 °C. Beginning in May after the ice-off period, temperatures were between 4 and 5 °C and remained fairly consistent throughout the water column (Figure 21). The thermocline became established at a depth of 15 meters, with the warmest surface water occurring in late July and early August. DO concentrations were higher during spring and fall when the surface water was cooler, and lower during mid-summer when the water was warmer. Observed DO concentrations ranged between 7.8 mg/L (August 9) and 10.1 mg/L (October 10).


NPS/ JEFF ARNOLD

Moon rise over Doane and Stevenson mountains of the Absaroka Range, east of Yellowstone Lake.

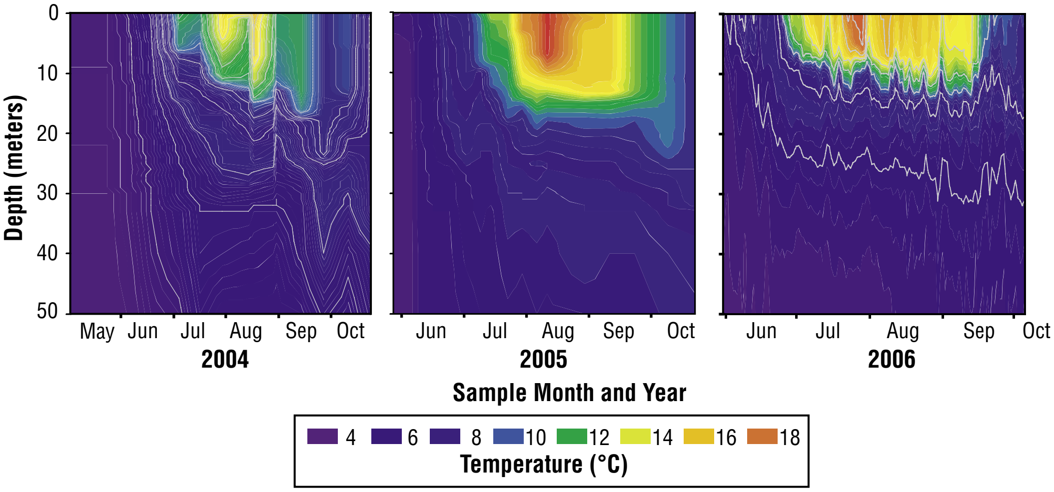


Figure 21. Yellowstone Lake isopleths showing seasonal and annual variation in temperature throughout the water column, 2004–2006. Only upper 50 meters are shown for better resolution of surface water temperatures.

Little variability in other measured parameters occurred on Yellowstone Lake seasonally or among sites. Overall, the lake was neutral to slightly basic; pH ranged between 7.1 and 8.5. Specific conductance remained relatively low with mean values near 100 µScm^{-1} for all sites and observed ranges between 70 and 126 µScm^{-1}. Turbidity ranged between 0.4 and 2.0 NTU; TSS between 0.1 and 1.8 mg/L. The highest turbidity and TSS were recorded in the southeast arm, an area that receives inputs from the upper Yellowstone River, which is often very turbid during spring snowmelt. Secchi readings, which were recorded for all sites when weather permitted (calm or slightly breezy days), ranged from 2.5 m (in the southeast arm) to 10.5 m.

Piscicide Impacts on Non-target Species

A critical element of native cutthroat trout restoration activities is to better understand the impacts of piscicides (fish toxins) on non-target species, especially amphibians and aquatic macroinvertebrates. The park is home to four amphibian species, including the Columbia spotted frog (*Rana luteiventris*), boreal chorus frog (*Pseudacris triseriata maculata*), boreal toad (*Bufo boreas boreas*), and blotched tiger salamander (*Ambystoma tigrinum melanostictum*) (Koch and Peterson 1995). During the summer of 2006, surveys for these species were conducted in the current and proposed native cutthroat trout restoration watersheds to (1) document the presence, distribution, and extent of amphibian breeding populations and the effects of piscicides on these populations; and (2) evaluate aquatic macroinvertebrate distribution and community structure and assess the impacts piscicides may have on these communities.

Amphibians of Specimen Creek and High Lake

Specimen Creek, a tributary of the Gallatin River, has a drainage area of approximately 7,751 hectares. East Fork Specimen Creek, one of two major tributaries, has a drainage area of approximately 3,437 hectares, comprising about 45% of the Specimen Creek watershed. Between 1997 and 1999, Patla (1998, 2000) conducted preliminary work on watersheds in the northwest portion of the park, including the Specimen Creek drainage. Results indicated that all four of the park's known amphibian species were present in this region, but only spotted frogs were found to reside and breed in the Specimen Creek watershed. Wetland sites within the East Fork Specimen Creek watershed, as identified by the National Wetlands Inventory (U.S. Fish and Wildlife Service 1998), were surveyed between July 7 and July 20, 2006 (Figure 22; Billman et al. 2007). Amphibians were observed at 12 of the 40 sites sampled, and included adult or juvenile spotted frogs (11 sites), chorus frogs (3 sites), and boreal toads (2 sites). Amphibian breeding populations (identified by the presence of eggs or larvae) were recorded at six sites; five had breeding spotted frogs and three had breeding chorus frogs.

Of particular importance during the 2006 surveys were the three breeding sites found near High Lake, including a breeding population of spotted frogs with 100–200 tadpoles in the High Lake outlet.

Of particular importance during the 2006 surveys were the three breeding sites found near High Lake, including a breeding population of spotted frogs with 100–200 tadpoles in the High Lake outlet (Billman et al. 2007). In addition, numerous juvenile and adult spotted frogs were observed throughout the shoreline of the lake along with two adult boreal toads. The two wetland sites located near High Lake were identified as breeding sites for spotted frogs and chorus frogs. Since the surface waters of these wetlands were not connected to High Lake, they


NPS/TODD KOEL

High Lake outlet area which contained juvenile and adult spotted frogs, an abundance of spotted frog tadpoles, and two large, adult boreal toads (see page 6).


NPS/TODD KOEL

NPS/ JEFF ARNOLD

Along the margin of the High Lake outlet area: NPS fisheries technician Hilary Billman searches for amphibians (top); a Columbia spotted frog tadpole camouflaged against the lake sediments (bottom).

were not treated with rotenone.

Before, during and after rotenone treatment water samples were collected from two sites at High Lake and one site on East Fork Specimen Creek approximately 3 km downstream from the lake. Rotenone was not detected prior to treatment in High Lake nor at any time in East Fork Specimen Creek. The highest rotenone levels (30 ppb) were recorded after the first treatment on August 9, 2006, and after the second treatment (11 ppb) on August 29, 2006. Approximately two weeks after the second treatment, the rotenone concentration had declined to 2.7 ppb in the main lake basin. Immediately after the first application, spotted frog tadpoles deviated from their normal cryptic behavior and were seen actively swimming in open water along the lake outlet margin. The concentrations of rotenone within High Lake proved lethal to larval amphibians; we noted 100% mortality of tadpoles held in sentinel cages within the treated waters. Adult and juvenile spotted frogs and boreal toads survived despite being directly exposed to the piscicide during each application. Further monitoring of the amphibian population in the High Lake area will continue in 2007.

Macroinvertebrates of Specimen Creek and High Lake

In the East Fork Specimen Creek watershed, aquatic macroinvertebrates were collected at a total of six sites on inlet and outlet streams and four sites on High Lake (Figure 22) that were sampled before and after rotenone application.

Of the 50 invertebrate taxa found in High Lake benthos and littoral areas, during 2005 and 2006, 44 were collected prior to rotenone treatment, including 22 Dipterans (20 chironomid midges, 1 phantom midge, and 1 no-see-um (midge), 2 Hemiptera (true bugs), 1 Coleoptera (beetle), 8 Trichoptera (caddisfly), 1 Ephemeroptera (mayfly), 1 Plecoptera (stonefly), 2 Odonata (dragonfly), and 7 non-insect taxa. Of these 44 taxa, 11 were not found after treatment, including 4 Chironomids (*Cladotanytarsus, Corynoneura, Metriocnemus,* and *Orthocladius* spp.*),*


NPS/JEFF ARNOLD

*Pre- and post-monitoring of invertebrates, such as this dragonfly, a Paddle-Tailed Darner (*Aeshna palmate *- emerging from its larval shell along the margin of High Lake), is being judiciously conducted to better understand potential impacts of a new rotenone formulation (CFT Legumine) on non-target, aquatic species.*

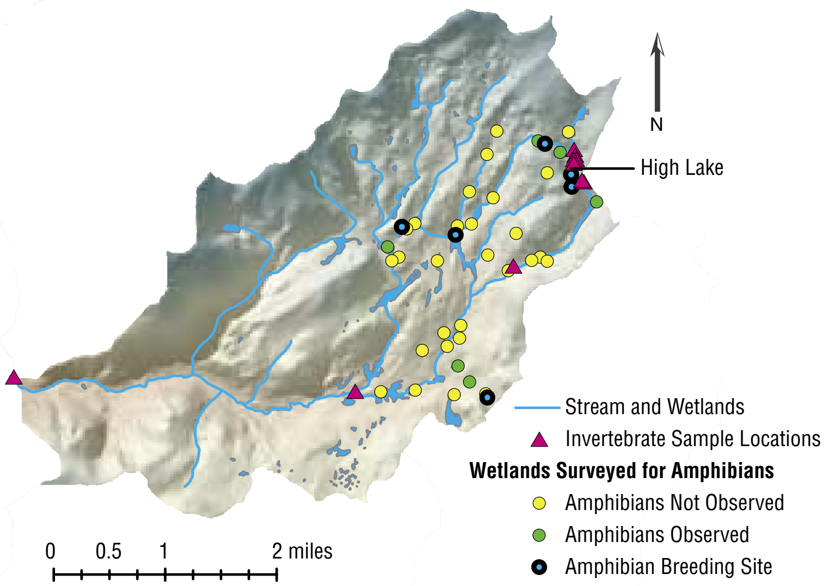


Figure 22. Invertebrate sample locations and wetlands surveyed for amphibian populations in the East Fork Specimen Creek drainage, 2006.

6 Trichoptera (*Allomyia, Glossosoma, Limnephilus, Molanna, Nemotaulius hostilis,* and Phryganeidae spp.), and 1 Ephemeroptera (*Callibaetis* sp.). Post-treatment collections did include 6 taxa not found beforehand, possibly because of variation in sampling intensity and/or the life history patterns of some insects.

During 2006 we found 68 aquatic invertebrate taxa in High Lake's inlet and outlet streams. Dipterans made up a majority of the invertebrate community at the sample locations both before and after rotenone treatment (Figure 23). In the inlet stream, 21 taxa were collected before treatment and 27 taxa afterward. However, in the outlet stream we found 46 taxa before treatment and only 28 taxa afterward. The invertebrates most affected (i.e., collected in high densities before treatment but absent afterward) included 2 mayflies (*Diphetor hageni* and *Paraleptophlebia* sp.*)*, 4 stoneflies (*Hesperoperla pacifica, Isoperla* sp., *Malenka* sp., and *Zapada cinctipes*), 1 caddisfly (*Micrasema* sp.), and 2 midges (*Eukiefferiella* and *Nanocladius* spp.). This reduction in taxonomic diversity could be attributed to the fact that the outlet stream received High Lake flows containing treatment-level concentrations of rotenone for several weeks, whereas a drip station was used at the inlet stream and removed after one day (although rotenone sand formulation remained in the inlet headwater springs for several days). Post-treatment surveys to be conducted in 2007 and 2008 will provide evidence of either recovery or sustained loss of invertebrates in the outlet stream.

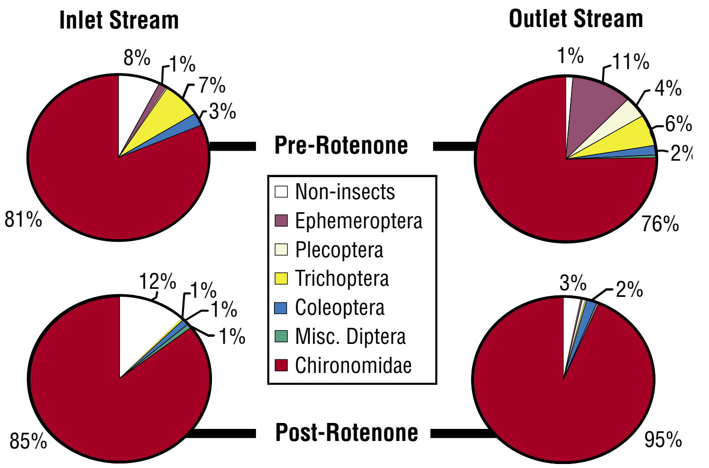


Figure 23. Percentage of major invertebrate groups collected from High Lake inlet and outlet streams before and after treatment with rotenone in 2006.

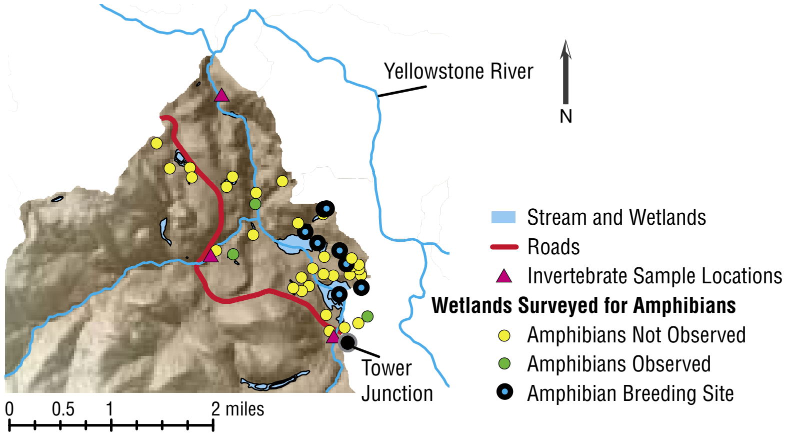


Figure 24. Invertebrate sample locations and wetlands surveyed for amphibian populations in the Elk Creek drainage, northern range, 2006.

NPS/ JEFF ARNOLD

Spotted frog from the Blacktail Ponds of the northern range.

Amphibians on the Northern Range

Both the Elk and Blacktail Deer creek drainages were sampled for amphibians in 2006. Forty wetland sites within the Elk Creek drainage, most of them north of the Grand Loop Road (Figure 24), were sampled between June 26 and July 1. Three amphibian species were observed at a total of 11 wetland locations, with 3 breeding sites for Columbia spotted frogs, 1 for boreal chorus frogs, and 4 for blotched tiger salamanders, although 2 of the salamander sites became dry before the larvae completed metamorphosis. At the seven wetland sites in the Blacktail Deer Creek drainage sampled on July 25, 2006, only adult Columbia spotted frogs were found at two locations, with no evidence of breeding occurring.

Angling in the Park

Trends from the Volunteer Angler Report Cards

Angling remains a popular pastime for those visiting, living near, and working in Yellowstone National Park. Fishing permits (required for fishing in park waters) and volunteer angler report (VAR) cards were issued to 50,243 of the 2,870,293 park visitors in 2006. VAR cards have been handed out since 1973 to provide anglers with an opportunity to share their fishing success and opinions about the park's fishing opportunities. Almost 4,000 angler outings have been reported on VAR cards annually in recent years. Interviews with visitors as they leave the park provide additional information about numbers of anglers. These surveys have revealed that nearly 1.5% of visitors who purchased a fishing permit did not fish, while 0.6% of visitors fished without a permit.

An estimated 49,794 visitors fished in the park during 2006 on a total of 286,664 days. They landed 764,588 fish, of which more than 97% were released and 29,088 were harvested. Anglers fished for an average of 2.92 hours a day for 1.76 days during the season. Fish were caught by 78% of anglers, despite the fact that a majority (64%) only fished one day. Anglers reported being satisfied with the overall fishing experience (76%), with the number of fish caught (63%), and with the size of fish (66%), representing a slight increase in satisfaction in all categories from 2005.


NPS/BILL VOIGT


NPS/BILL VOIGT

Top: Non-native brook trout sampled using hook and line from Little Blacktail Deer Creek. Bottom: A fly fishing volunteer samples Blacktail Deer Creek in the park's northern range.


NPS/BILL VOIGT

Fly fishing volunteers sample Slough Creek's first meadow in an attempt to suppress the non-native rainbow trout that have invaded there.

The mean length of the 21,804 reported fish was 11.5 inches; 41.5% of these fish were longer than 12 inches and 28.1% were longer than 14 inches. Lake trout were the longest species on average (17.1 inches, 0.5" decrease from 2005), followed by cutthroat (12.3 inches, 1.0" decrease), whitefish (12.8 inches, 0.2" increase), brown trout (10.8 inches, 0.4" decrease), rainbow trout (10.1 inches, 0.2" increase), grayling (8.3 inches 1.2" decrease), and brook trout (6.9 inches, 0.3" decrease).

Native cutthroat trout remained anglers' most sought after and caught fish species in 2006, comprising 49% of all fish caught


NPS/KEN BURGWIN

Cutthroat trout from the Yellowstone River downstream of Hayden Valley.

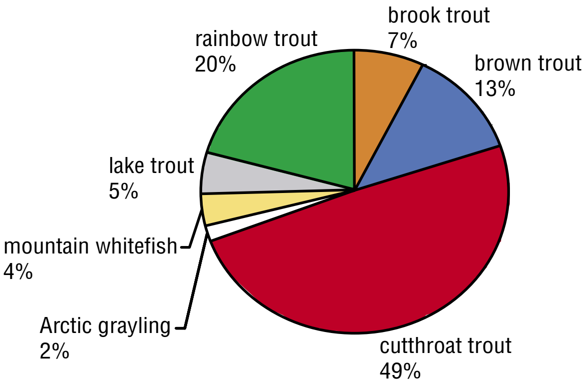


Figure 25. Percentage of each species in angler-reported catch during the 2006 fishing season.

...it took about 2½ hours on average to catch...a Yellowstone Lake cutthroat trout in 2006.

(Figure 25). Rainbow trout were caught the second most (20%), followed by brown trout (13%), brook trout (7%), lake trout (5%), mountain whitefish (4%), and grayling (2%). Native fish species (cutthroat, whitefish, and grayling) comprised 55% of all fish caught.

Yellowstone Lake remained the most popular destination for anglers despite the declining catch-rate of Yellowstone cutthroat trout there. The cutthroat trout fishery has been hindered by predation from non-native lake trout, whirling disease, and drought. An estimated 9,070 anglers caught an estimated 69,405 cutthroat trout in the lake in 2006 (down from 79,968 in 2005, Figure 26), and it took about 2½ hours on average to catch one of these fish. The average size of cutthroat trout caught in Yellowstone Lake increased again in 2006 to 454 mm (17.9"), from 447 mm (17.6") in 2005.

Anglers also caught an estimated 18,497 lake trout in Yellowstone Lake in 2006 (Figure 26), a slight increase over 2005, which could be due to local anglers targeting lake trout along with increased knowledge and tactics designed to catch lake trout, such as downriggers and weighted fishing line. Anglers reported good catches of lake trout in 40 to 70 feet of water in Breeze Channel and around Frank Island.

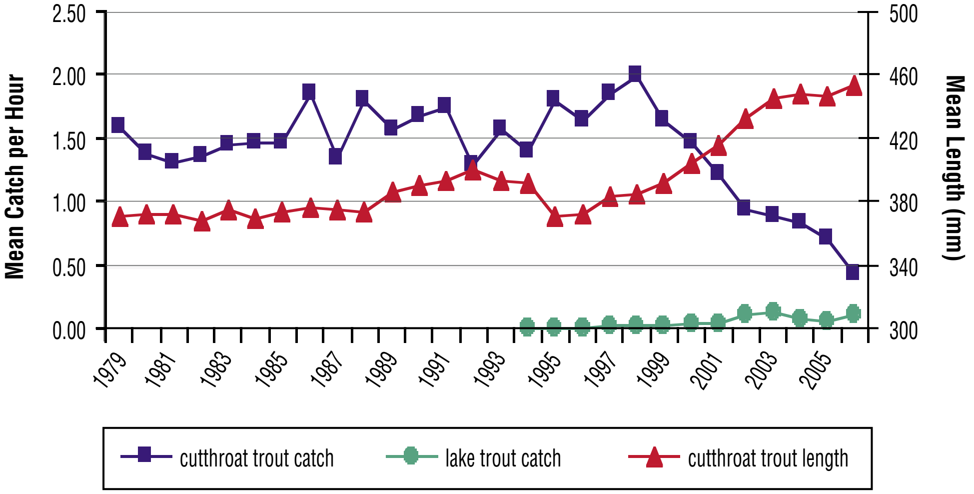


Figure 26. The 2006 angler-reported catch of Yellowstone Lake cutthroat trout continued a long-term trend of fewer but larger cutthroat trout, while the reported lake trout catch per hour remained relatively unchanged.

Fly Fishing Volunteers Program

The Fly Fishing Volunteers program initiated in 2002 has used visiting anglers to collect biological information about fish populations throughout the park. Under the direction of Tim Bywater, Bill Voigt, and Joann Voigt, the program continued in 2006 from late May through mid-September, focusing on Blacktail Deer Creek, Gibbon River, Grayling Creek, Slough Creek, and Soda Butte Creek. A total of 78 volunteer anglers contributed over 1,400 hours, gathering data on Arctic grayling population dynamics, the genetic integrity of native cutthroat trout, and the presence/abundance of non-native brook trout.

Data generated during the first five years of the program have filled large gaps in our understanding of many basic native fish conservation questions. Perhaps equally important is the awareness generated among angling organizations, within local fly shops, and between anglers about current issues faced by Yellowstone's native fish. Because of the value of this program, the Yellowstone Park Foundation has committed to continue funding for the Fly Fishing Volunteers through 2009.

Long-term Volunteer Assistance

The Aquatics Section recruits volunteers through the Student Conservation Association (SCA) and other sources (see Appendix iii). These volunteers stay in park housing at Lake or Mammoth for 12 or more weeks and work a full-time schedule similar to paid National Park Service staff. Typically, two groups of SCA volunteers participate: the first from mid-May through early August, and the second from early August through late October. Our goal is to have the volunteers gain experience with as many Aquatics Section activities as possible. Given that 10,000s of hours of assistance have been provided by volunteers over the years, there is no question that all aspects of our program have greatly benefited from both long- and short-term volunteer support.

Educational Programs

Aquatics Section staff continued to provide a variety of short-term educational programs for visiting schools and other interested groups, with an emphasis on native fish conservation. The staff also provided American Red Cross first aid certification, CPR, electrofishing certification, and the DOI Motorboat Operator Certification Course for National Park Service employees and other agencies.

Collaborative Research

The Aquatics Section, through the Yellowstone Center for Resources, 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.

NPS/MOLLY PICKALL

Bill Voigt is one of two coordinators for the Fly Fishing Volunteers Program.

NPS/BILL VOIGT

A total of 78 fly fishing volunteers contributed over 1,400 hours to the park's fisheries program in 2006.

...gametes from the population located in Last Chance Creek will be incorporated in 2007 into the upper Missouri River westslope cutthroat trout broodstock at the Sun Ranch...

Projects by Graduate Students

Graduate student: Julie Alexander (Doctor of Philosophy candidate).
Committee co-chairs: Drs. Billie Kerans and Todd Koel, Department of Ecology, Montana State University.
Title: Detecting *Myxobolus cerebralis* infection in *Tubifex tubifex* of Pelican Creek.

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.

Graduate student: Brian Ertel (Master of Science candidate).
Committee chair: Dr. Thomas McMahon, Department of Ecology, Montana State University.
Title: Distribution, movements, and life history of Yellowstone cutthroat trout in the upper Yellowstone River basin.

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 cutthroat trout population of Yellowstone Lake.

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

Graduate student: Amber Steed (Master of Science candidate).
Committee co-chairs: Drs. Al Zale, U.S. Geological Survey Cooperative Fisheries Research Unit, and Todd Koel, Department of Ecology, Montana State University.
Title: Spatial dynamics of Arctic grayling in the Gibbon River.

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.

Interagency Workgroups

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

Cutthroat Trout Broodstock Development

Wyoming Game and Fish employees have collected a limited number of Yellowstone cutthroat trout gametes from the Yellowstone River at LeHardys Rapids that have been 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, age-0 Yellowstone cutthroat trout from the broodstock (LeHardys Rapids origin) in Wyoming are returned to the park each year for whirling disease exposure studies.

The park has verified two genetically pure westslope cutthroat trout populations. Preparations are being made for gametes from the population located in Last Chance Creek to be incorporated in 2007 into the upper Missouri River westslope cutthroat trout broodstock at the Sun Ranch in Madison Valley, Montana. 

Acknowledgements

Julie York of the Planning, Compliance, and Landscape Architecture Division guided NEPA compliance and made possible initiation of the Restoration of Westslope Cutthroat Trout in the East Fork Specimen Creek Watershed project in 2006. This work was a milestone for the park, made possible largely by her dedication and first-class work ethic. Thank you, Julie!

Much-appreciated administrative support for the Aquatics Section was provided by Barbara Cline, Montana Lindstrom, Melissa McAdam, and Becky Wyman, with special thanks to Joy Perius for all of her assistance and patience when working with the fisheries staff through the years—best of luck in your new position, we will miss you, Joy!

The Aquatics Section is supported through Yellowstone Center for Resources base funding and a portion of the fees collected from anglers who purchase fishing permits). In 2006, additional funding was received from these sources:

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

We would like to extend special thanks to the Yellowstone Park Foundation board and staff, and to the many private individuals who have graciously provided support for our critical fisheries projects in the park. Elizabeth Marum and Sarah DeOpsomer made all arrangements for the Fish Tails & Trails Benefit Dinner and Auction on June 8, 2006, at the Racquet Club, New York City, and for that we are especially grateful.

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


NPS/TODD KOEL

Dave Elwood and friends from Corral Operations stop along East Fork Specimen Creek for a water break during a trip to High Lake. Dave is one of several park staff that made it possible to initiate on-the-ground restoration activities for westslope cutthroat trout in 2006.


NPS/TODD KOEL

NPS/ JEFF ARNOLD

NPS/TODD KOEL

Success of Fisheries and Aquatic Science activities in Yellowstone is due to a tremendous amount of support by short- and long-term volunteers, and the shared expertise of staff from several partner agencies, universities, and other organizations. Molly Bensley, Bozeman Fish Health Center (left), examines rainbow cutthroat hybrids from Rose Creek; Don Skaar, Fish Management Bureau Chief, Montana Fish, Wildlife and Parks (center) traveled to High Lake and guided rotenone applications; Dale White, Gallatin National Forest (right) conducted analyses to better understand implications of a fish barrier on the hydrology of East Fork Specimen Creek.

Genetic analyses of cutthroat trout were kindly provided by Matt Campbell, Idaho Department of Fish and Game; Robb Leary, Montana Department of Fish, Wildlife and Parks; Steven Kalinowski, Montana State University; and Dennis Shiozawa, Brigham Young University. Results of these analyses have been pivotal in our recent progress toward restoration of cutthroat trout to stream systems in the park. We received much appreciated support and guidance for our cutthroat trout restoration activities from Lee Nelson, Don Skaar, and Ken Staigmiller, Montana Department of Fish, Wildlife and Parks; and Dale White and Mark Story, Gallatin National Forest.

Special thanks for help on Yellowstone Lake with gillnetting, electrofishing, and hydroacoustics to Beth Bear, Mark Smith, Andy Dux, and Bob McDowel of the Wyoming Game and Fish Department, and to the U.S. Fish and Wildlife Service for assistance with gillnetting (Ennis National Fish Hatchery staff) and for use of their electrofishing boat (Idaho Fishery Resources Office).

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

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

Many other people from within Yellowstone National Park contributed to the success of Aquatics Section activities in 2006; unfortunately, we cannot mention them all here. However, we would like to especially thank Ben Cunningham, Dave Elwood, Tim McGrady, and Wally Wines from Corral Operations; Wendy Hafer and Andy Mitchell from the Fire Cache; Susan Ross, Bruce Sefton, Lynn Webb, and Dave Whaley from Lake Maintenance; Dan Reinhart from Resource Management; Rick Fey, Brad Ross, and Kim West from the South District Rangers; and Bonnie Gafney from the West District Rangers.

Glenn Plumb, Natural Resources Branch Chief, and S. Thomas Olliff, Chief, Yellowstone Center for Resources, provided guidance and support for the Aquatics Section in 2006.

Special thanks to our dedicated technicians and volunteers for their contributions to our program. The accomplishments of 2006 would not have occurred without your hard work and tireless efforts!

Hillary Billman provided a detailed, critical review and helpful editing for this report. This report is made possible only by the dedicated work of the Resource Information Team, Yellowstone Center for Resources. Special thanks to Tami Blackford, Mary Ann Franke, and Sarah Stevenson for making this report a reality.

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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 clarkii bouvieri*	Native	I	N	N
	westslope cutthroat trout	*Oncorhynchus clarkii lewisi*	Native	N		
	Snake River finespotted cutthroat trout	*Oncorhynchus clarkii 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); 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)
Lake number	150
Lake surface area total	43,706 hectares
Lakes fishable	45
Yellowstone Lake surface area	36,017 hectares
Stream number	>500
Stream length total	4,265 kilometers
Stream surface area total	2,023 hectares
Streams fishable	>200


NPS PHOTO

Jennifer Mitton is one of several long-term volunteers that worked side-by-side with park biologists in 2006.

Appendix iii. Long-term Volunteers, 2006

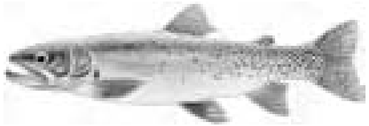
- Bradley, Katie
- Dickson, Amanda
- Frair, Megan
- Griffis, Bonnie
- Haslick, Brandon
- Voigt, Joann
- Kollaus, Kristy
- Kraegel, Connor
- Mitton, Jennifer
- Polucci, Ashley
- Rupert, Derek
- Squires, Audrey
- Walters, Matthew

Appendix iv. Seasonal Staff, 2006

- Adams, Rebecca
- Billman, Hilary
- Bywater, Tim
- Erickson, Jeremy
- Hall, Margaret
- Hutchinson, Hunter
- Keep, Shane
- Klibansky, Nikolai
- Kreiner, Ryan
- Legere, Nicole
- Romankiewicz, Christopher
- Sigler, Stacey
- Voigt, Bill
- Wethington, Don
- Wiggins, Justin

NPS/STACEY SIGLER

To better understand the biology of recently-discovered westslope cutthroat trout, NPS fisheries technician Nicole Legere places a temperature logger in Last Chance Creek (March 21).



MICHAEL SIMON

Appendix v. Reporting Limits for Chemical Analysis of Water and Sediment, 2006.

Chemical in Water	Reporting Limit (mg/L)
Anion	
Alkalinity-total	N/A
Chloride-dissolved	1.000
Sulfate-dissolved	10.000
Cation	
Calcium-dissolved	0.100
Magnesium-dissolved	0.100
Potassium-dissolved	0.100
Sodium-dissolved	0.500
Nutrient	
Ammonia-nitrogen	0.100
Nitrate-nitrogen	0.100
Nitrite-nitrogen	0.100
Orthophosphate-phosphorus	0.200
Posphorus-total	0.025
Metals-Water	
Arsenic-total	0.010
Arsenic-dissolved	0.010
Calcium-total	0.100
Calcium-dissolved	0.100
Copper-total	0.005
Copper-dissolved	0.005
Iron-total	0.100
Iron-dissolved	0.100
Magnesium-total	0.100
Magnesiulm-dissolved	0.100
Selenium-total	0.010
Selenium-dissolved	0.010
Metals-Sediment	**mg/Kg**
Arsenic	**1.0**
Copper	0.5
Iron	50.0
Selenium	5.0