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Yellowstone cutthroat trout

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

Front cover photo captions (left to right): NPS fisheries technician Stacey Sigler and Student Conservation Association (SCA) intern Allison Millar lifting a lake trout gillnet from Yellowstone Lake (photo by Audrey Squires); westslope cutthroat trout from Geode Creek (photo by Todd Koel); Specimen Creek trail after the Owl Fire (photo by Todd Koel). Back cover photo captions (left to right): fisheries workskiff on Yellowstone Lake (photo by Stacey Sigler); Yellowstone cutthroat trout from Clear Creek (photo by Pat Bigelow); MSU fisheries technician Derek Rupert prepares an incubator for westslope cutthroat trout eggs at High Lake (photo by Todd Koel).

Facing page photo: MSU fisheries restoration biologist Mike Ruhl setting up an incubator for westslope cutthroat trout eggs at High Lake (photo by Todd Koel).

Note: Native fishes shown out of water were not injured.

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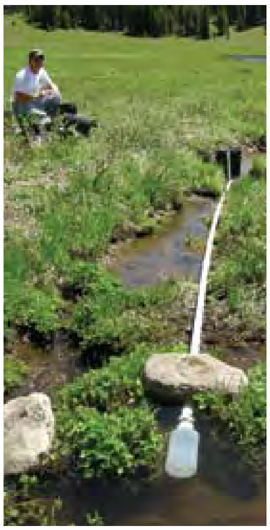


NPS/TODD KOEL

Background

When Yellowstone National Park was established in 1872, it was the only wildland under active federal management. Early visitors fished and hunted for subsistence, as there were almost no visitor services. Fishes 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 (Varley and Schullery 1998).

To supplement fishing and counteract "destructive" consumption by wildlife, a fish "planting" program was established. 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 an accepted use of national


NPS PHOTO

Fisheries crew from Spearfish federal fish hatchery preparing nets to capture spawning cutthroat trout at Clear Creek, ca. 1910.


NPS PHOTO

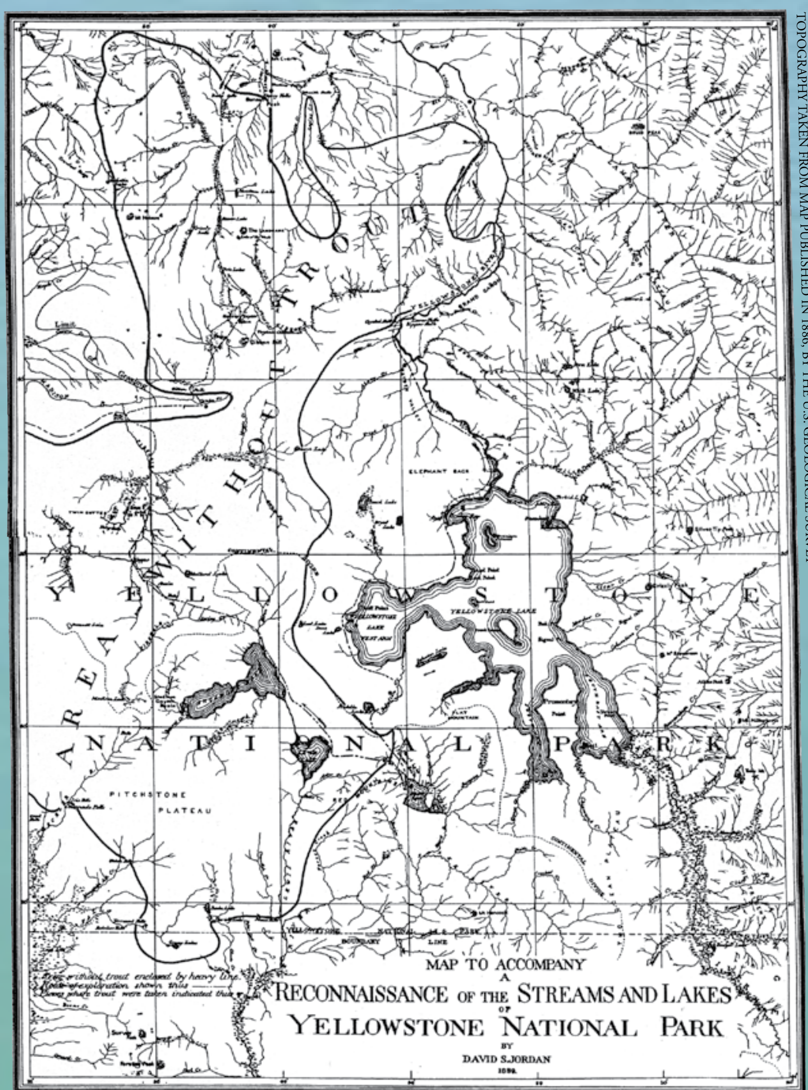
Ranger McCarty (right) and angler John Harvey with a catch from Slough Creek, July 1936.

parks throughout the country. In Yellowstone, fisheries management, as the term is understood today, began with the U.S. Army, and was taken over 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, when they became the responsibility of the National Park Service.

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 are known to exist in Yellowstone National Park; 13 are considered native (they were known to exist in park waters prior to Euro-American settlement), and 5 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 public 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 anglers through a catch-and-release requirement. Because the primary mission of Yellowstone's Fisheries and Aquatic Sciences Program (Fisheries Program) is the preservation of natural ecosystems and ecosystem processes, it does not emphasize maintenance of 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 harming native cutthroat trout or Arctic grayling. Fisheries Program 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.



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 harming native cutthroat trout or Arctic grayling.

2007 Summary

Environmental conditions for fishes and other aquatic resources in 2007 were driven by low winter snowpack and snow water equivalent, early snow melt and stream runoff, low summer precipitation, and warmer than average summer temperatures. Yellowstone Lake's ice succumbed to waves on May 14, a date that was among the earliest on record, allowing lake trout gillnetting crews early access. Within three days of deploying our boats, >9 miles of gillnet had been placed to kill lake trout. This early netting proved highly productive, as >10,000 lake trout were removed when these nets were first lifted by our crews the following week. Overall, 74,038 lake trout were removed from Yellowstone Lake via gillnetting in 2007 in an effort nine times greater than that conducted in 2000, prior to acquisition of the gillnetting boat *Freedom*. However, along with increases in total number harvested, the catch-per-unit-effort of lake trout has been steadily increasing each year and is a serious cause for concern.

Indices of abundance suggest that the Yellowstone Lake cutthroat trout spawning population has yet to demonstrate a significant positive response to our lake trout suppression efforts. The number of upstream-migrating cutthroat trout counted at Clear Creek, one of the cutthroats' largest spawning tributaries, was only 538 during 2007—very similar to the count of 489 obtained in 2006. Historically, Clear Creek supported >30,000 spawning cutthroat trout, but those numbers have not been seen since the mid-1990s.

NPS/BILL VOIGT

Yellowstone cutthroat trout from Tower Creek below Tower Falls.

Cutthroat trout abundance has also been monitored annually by a fall netting assessment at sites across Yellowstone Lake. This year, the average number of cutthroat trout caught per gillnet was 9.1, much higher than in previous years; it hasn't been that high since 1998, when 9.9 were caught per gillnet. While this is exciting to see, it is important to consider that most of the cutthroat trout we captured in 2007 were small, juvenile fish. We remain hopeful that these young cutthroat will survive and recruit to the spawning population so we can observe them within the lake's spawning tributaries, including Clear Creek.

The East Fork Specimen Creek westslope cutthroat trout restoration project focused on High Lake in 2007. Fish from both of the genetically pure populations known within the park were used in an effort to restock High Lake following rotenone treatment in 2006. Embryos from Last Chance Creek and the Sun Ranch upper Missouri River broodstock were introduced using remote site incubators placed in High Lake inlet streams. Juveniles and adults were collected from the Oxbow/Geode Creek complex and moved to High Lake via helicopter. Monitoring indicated initial success of all 2007 High Lake stocking efforts. The introduction of westslope cutthroat trout to High Lake is expected to continue in 2008 and 2009.

The Owl Fire, a naturally caused 2,810-acre wildfire, burned through a large portion of the East Fork Specimen Creek restoration area. One of the most intensely burned areas was the site where construction of a barrier to upstream fish movement had begun. Considerable work, including a 76-m water diversion structure built in 2006, and approximately 40 mule loads of equipment and supplies were completely destroyed by the fire. However, the fire's most significant impact was that we were unable to work at the site due to dangers posed by the fire itself and later by the hazard trees left in the wake of the burn.

The ecological health of the park's aquatic systems continues to be monitored. 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. New emphasis is being placed on the assessment of potential impacts of piscicides on non-target species during native fish restorations. We continued to monitor amphibians and aquatic invertebrates at High Lake after the rotenone treatment. Overall, the invertebrate populations within the High Lake outlet stream demonstrated recovery one year following rotenone treatment, while those in the inlet stream did not. Additional surveys in 2008 will allow for a much more complete understanding of rotenone's potential impacts.

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 90 anglers from across the United States contributed over 1,776 hours to fisheries projects throughout the park. Data were gathered on the native cutthroat trout of Slough Creek, the effectiveness of existing waterfalls and cascades in restricting movements of trout, and the presence/abundance of trout in several small accessible lakes.

NPS/TODD KOEL

Fisheries crew collecting genetically-pure westslope cutthroat trout from Geode Creek to be stocked to High Lake.

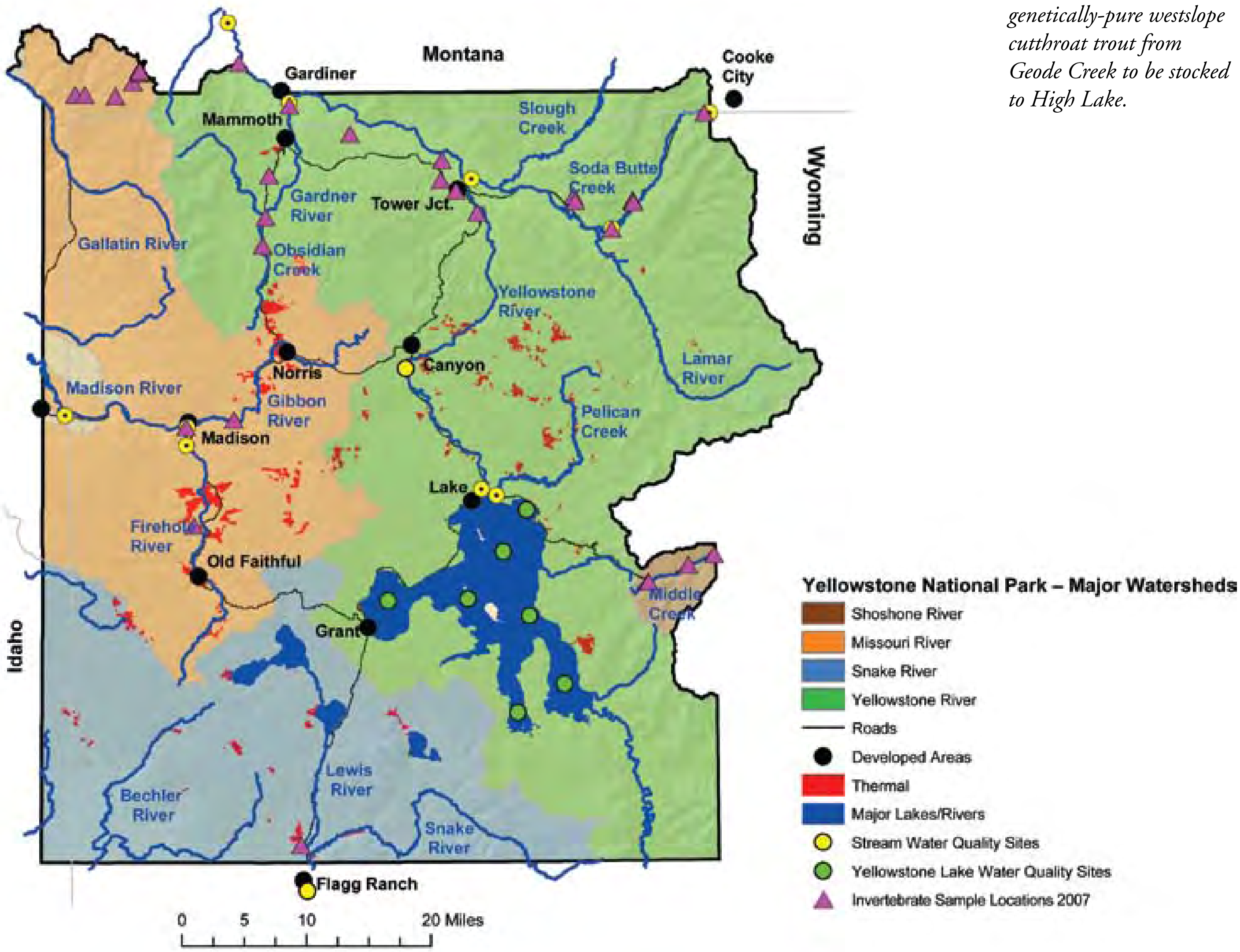


Figure 1. Major watersheds and surface waters of Yellowstone National Park, with sites established for long-term water quality monitoring on streams (12 sites–yellow circles) and Yellowstone Lake (7 sites–green circles). Areas sampled for aquatic invertebrates in 2007 (29 sites–purple triangles) are also shown.

The 2007 Water Year

NPS/BILL VOIGT

Lamar River during August 2007.

For the park's coldwater fishes, the heat and drought reduced available habitat (reduced volume) and elevated stream temperatures, causing high stress and mortality.

Environmental conditions for fishes and other aquatic resources in 2007 were driven by low winter snowpack and snow water equivalent (SWE), early snow melt and stream runoff, summer drought conditions, and higher than average summer temperatures. In fact, March was more than 5°F warmer than average all across the contiguous United States, making it the warmest March since 1910 (NOAA 2007). Mountain snowpack in the Yellowstone region and much of the West was far below normal as May began. In the upper Yellowstone River basin, SWE on May 1 was only 65% of the 30-year average (1971–2000; Phil Farnes, personal communication, 2008). Discharge of the Yellowstone River near Corwin Springs peaked on May 13 at 11,000 cfs, the third lowest peak since the Yellowstone fires of 1988 (1987–2007; Figure 2). The heat continued through May, accelerating the rate of snow melt through much of the West. The 2007 ice-off date for Yellowstone Lake, May 14, was among the earliest recorded since 1951 (Figure 3). Ice-off has been taking place earlier in recent decades; seven of the earliest recorded ice-off dates on Yellowstone Lake have occurred in the last 30 years.

During summer 2007, the Yellowstone region experienced the warmest July since statewide recording of temperatures began in 1895, with mean temperature records broken in Idaho, Montana, and Wyoming (NOAA 2007). Unusually dry conditions and severe to extreme drought persisted across most of the West during summer, resulting in a fire season with the second most burned acres in the U.S.

NPS/TODD KOEL

Nez Perce Ford of the Yellowstone River during September 2007.

NPS/BRIAN ERTEL

High stream temperatures resulted in fish die-offs on the Firehole River (pictured above) and Pelican Creek.

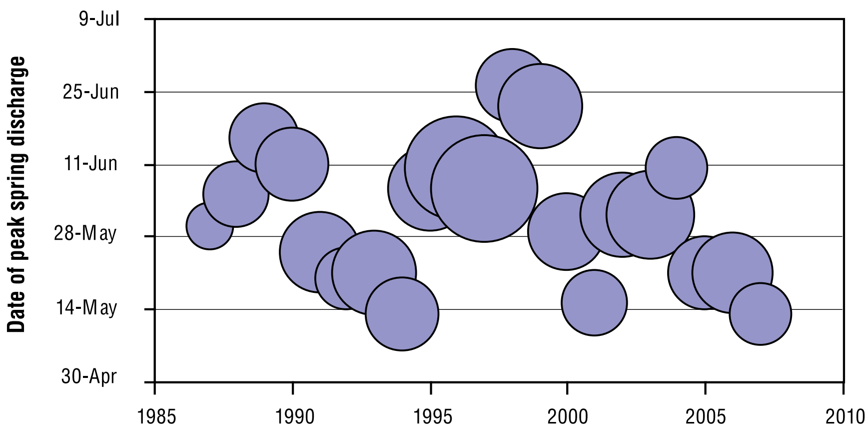


Figure 2. Dates when discharge of the Yellowstone River peaked at the U.S. Geological Survey gaging station (06191500) near Corwin Springs, Montana, January 1987–December 2007. Circle size relates to magnitude of peak discharge, which ranged from 29,900 cubic feet per second (cfs) on June 6, 1997, to 6790 cfs on May 30, 1987. The year 2007 had the lowest peak discharge since 1987, and it was tied with 1994 for having the earliest date of spring peak discharge (May 14) during this period of record.

in the historical record. In Yellowstone, a total of 27 fires occurred in 2007, the most significant of which were the Columbine Fire (east side of Yellowstone Lake; 18,595 acres) and the Owl Fire (Specimen Creek watershed; 2,810 acres; Joe Krish, Yellowstone Wildland Fire, personal communication, 2007). For the park's coldwater fishes, the heat and drought reduced the available habitat (reduced volume), and elevated stream temperatures caused high stress. These conditions affected popular fisheries throughout the park, including those on the northern range (Figure 4). Overall, the 2007 water year in Yellowstone resulted in challenging conditions for fish, visiting anglers, and park managers alike.

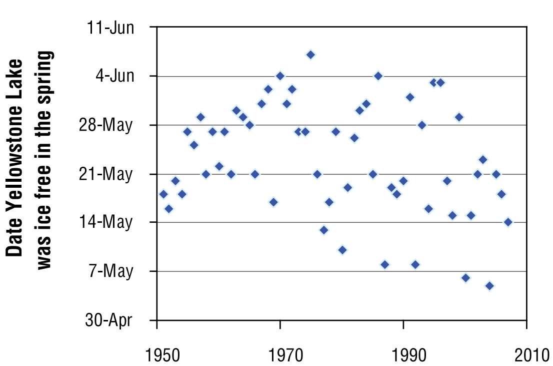


Figure 3. Dates in the spring when Yellowstone Lake first became free of ice, 1951–2007. The seven earliest dates (all before May 14) have occurred in the last 30 years. Data complied by Phil Farnes.

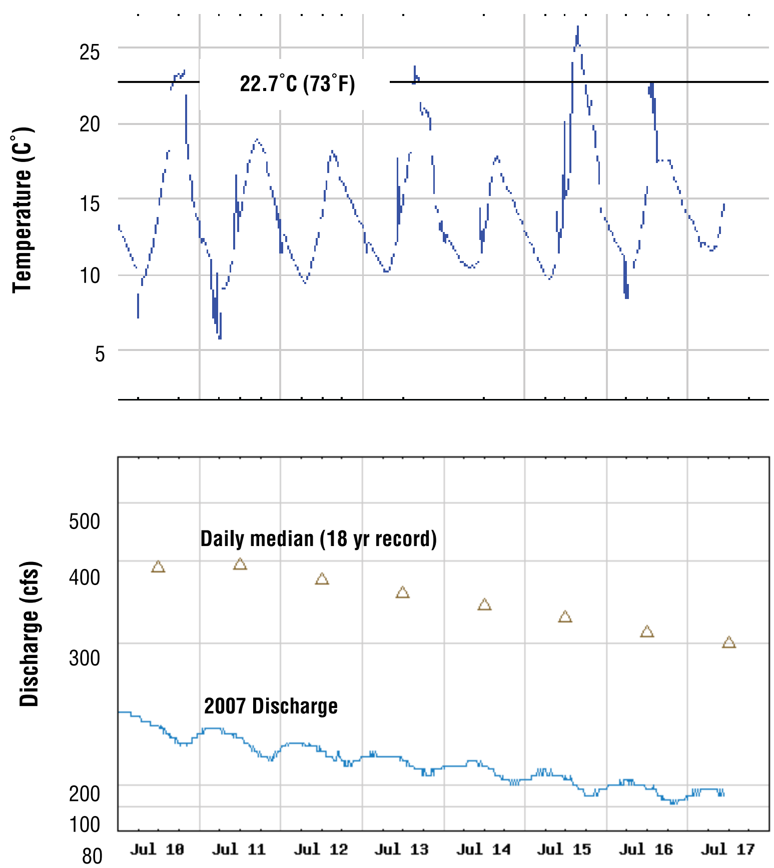


Figure 4. Hourly stream temperature and discharge, and the long-term (18 years) median discharge of Soda Butte Creek at the U.S. Geological Survey gaging station (06187950) during a period when restrictions were placed on fishing in the park, July 2007. Horizontal line (22.7°C [73°F]) represents temperature criteria used (in part) to guide fishing closures.

The Fisheries Program

NPS/TODD KOEL

Fisheries crew hiking to an electrofishing site at the headwaters of Mountain Creek in the Teton Wilderness.

NPS/DEREK RUPERT

Yellowstone cutthroat trout-westslope cutthroat trout hybrid from Grayling Creek.

Primary Emphasis Areas

The aquatic resources of Yellowstone National Park and the ecosystems they support are threatened by the presence of species that are non-native (from elsewhere in North America) and exotic (from another continent). For the foreseeable future, the Fisheries Program will focus the greatest effort on two 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 planning/compliance efforts leading toward Yellowstone cutthroat trout restoration on streams across the northern range.

EEFJE SMIT

NPS aquatic ecologist Jeff Arnold and MSU water quality technician Ty Harrison sampling Soda Butte Creek for metals in September 2007.

AUDREY SQUIRES

NPS fisheries technician Stacey Sigler with a lake trout from Yellowstone Lake.

Preservation of Yellowstone Lake Cutthroat Trout

Yellowstone Cutthroat Trout Long-term Monitoring

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 primarily because of isolation provided by the Lower and Upper Falls of the Yellowstone River, located 25 km downstream from the lake. In addition, purity has been maintained because of the fortuitous failure of early attempts to introduce several non-native species (Varley 1981). The genetic purity of these Yellowstone Lake cutthroat trout makes them extremely valuable; however, the population has been exposed to three stressors, including non-native lake trout (Kaeding et al. 1996), the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease; Koel et al. 2006*a*), and the effects of a continued drought across the Intermountain West.

The presence of lake trout in Yellowstone National Park is the result of the intentional stocking of the historically fishless Lewis and Shoshone lakes in 1890 (Varley 1981). In the mid-1980s, lake trout were moved illegally from Lewis Lake to Yellowstone Lake (Munroe et al. 2005; Stott 2004) where, as top-level predators, they consume native cutthroat trout. The park places a high priority on preservation and recovery of this cutthroat trout population because of its 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, especially in the Yellowstone Lake area (Schullery and Varley 1995).

The declining number of cutthroat trout that return to Yellowstone Lake tributaries to spawn in the spring suggests that cutthroat trout abundance in the lake has declined to its lowest recorded level. The Fisheries Program maintains

NPS/PAT BIGELOW

NPS fisheries technician Brian Ertel with a Yellowstone cutthroat trout from the Clear Creek spawning migration trap.

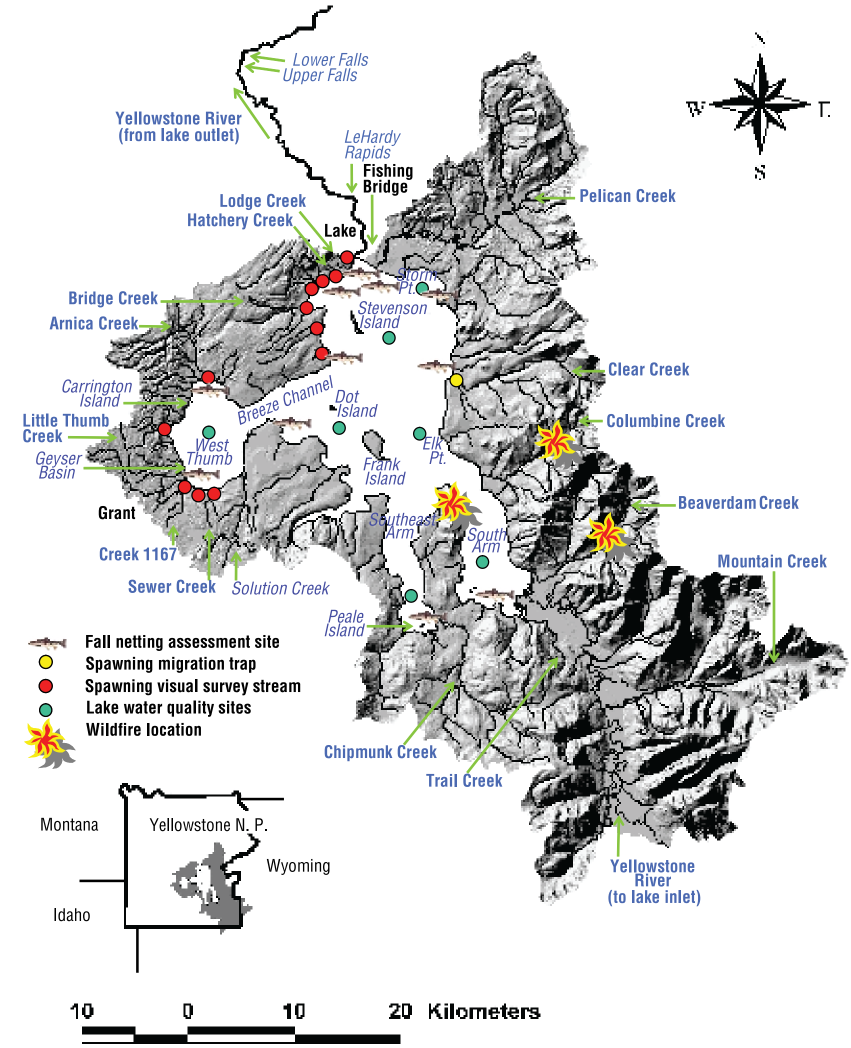
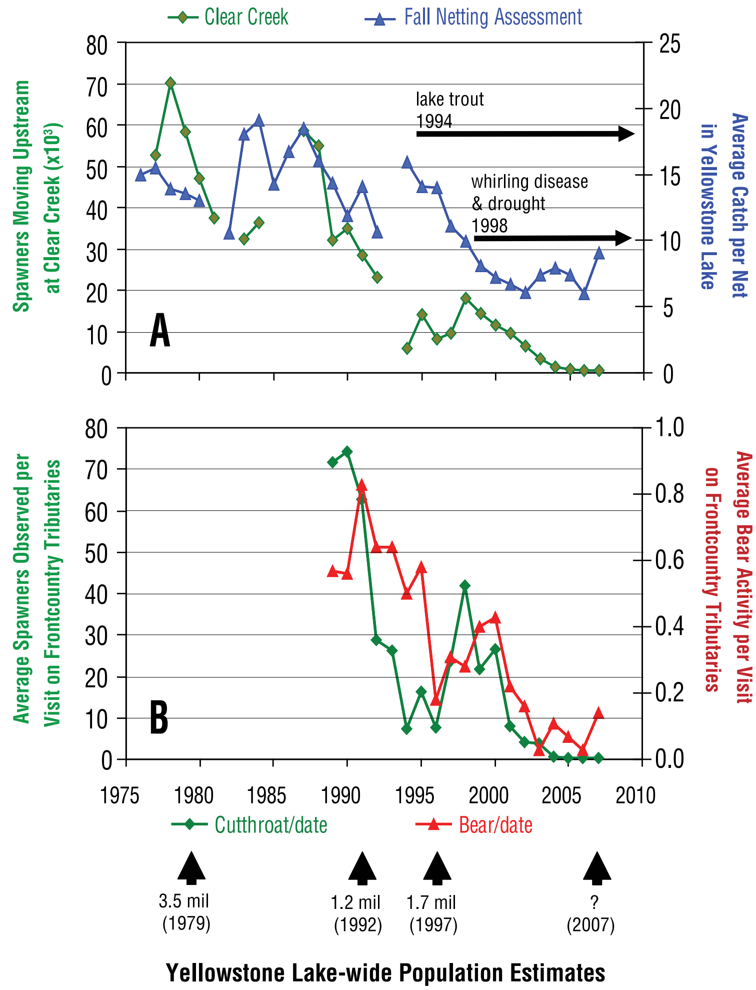


Figure 5. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

a weir/fish trap and backcountry cabin at Clear Creek, a large tributary along the lake's eastern shore (Figure 5). We counted 538 cutthroat trout as they migrated up Clear Creek in 2007; very similar to the count of 489 obtained in 2006 (Figure 6A), but far below the 917 seen in 2005; 1,438 in 2004; 3,432 in 2003; and 6,613 in 2002. The largest number of cutthroat trout recorded at Clear Creek since the first count in 1945 was 70,105 in 1978 (Jones et al. 1979). The 1970s and early 1980s were certainly the "good old days" for cutthroat trout and angling on Yellowstone Lake and the Yellowstone River. Closure of the lake hatchery operations, more restrictive harvest regulations, and the shift to a catch-and-release ethic by anglers allowed the fishery to rebound from the low levels of the 1950s (Gresswell and Varley 1988). Because some fish avoid the Clear Creek trap, especially in years when the weir is overtopped with flood flows, and some fish may have passed through the trap more than once and been double counted in years when electronic counters were used, the counts we obtain are not the actual total number of fish migrating to spawn. However, despite this imprecision in the annual counts, they provide an index of cutthroat trout abundance in Yellowstone Lake that is relatively consistent and has proven invaluable as we ascertain the impacts of lake trout, whirling disease, and persistent drought on the system (Koel et al. 2005).

The prevalence of cutthroat trout as well as bear activity is also estimated annually by walking the stream banks of 9–11 tributaries along the western side of the lake between Lake and Grant (Reinhart and Mattson 1990; Reinhart et al. 1995; Figure 5). Since this monitoring began in 1989, when spawning reaches were delineated on each tributary, the reaches have been walked upstream once each week from May through July. The cutthroat trout are often seen from behind as spawning pairs near redds. In addition to counting the cutthroat, any evidence of black bears (*U. americanus*) and grizzly bears—such as the presence of scat, parts of consumed trout, fresh tracks, and/or bear sightings—is recorded. These surveys indicate a significant decline of spawning-aged cutthroat trout in Yellowstone Lake, and the variation in spawner abundance (the annual means in all surveyed tributaries) follows a trend very similar to that observed at Clear Creek (Figure 6B). Spawning cutthroat trout declined for several years after the 1988 fires and comparatively low numbers spawned in 1994–95. A slight rebound occurred after the high water years of 1996–97, but numbers of spawning cutthroat showing up in tributaries have fallen annually since then to unprecedented levels. Of great concern is the potential impact of this decline on consumer species. Bear activity at the 9–11 frontcountry streams has mirrored the spawning cutthroat decline, revealing the cascading effects of the cutthroat loss (Figure 6B; Koel et al. 2005; Gunther et al. 2007).

Figure 6. (A) 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 (1976–2007) and (B) 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, 1989–2007. 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 estimate is available for the current population.



In most years since 1969, cutthroat trout have also been monitored by a fall netting assessment in which five 125-foot long, multi-mesh-size gillnets are set in shallow water at 11 sites throughout the lake (Figure 5) overnight. The average number of cutthroat trout caught per gillnet this year was 9.1, which is much higher than in previous years and the highest since 1998 when 9.9 trout were caught per gillnet (Figure 6A). While this is exciting to see, it is important to consider that most of the cutthroat trout captured were small, juvenile fish, whereas those caught in earlier years, such as 1998, were larger and had much higher reproductive potential. A large proportion of the cutthroat trout currently in Yellowstone Lake are 180–300 mm, whereas prior to the lake trout population expansion (in 1982, for example), the population was comprised largely of fish 340–460 mm (spawning-sized adults) (Figure 7). The current population abundance and size structure appears better than that seen in the previous five years (2002 for example; Figure 7), and our hope is that these young cutthroat survive and return as spawning adults in tributary streams in the coming years.

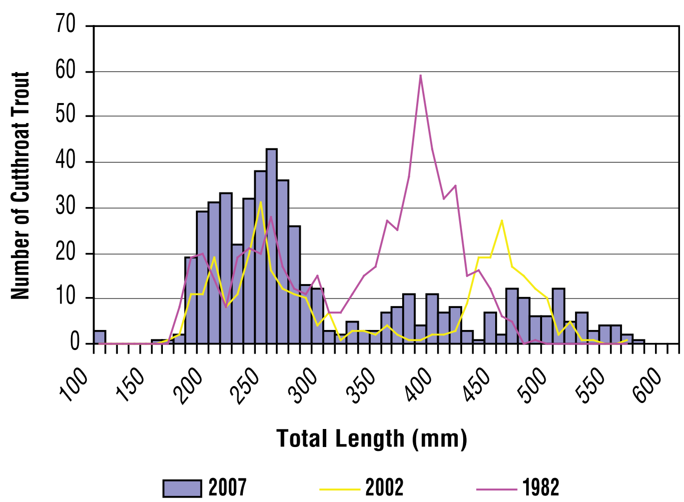


Figure 7. Length-frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake following high (2007), moderate (2002), and no (1982) predation pressure by non-native lake trout. The 1982 cutthroat trout population was free from most threats and had a healthy size/age structure. By 2002 the population had undergone significant predation pressure from lake trout, with an apparent failure of recruitment to maturity for multiple year classes.

Status of Cutthroat Trout in the Upper Yellowstone River

In 2003 the Yellowstone Fisheries Program partnered with the Wyoming Game and Fish Department to initiate a comprehensive survey of the remote upper Yellowstone River region (Koel et al. 2004). The fifth and final field season of work associated with this project took place in 2007, when several previously unsurveyed watersheds were searched for cutthroat trout. Mountain Creek was sampled from June 27 to June 30 above its confluence with Howell Creek to verify the upstream extent of spawning cutthroat from Yellowstone Lake and locate any resident fish (Figure 8). We also completed sampling in Badger, Cliff, and Escarpment creeks. In an attempt to document the presence of any fluvial, stream-resident populations, our sampling took place after August 1 because information obtained via radiotelemetry in previous years indicated that migratory, spawning cutthroat trout from Yellowstone Lake would likely have returned to the lake by that time. Sampling later in the year also allows time for fry to emerge from the stream bottom and become susceptible to our electrofishing gear. To aid in correlating distribution and movement of cutthroat trout with physical characteristics

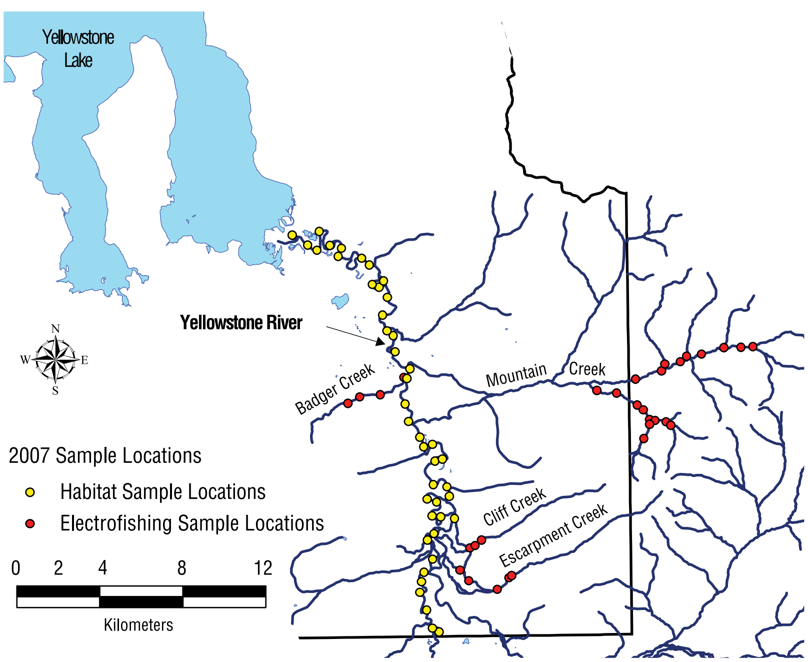


Figure 8. Locations of habitat and electrofishing surveys in the Yellowstone River drainage upstream of Yellowstone Lake in 2007.

NPS/TODD KOEL

NPS/TODD KOEL

Yellowstone cutthroat trout juveniles (top) and adult from the Mountain Creek watershed, Teton Wilderness. The adult was a migrant from Yellowstone Lake.

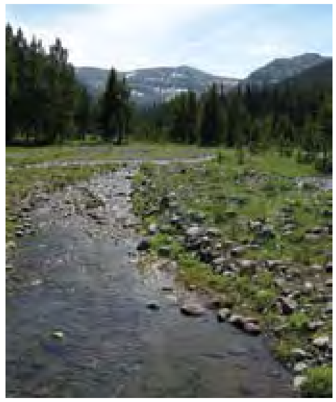
of the river, we also completed fisheries habitat assessment surveys on the main stem of the Yellowstone River.

As has been the case in previous years, access to the upper Yellowstone River region was difficult in June, and sampling of Mountain Creek was only minimally successful. Early season run-off contributed to high water flows, making it difficult to net fish. We were able to net a total of 31 cutthroat trout in 8 sections of Mountain Creek's mainstem, and just 6 cutthroat trout were captured within 10 sections of the largest tributary. Only two of the captured fish were old enough to spawn, indicating that spawning activity in the upper reaches of Mountain Creek and its tributaries may be minimal.

Only Yellowstone cutthroat trout were captured during our sampling of Badger, Cliff, and Escarpment creeks. Cutthroat trout lengths ranged from 29 to 195 mm (mean 54.8 mm) and ages were 0–2 years. Fish were captured throughout Badger Creek, but were limited to the lower 3 km of both Cliff Creek (due to a barrier waterfall) and Escarpment Creek (possibly due to a lack of habitat). Cutthroat trout densities were highest in Cliff Creek, averaging 500 fish/km, of which 66% were newly emerged fry. Badger Creek supported 187.5 fish/km (83% fry), and Escarpment Creek held just 10 fish/km (60% fry). These data

Cutthroat trout densities were highest in Cliff Creek, averaging 500 fish/km, of which 66% were newly emerged fry.


NPS/BRIAN ERTEL


NPS/TODD KOEL


NPS/TODD KOEL

Fisheries stock Sammy, Scotty, Pat, and Ethan packing in to Mountain Creek (left); Howell Creek within Yellowstone Park (center); fisheries technician Brian Ertel leading an electrofishing crew on a small tributary to Mountain Creek (right).

suggest that Cliff and Badger creeks support substantial cutthroat trout spawning activity but not resident, adult fish.

Fisheries habitat assessment conducted in 41 (500 m) sections of the mainstem Yellowstone River indicated that the river drops only 34 m in elevation over the 41 river km between the park's south boundary and Yellowstone Lake (Figure 8). Habitats classified as run/glide comprised 91% of the mainstem river, with low gradient riffles and pools making up 8% and 1%, respectively. Dominant substrates were gravel and sand, each comprising 37% of the stream bottom. Other substrates included cobble (25% of the bottom) and clay (1%).

Multiple Stressors Affect Cutthroat Trout

Yellowstone fisheries biologists are often asked which of the three stressors in the lake system—whirling disease, lake trout, or drought—has caused the most harm to the cutthroat trout population. To date we have documented whirling disease severe enough to cause population-level declines only in Pelican Creek and the Yellowstone River downstream of Fishing Bridge. This has coincided with the disease being most prevalent in juvenile and adult fish netted from the lake's northern regions (Koel et al. 2006*a*). Lake trout continue to be most abundant in the West Thumb, although they occur lake-wide and we have continued to note a reduction in available habitat and disconnect of tributaries all around Yellowstone Lake due to persistent drought. This tributary/lake surface water disconnect has occurred most often during late summer and fall, when young cutthroat trout fry would typically be attempting to escape to the lake. Overall, however, cutthroat survival to spawning age in this system is dependent on 1) the ability of fry to avoid whirling disease; 2) the ability of fry and juveniles to avoid predation by lake trout within Yellowstone Lake; 3) the ability of fry to out-migrate from tributaries to Yellowstone Lake; and 4) other normal environmental factors. These factors represent a truly incredible gauntlet that the native cutthroat trout are required to run in order to survive! Because of the relatively restricted distribution of whirling disease, we attribute a majority of the cutthroat trout loss to lake trout predation and continued drought conditions.

…we attribute a majority of the Yellowstone Lake cutthroat trout loss to lake trout predation and continued drought conditions.

Lake Trout Suppression Program

Efforts to remove lake trout from Yellowstone Lake have been ongoing since their presence was first confirmed in 1994. The initial focus was on developing basic removal techniques using gillnets, the recommended action (McIntyre 1995). By 1998, however, we began more aggressive efforts, such as netting much deeper (40–60 meters) and extending net soak times to a week or more. Further strides were made beginning in 2001 with increases in net inventory, seasonal staff dedicated solely to lake trout removal, and acquisition of a Great Lakes-style gillnetting boat, the NPS *Freedom*, which has made it possible to deploy and process more gillnets.

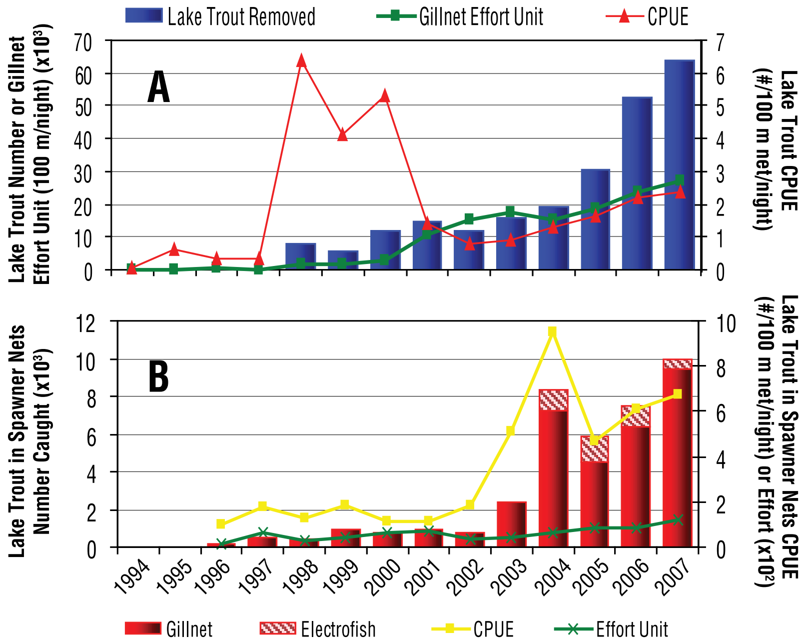


Figure 9. (A) Number of lake trout removed, gillnet units of effort (1 unit = 100 m of net/night), and lake trout catch per unit of effort obtained with control nets, 1994–2007. (B) Number of mature lake trout removed by gillnetting and boat-mounted electrofishing near Yellowstone Lake spawning locations (Breeze Channel, Carrington Island, Geyser Basin, and Solution Creek) late August–early October, 1996–2007.

Since 1994, more than 272,000 lake trout have been removed from Yellowstone Lake (Figure 9). Lake trout suppression efficacy has increased as a result of advances in staff knowledge and use of technologies, as evident in improved gear-handling, development of a detailed bathymetric map of the lake, and a better understanding of variation in seasonal lake trout distribution. By using a geographic information system (GIS) to map catch rates of both lake trout and cutthroat trout for each gillnet mesh size, we have been able to adapt site selection in real time during the netting season, and maintain high catch rates of lake trout while minimizing the catch of cutthroat trout.

In 2007, we removed 74,038 lake trout from Yellowstone Lake, most via a gillnetting effort that was nine times greater than that undertaken in 2000 (Figure 10). However, along with increases in total number harvested, catch-per-unit-effort (CPUE) has been increasing since 2002 and is a serious cause for concern. Further, 2007 saw the second highest number of spawning lake trout removed from

NPS/STACEY SIGLER

Gut contents of five lake trout from Yellowstone Lake provide evidence of the significant impact that these predacious fish can have on a native cutthroat trout population.

NPS/PAT BIGELOW

NPS/PHILIP DOEPKE

NPS/STACEY SIGLER

NPS/STACEY SIGLER

(Top to bottom) Gillnets used by the lake trout suppression program require constant repair and periodic replacement; volunteers from Montana Fish, Wildlife and Parks assist with gillnetting; each lake trout remaining in Yellowstone Lake consumes many native cutthroat trout each year; Student Conservation Association intern Connor Gorgi with a large lake trout netted near a spawning area on Yellowstone Lake.

the population to date. Catches from both the deep water netting (targeting younger lake trout) and spawner netting (targeting those fish congregating in preparation to spawn) indicate exponential growth in numbers (r^2=0.89 and r^2=0.91, respectively), suggesting that more effort or new techniques are needed in order to slow further population growth.

In recent years we have noted that gillnet catch rates tend to be very high immediately after the lake is ice-free, usually in late May. In 2007 we made a concerted effort to take advantage of this period, which led to the removal of over 10,000 lake trout during the first five days that we lifted nets (15.8% of the total annual catch in control nets). In addition, in 2007 we used some smaller (38-mm bar measure) gillnets, along with larger sizes (44, 51, 64, and 76 mm) during the spawning season to target immature lake trout that have been aggregating near known spawning areas. Hopefully the removal of these fish will help to slow recruitment to spawning age in the coming years.

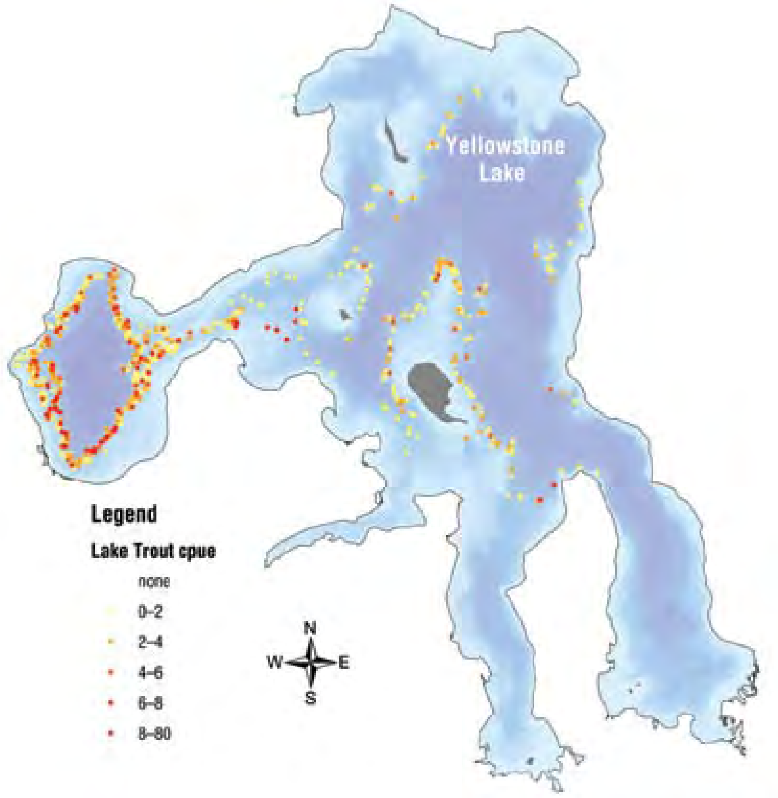


Figure 10. Catch-per-unit-effort (1 unit = 100 m of net set per night) of lake trout by gillnets set on Yellowstone Lake, 2007.

Lake Trout Control Netting

The majority (95%) of removal efforts in 2007 were control net sets targeted at young lake trout residing at depths typically greater than those occupied by cutthroat trout. On a typical day during June through August, up to 15 miles of 25–38-mm bar measure gillnets were in place along the lake bottom in 40–65 m of water. Beginning in mid-August, the use of these nets was reduced so that staff could target lake trout preparing to spawn. From mid-September through mid-October, we fished approximately 6 miles of control nets daily. As in past years, lake trout carcasses were returned to the lake to avoid removing nutrients from the system and to increase handling efficiency.

Control nets removed 63,776 lake trout (87% of the overall catch) in 2007 (Figure 9). For the third year in a row, the majority of this catch (46% in 2007) was in our 25-mm gillnets, the smallest size used consistently. Catch rates for 32-mm mesh were also high, similar to those obtained in 2006 (Figure 11). This likely indicates strong recruitment from spawning in 2003 and 2004, when we had high catch rates of spawning lake trout. Given the abundance of spawning fish seen in 2005, 2006, and 2007, we expect high catch rates in small mesh-size nets to continue in coming years.


NPS/AUDREY SQUIRES

Lake trout entangled in a gillnet set during the spawning season on Yellowstone Lake.

NPS/PHILIP DOEPKE

The Wyoming Game and Fish Department continues to support efforts to suppress lake trout. Here, Rob Gipson and Bill Wengert electrofish near Carrington Island.

Lake Trout Spawner Removal

Lake trout in Yellowstone Lake congregate from late August until early October in preparation for spawning. Focusing on these larger lake trout when the opportunity arises is important to reduce both predation on cutthroat trout and the reproductive potential of and further recruitment to the lake trout population. Spawning areas identified to date are near Carrington Island, northwest of Solution Creek, northeast of West Thumb Geyser Basin, in the middle of Breeze Channel, and north of Snipe Point (Figure 12). An area adjacent to the Grant Marina has proven productive as well. Except for Snipe Point, these areas were intensely netted during the spawning season using 38- to 89-mm mesh sizes (Figure 13). Nets were also deployed in a search for spawners throughout West Thumb, Breeze Channel, and in a few areas in the main basin of the lake. Overall, we increased our spawner netting efforts 33% over 2006 and removed 9,543 lake trout (Figure 9).

Because spawner nets cover more than just the spawning area, and because of the mesh sizes used, many of the lake trout captured were immature and would not have spawned in 2007. Mean total length of spawning lake trout caught in gillnets was 535.4 mm, similar to that of the

...of the mature lake trout caught near spawning areas in 2007, 95% were removed before being able to complete spawning.

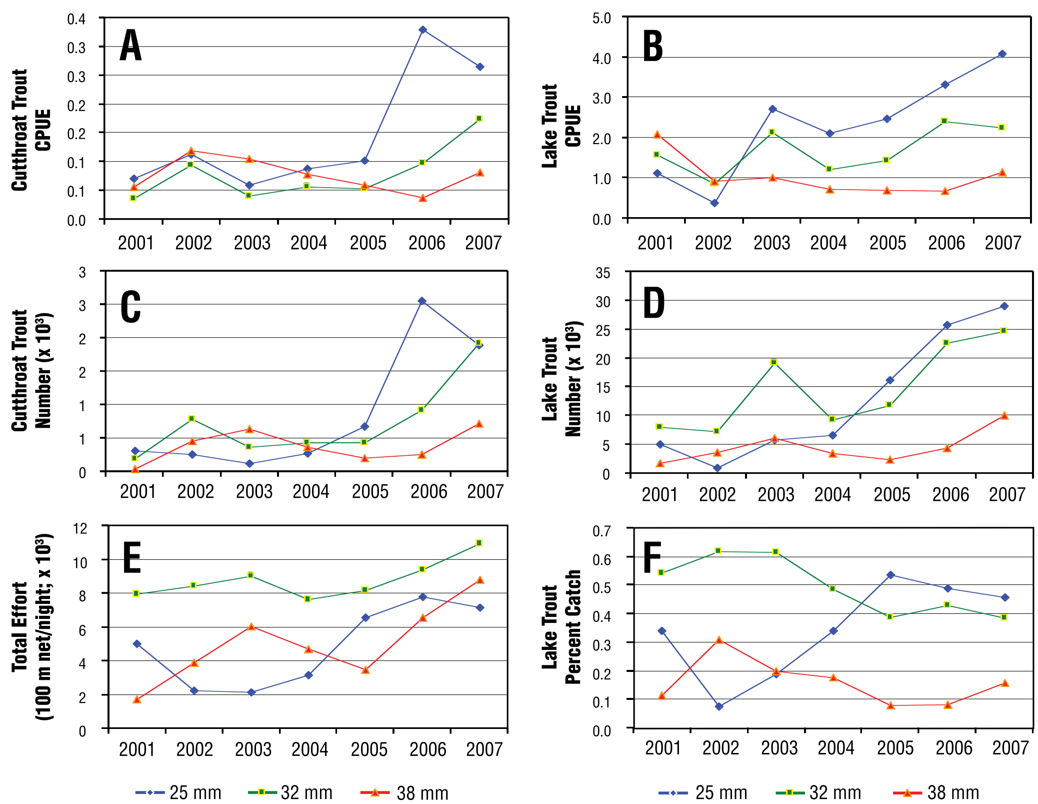


Figure 11. (A, B) Catch-per-unit-effort (1 unit = 100 m of net set per night), (C, D) total catch, (E) total effort of both lake trout and cutthroat trout and (F) percent of total catch of lake trout among three gillnet mesh sizes used on Yellowstone Lake, 2001–2007.

past four years (Figure 14). However, the mean total length of females was larger than males, at 572.5 mm and 519.7 mm, respectively, and the male-to-female catch ratio was 2.3:1. The total length of the largest male and female fish caught has generally increased since 1999 (Figure 14). Overall in 2007, the lake trout caught near spawning sites included 24% that were not preparing to spawn, 49% "green" (gametes maturing but not yet ready for spawning), 22% "ripe" (ready to spawn), and 4% "spent" (had already spawned); 1% were not evaluated for spawning condition. Thus, of the lake trout caught near spawning areas in 2007, 95% were removed before being able to complete spawning.

For the fourth consecutive year, electrofishing was used to remove lake trout during the spawning season. The U.S. Fish and Wildlife Service Fishery Resource Office in Ahsahka, Idaho, again lent us their electrofishing boat. In addition, the Wyoming Game and Fish Department lent their electrofishing boat and donated staff time to assist. Poor weather conditions and mechanical difficulties limited electrofishing at the shallow spawning area surrounding Carrington Island to eight nights during September, removing 484 lake trout. An additional 49 lake trout were collected in two nights of electrofishing north of Snipe Point and the Flat Mountain Arm. Because of assistance from the U.S. Fish and Wildlife Service and the Wyoming Game and Fish Department, an a total of 533 lake trout were removed from the lake (Figure 9).

Angler catch rates have proved to be a reliable indicator of the following year's spawner catch rates by gillnetting. Simple linear regression between spawner catch rate and angler catch per hour as reported by Volunteer Angler Report (VAR) cards indicate a high correlation (R^2=0.833, $p<0.0001$; Figure 15). In 2007, reported angler catch of lake trout per hour in Yellowstone Lake tripled that of previous years, and 32% of the lake trout were 18–20 inches long, a size class likely to spawn in 2008. It's worth noting that during 2002 and 2003, the last two years that high angler catches occurred in this size class, the spawning catch rate tripled in the subsequent season. This is an indication

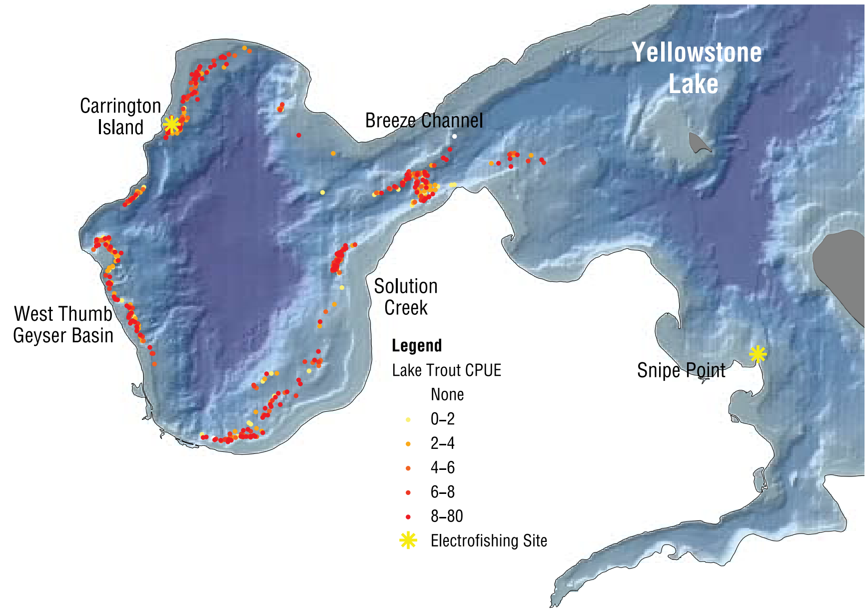


Figure 12. Catch-per-unit-effort (1 unit = 100 m of net set per night) for gillnets and locations of sites electrofished during the spawning season, 2007.

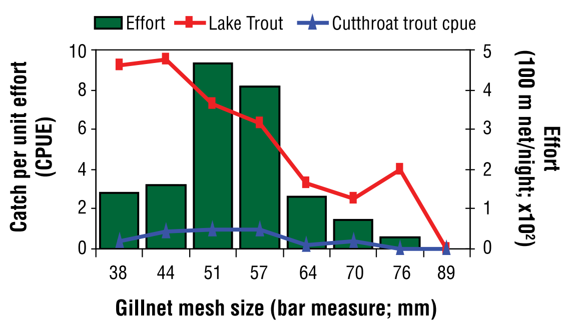


Figure 13. Catch-per-unit-effort for lake trout and cutthroat trout and total effort (1 unit = 100 m of net set per night) by gillnet mesh size for control nets used on Yellowstone Lake, 2007.

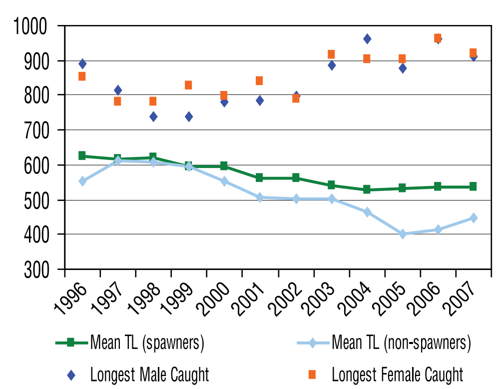


Figure 14. Mean and maximum total length (TL) of mature male and female lake trout caught near spawning areas in Yellowstone Lake, 1996–2007.

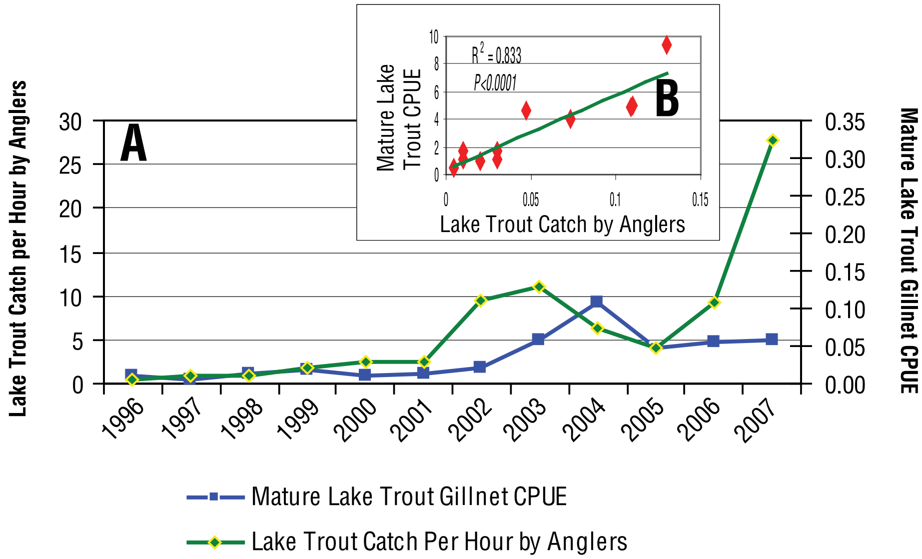


Figure 15. (A) Lake trout catch per hour by anglers and catch-per-unit-effort for gillnets set during the spawning season on Yellowstone Lake, 1996–2007. (B) Relationship between lake trout catch per hour by anglers and the catch-per-unit-effort of spawning lake trout the following year.

Angler catch rates have proved to be a reliable indicator of the following year's spawner catch rates by gillnetting.

that we should be prepared for a substantial increase in lake trout spawning in Yellowstone Lake in 2008.

Electrofishing of Lake Trout Fry

Electrical and mechanical shock has been shown to be detrimental to developing salmonid embryos (Dwyer and Fredenberg 1991; Dwyer et al. 1993). However, there is limited access to spawning areas on Yellowstone Lake while lake trout eggs are incubating (winter ice cover period). In past years, snorkelers near Carrington Island have found lake trout fry emerging from rocky substrate immediately following ice-off. In an experiment to kill these developing fry, biologists from the Wyoming Game and Fish Department brought electrofishing rafts to Yellowstone Lake within a couple weeks of ice off and shocked the spawning areas at Carrington Island. Snorkel surveys were conducted immediately before and after the shocking. Unfortunately, the relatively low electrical conductivity of Yellowstone Lake and the small fish size made the fry difficult to kill. Free swimming fry were encountered both before and after the electrofishing and no dead fry were encountered. More research into the timing of when these fish might be more susceptible to electrofishing is being planned as the method continues to hold promise for suppressing lake trout.

Accidental Catch of Cutthroat Trout

Although occasional bycatch of cutthroat trout is unavoidable, it is minimized by paying careful attention to net locations, mesh sizes, and depths. The majority of our nets are set deeper than the cutthroat trout tend to reside. When we do set nets shallow, we strive to tend them daily so that any cutthroat trout can be released alive. Despite these efforts, 2006 saw a 3.5-fold increase in cutthroat trout bycatch in 25-mm (our smallest) control nets (Figure 11). This was followed by an almost doubling of bycatch in 32-mm gillnets in 2007, indicating the persistence of these fish into another year. Bycatch in the 25-mm nets in 2007, while not as high as in 2006, was greater than in previous years (2005 and earlier) of the program. Results from our annual cutthroat trout netting assessment (described above) indicate a similar trend of increased numbers in the smallest size classes, only slight increases in the mid-size classes, and a continued decrease in the older, larger cutthroat trout as these fish reach senescence.

Restoring Fluvial Populations of Native Trout

Westslope Cutthroat Trout Source Populations

Over the past three years two populations of genetically pure westslope cutthroat trout have been discovered in Yellowstone National Park. A small tributary of Grayling Creek, now known as "Last Chance Creek," contains the only known remaining genetically pure aboriginal population. The only other known genetically pure population is in the Oxbow/Geode Creek Stream Complex in the Yellowstone River drainage, where westslope cutthroat trout were probably stocked in the 1920s (Figure 16). Both populations have been independently verified as genetically pure by multiple laboratories and found to be free of pathogens, making them extremely valuable to westslope cutthroat restoration within the park and around the region. Both populations were used this year in the High Lake restocking effort (see below), and gametes from the Last Chance Creek population were incorporated into the Upper Missouri River broodstock at the Sun Ranch hatchery in Ennis, Montana.

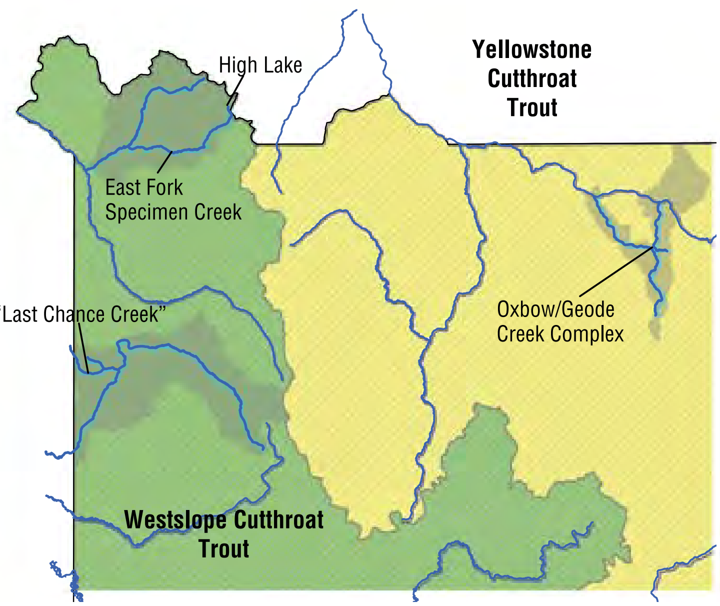
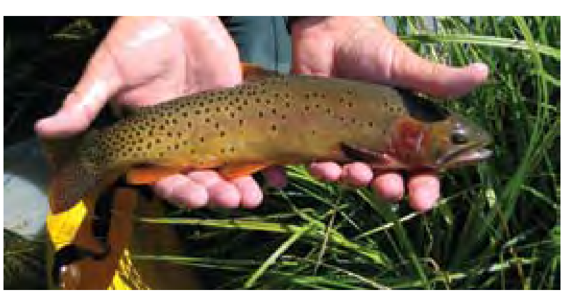


Figure 16. Historical cutthroat trout distribution in the northwestern region of Yellowstone National Park and locations of Oxbow/Geode Creek Complex, Last Chance Creek, and Specimen Creek.

Population estimates made within the past three years have revealed a stark difference between the streams. While Last Chance Creek harbors a viable population of more than 700 westslope cutthroat trout at an estimated density of 35 fish per 100 m of habitat, the Oxbow/ Geode Complex population is extraordinarily



NPS/BILL VOIGT

NPS/DEREK RUPERT

Yellowstone cutthroat trout from Trout Lake in the Soda Butte Creek watershed (left). Westslope cutthroat trout from Geode Creek, a tributary of the Yellowstone River (right).


NPS/TODD KOEL


NPS/TODD KOEL


NPS/TODD KOEL


NPS/DEREK RUPERT


NPS/TODD KOEL


NPS/TODD KOEL

Top: Montana Fish, Wildife and Parks westslope cutthroat trout specialist Lee Nelson and MSU fisheries technician Derek Rupert collecting gametes on Last Chance Creek (left); Sun Ranch westslope cutthroat trout hatchery (center); egg incubation trays at the Sun Ranch hatchery (right). Bottom: Gametes after maturation at Sun Ranch (left); High Lake inlet stream with remote site incubator (center); westslope cutthroat trout fry in their new habitat at High Lake (right).

robust, with more than 13,000 individuals at a density 158 fish per 100 m. The reasons for the extremely high fish density in the Oxbow/Geode Complex are unclear and cannot be simply explained by stream size or temperature. The difference in population size warrants different approaches to their utilization as brood sources for restoration efforts (see below). Both populations are being closely monitored to ensure egg and fish collection efforts do not jeopardize their viability.


NPS/TODD KOEL

High Lake and one of its inlet streams at the headwaters of Specimen Creek.

High Lake Westslope Cutthroat Trout Introduction

In 2007 the East Fork Specimen Creek westslope cutthroat trout restoration project again focused on High Lake. To assess the efficacy of the two piscicide treatments done in 2006 (Koel et al. 2007), we checked gillnets that had been left overwinter for evidence of any remaining, introduced adult Yellowstone cutthroat trout and seined the entire littoral zone to look for juvenile fish. These efforts and extensive visual surveys confirmed the absence of fish in High Lake and eliminated the need for an additional piscicide application planned for 2007. It also ensured that stocking westslope cutthroat in the lake could begin during the 2007 field season.

The stocking effort used genetically pure westslope cutthroat trout from the park's two known populations and from the Upper Missouri River broodstock at the Sun Ranch Hatchery. On June 22, 1,200 eyed eggs were flown from the Sun Ranch Hatchery to High

Lake via helicopter and placed in remote site incubators (RSIs). Three weeks later, 177 fertilized eggs collected from 8 female and 12 male wild trout in Last Chance Creek were taken to High Lake on horseback and placed in additional RSIs (Figure 17). On July 25 and 27, trout of various age-classes were flown from the Oxbow/Geode Creek Complex to High Lake via helicopter (Figures 18 and 19).

Subsequent monitoring indicated initial success of all 2007 stocking efforts. Eggs from both sources had a high hatching success rate, indicated by the low number of unhatched eggs left in the incubators and an abundance of fry visible in the inlet streams. Fry were also observed in various locations around the lake margin. Adult fish were seen in the littoral zone feeding on aquatic invertebrates, and several were captured by hook and line. The captured adults appeared robust and healthy and all were released

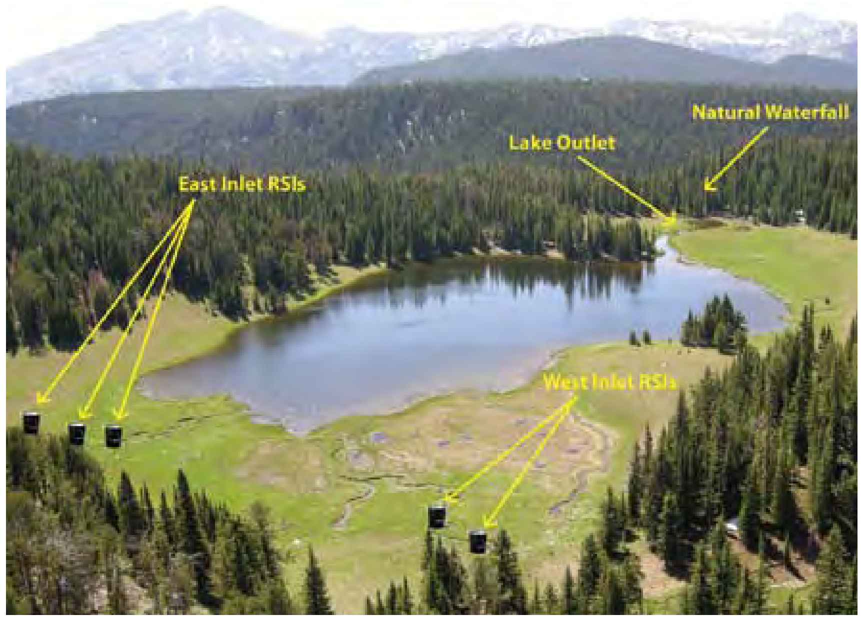


Figure 17. High Lake at the headwaters of East Fork Specimen Creek with locations of remote site incubators (RSIs) during westslope cutthroat trout introduction efforts in 2007.

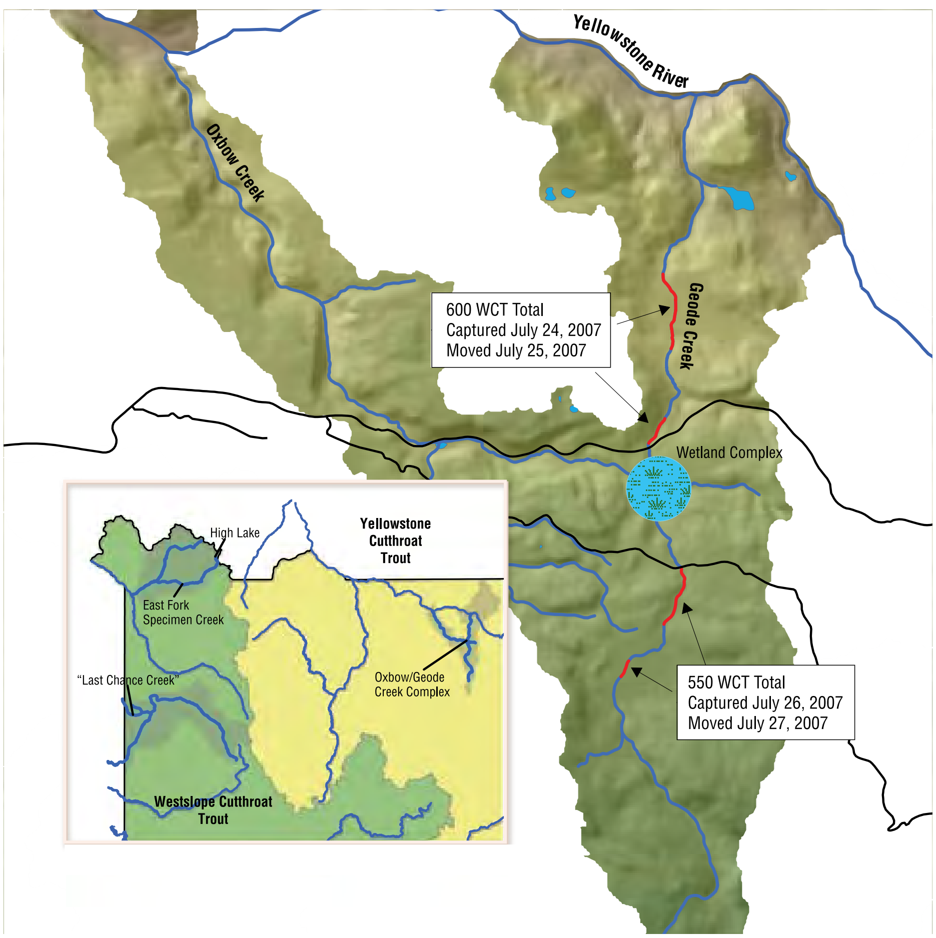


Figure 18. Oxbow/Geode Creek Complex in the northern range of Yellowstone National Park with locations of westslope cutthroat trout collections from Geode Creek in 2007 for purposes of restocking High Lake.


NPS/TODD KOEL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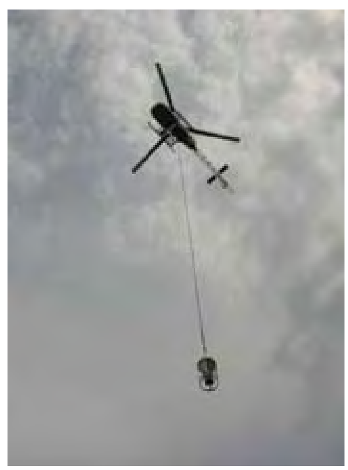
NPS/TODD KOEL


NPS/TODD KOEL

Top row: Geode Creek watershed downstream from the Grand Loop Road (left); fisheries crew collecting westslope cutthroat trout from Geode Creek (center); westslope cutthroat trout held in the shade prior to transport (right). Center row: Examples of westslope cutthroat trout introduced to High Lake. Bottom row: Crew from Yellowstone Wildland Fire use a helicopter to quickly move westslope cutthroat trout to High Lake.

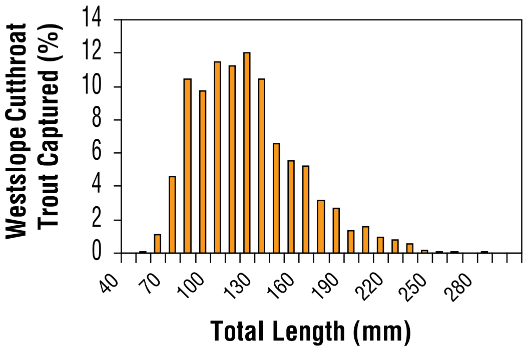

Figure 19. Length-frequency distribution of westslope cutthroat trout collected from Geode Creek and moved to High Lake in 2007.

unharmed. A grebe, a bird species that often eats fish, was also observed on the lake during this time, indicating that other wildlife dependent on fish were beginning to return to the area.

Owl Fire Impacts Specimen Creek Operations

Westslope cutthroat trout restoration efforts in 2007 were limited to High Lake largely because the Owl Fire, a naturally caused 2,810-acre wildfire, burned through a portion of the East Fork Specimen Creek restoration area. One of the most intensely burned areas was the barrier construction site, where construction of a 2-m tall, beaver dam-style barrier to upstream fish movement had begun in 2006. Considerable work, including a 76-m water diversion structure, and approximately 40 mule loads of equipment and supplies were completely destroyed by the fire. However, the fire's most significant impact was that we were unable to work at the site due to dangers posed by the fire itself and later by hazard trees left in the wake of the burn. In-stream bioassays planned for the 2007 field season were cancelled and no progress was made toward construction of the barrier. Delays in overall project completion will likely result.

NPS PHOTO

The Owl Fire burned the Specimen Creek watershed in 2007.

NPS/DEREK RUPERT

NPS/DEREK RUPERT

The water diversion structure built at the East Fork Specimen Creek fish barrier site before (top) and after (bottom) the Owl Fire.

Considerable work, including a 76-m water diversion structure, and approximately 40 mule loads of equipment and supplies were completely destroyed by the fire.

Potential of Returning Arctic Grayling to Grayling Creek

"Among the native (fish) species, the Arctic grayling have suffered the most from man's activities (Dean and Mills 1974)."

Grayling Creek, a tributary of the Madison River (now of Hebgen Reservoir), was historically home to fluvial (stream-dwelling) Arctic grayling (Jordan 1891; Evermann 1893). However, like the fluvial grayling in all other park waters, the grayling of Grayling Creek disappeared by the 1950s due to non-native

NPS/DEREK RUPERT

fish introductions and completion of the Hebgen Dam (Kaya 2000), which submersed the stream's lower reaches where grayling were most abundant. Grayling Creek was investigated in 1970 as the most likely watershed for fluvial grayling restoration (Dean and Mills 1971). Although the lower of the two barriers reported by this survey would have prevented the upstream invasion of non-native fish from Hebgen Lake into the restoration area (Figure 20), a subsequent investigation in 1973 revealed that the lower barrier had been the 12-ft scarp of the 1959 Hebgen Lake earthquake, and that it had since been washed away. Grayling Creek therefore appeared to hold little promise as a grayling refuge and the restoration plans were abandoned (Dean and Mills 1974). However, a 1982 survey of Grayling Creek to assess water quality, fish habitat, and existing barriers (Jones et al. 1983) determined that the upper falls, approximately 2 m in height at that time, would be an effective barrier to upstream movement by fish.

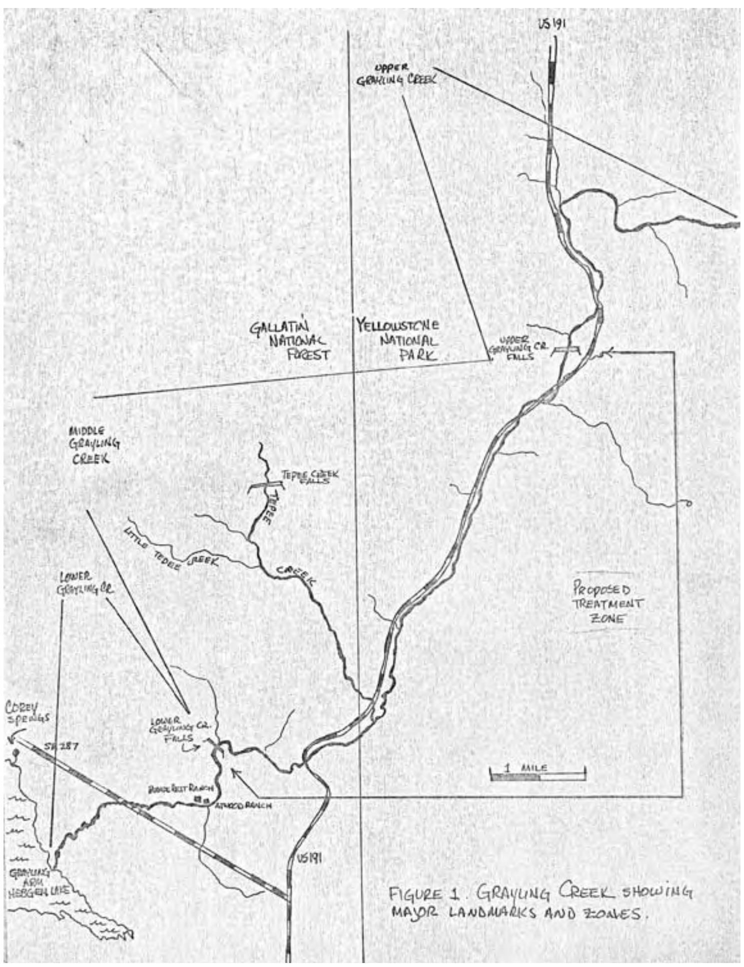

Figure 20. Previously unpublished map from 1970 of Grayling Creek in Yellowstone National Park and the Gallatin National Forest indicating the (middle) reach proposed for piscicide treatment to remove non-native and hybridized fish and restore fluvial Arctic grayling. By 1973, the lower falls, which were a scarp from the 1959 Hebgen Lake earthquake, had been cut through by the creek and judged not to be an effective fish barrier.

MTFWP/AUSTIN MCCULLOUGH

The upper reaches of Grayling Creek were surveyed in 2007 for trout and habitat suitable for supporting Arctic grayling.

We recently determined that the Arctic grayling of the Gibbon River, occasionally caught by anglers, are genetically similar to the introduced, adfluvial populations inhabiting Grebe and Wolf lakes at the system's headwaters (Steed 2007; Koel et al. 2007). As such, they do not represent remnants of the fluvial grayling which were once native to this stream below Gibbon Falls. Because we do not know of any remaining fluvial Arctic grayling in Yellowstone, there is a need to reevaluate all watersheds within the species' native range to locate suitable habitat for fluvial grayling reintroduction efforts. Similar to biologists in the early 1970s and 1980s, we view Grayling Creek as having great potential for a native species restoration project. In September 2007 park fisheries staff teamed with Montana Fish, Wildlife and Parks to survey reaches of Grayling Creek upstream of the natural, bedrock barrier that exists deep in the canyon adjacent to U.S. Highway 191 (upper barrier of Dean and Mills 1971; Figure 20) and assess its suitability for a fluvial Arctic grayling and westslope cutthroat trout restoration project. The stream was walked from its uppermost crossing with the highway to the headwater reaches of the two forks nearly 10 miles upstream. Montana Fish, Wildlife and Parks staff collected habitat data (pool size and depth and spawning tributary suitability) and park staff collected fisheries

data (species composition, length, weight, and genetics) via hook and line sampling.

Results of this cooperative effort indicated that Grayling Creek upstream of the upper falls may be suitable for fluvial arctic grayling introduction; however, brown trout persist for several miles upstream and would need to be removed for the project to succeed. Results of the genetic analyses are pending, but visual inspection indicates that genetic purity of westslope cutthroat trout improves in the uppermost reaches of the drainage. Montana Fish, Wildlife and Parks and the Gallatin National Forest have already contributed significantly to the project and indicated that this effort would have important implications for the overall status of fluvial Arctic grayling throughout the region. Further study of the existing fish populations and the Grayling Creek's restoration potential is planned for 2008.

Yellowstone Cutthroat Trout Restoration on the Northern Range

Additional sampling, planning, and preparations were carried out for streams across Yellowstone's northern range in anticipation of future Yellowstone cutthroat trout restoration. Most importantly, extensive barrier testing was conducted on the lower Elk Creek cascades. During four sampling events almost 300 brook trout were captured above the cascades, marked, inspected for previous marks, and moved downstream. No marks were recovered upstream (which would have indicated upstream fish passage) and initial indications are that the cascades are a barrier to upstream fish movement. Additional sampling will be conducted during the summer of 2008 to confirm these findings.

A similar testing method was applied to artificial beaver dams placed by willow researchers on Blacktail and Little Blacktail Deer creeks, none of which were barriers to upstream movement of brook trout. Brook trout distribution was sampled on Carnelian Creek, Glen Creek, and the Joffe Lake system, and the upstream extent of Yellowstone cutthroat and westslope cutthroat was determined for the West Fork of Antelope Creek and Geode Creek, respectively.

NPS/BRIAN ERTEL

Yellowstone cutthroat trout from Rose Creek in the park's northern range.

Yellowstone cutthroat trout distribution, abundance, and genetic purity were also assessed in Rose, Crystal, Amethyst, and Chalcedony creeks of the Lamar River drainage. A randomly chosen 100-m section in each kilometer of stream (Figure 21) was sampled by completing a single pass with a backpack electrofishing unit. We found Yellowstone cutthroat trout, rainbow trout, and their hybrids (Table 1). Large trout (>400 mm) were present in Amethyst and Rose creeks, many in spawning condition. Although most of the habitat associated with these streams was considered either good or poor for spawning (because of large substrates), rearing habitat was good and evidence suggests that all four of these streams support migratory spawners from the mainstem Lamar River. The field work conducted during the 2007 field season will help us prepare the NEPA documents necessary to move forward with specific restoration projects. Rose Creek as well as the Elk Creek Complex and Reese Creek (both tributaries to the Yellowstone River) continue to be the focus of potential restoration activities. The 2008 Fisheries Program will also look at two of the Lamar River's largest tributaries, where there is strong evidence that the rainbow trout population in Slough Creek and the brook trout population in Soda Butte Creek are expanding.

NPS/DEREK RUPERT

Carnelian Creek, a remote tributary to Tower Creek, was surveyed to determine the uppermost extent of non-native brook trout in the watershed.

Table 1. Tributaries to the Lamar River in Yellowstone National Park that were surveyed in 2007 to determine the status of Yellowstone cutthroat trout (YCT), rainbow trout (RBT), and their hybrids (CTX).

Data includes fish lengths (mean in parentheses), whether or not fish were found in spawning condition, qualitative assessments of spawning and rearing habitats, the presence/absence of any barriers to upstream migration of fish, and the presence/absence of fish that likely migrated into the stream from the mainstem Lamar River.

Stream Name	Mainstem Length (km)	Fish Species	Length Range (mm)	Spawning Condition	Spawning Habitat	Rearing Habitat	Upstream Barrier	Lamar Migrants
Amethyst Creek	8.5	YCT, CTX	66–436 (275)	Yes	Poor	Good	Fairies Falls	Yes
Chalcedony Creek	8.5	YCT, RBT, CTX	62–346 (113)	No	Good	Good	Eden Falls	Possible
Crystal Creek	4.5	YCT, CTX	31–362 (112)	Yes	Poor	Good	Unnamed*	Yes
Rose Creek	10.1	YCT, RBT, CTX	59–442 (242)	Yes	Good	Good	None	Yes

*Several small unnamed seasonal barriers were found on Crystal Creek.

Implications of a Soda Butte Creek Brook Trout Invasion

Non-native brook trout have resided in the headwaters of Soda Butte Creek for decades (Shuler 1995), but were not found in the park until 2003. In 2004 and 2005, biologists from Montana Fish, Wildlife and Parks (FWP) and the U.S. Forest Service chemically removed the source population from a small unnamed tributary upstream of the McClaren Mine tailings. In addition, a multi-agency team led by Jim Olsen, FWP, intensively electrofished Soda Butte Creek for the last four years to remove brook trout. To date, the team has removed nearly 1,800 brook trout of various sizes/ages from seven long river reaches and small tributaries, extending from above Cooke City and downstream to near Ice Box Canyon in the park (Table 2). Although this effort appears to have reduced brook trout abundance (309 were removed in 2004 and only 150 in 2007), of particular concern is an increase in the relative abundance of young-of-year brook trout moving downstream into the park. This trend was also detected via routine electrofishing surveys during 2001–2005 (Koel et al. 2006*b*).

The end result of a brook trout invasion for cutthroat trout has been well-documented

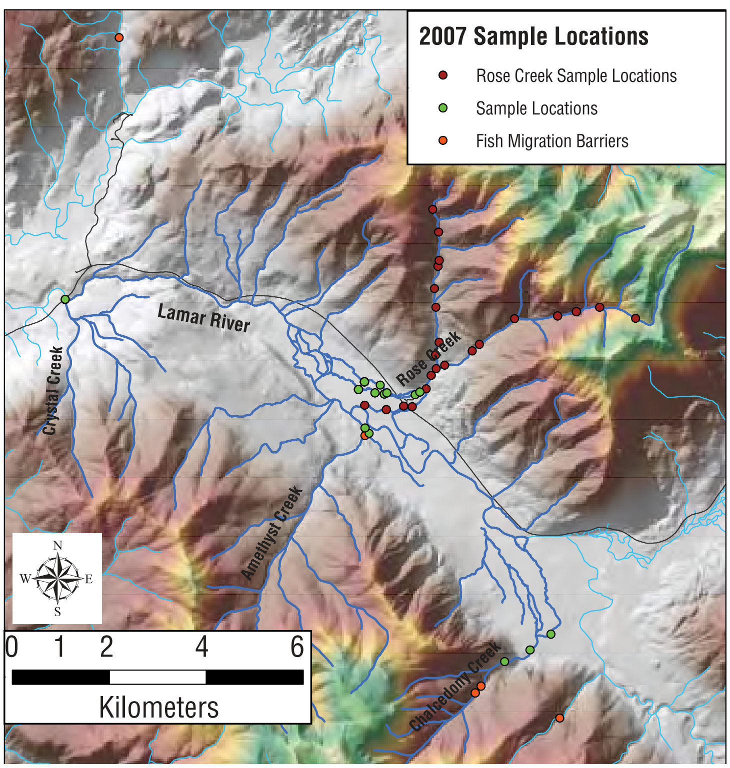

Figure 21. Locations of 2007 electrofishing sample sites and physical barriers to fish movement in the lower Lamar River watershed, Yellowstone National Park.

NPS/TODD KOEL

Slough Creek's third meadow during September 2007.

Table 2. Total (and young-of-year [YOY] only) brook trout removed via electrofishing on upper Soda Butte Creek within the Gallatin National Forest, State of Montana, and Yellowstone National Park, 2004–2007.

Note the downstream shift into the park by YOY brook trout over the four years of this removal effort. Data provided by Jim Olsen, Montana Fish, Wildlife and Parks.

	Removal Reach	2004	2005*	2006	2007
Downstream–Upstream	Hwy 212 to McClaren Mine Tailings	19(1)	3(0)	0(0)	0(0)
	McClaren Mine Tailings to Woody Creek	15(0)	17(0)	3(0)	3(0)
	Woody Creek to Sheep Creek	8(2)	43(0)	16(0)	0(0)
	Sheep Creek to Silver Gate	251(79)	932(51)	142(6)	45(8)
	Silver Gate to Yellowstone Park Boundary	9(3)	80(9)	54(2)	48(19)
	Yellowstone Park Boundary to Warm Creek	7(0)	11(0)	0(0)	50(27)
	Warm Creek to Road Bridge	0(0)	1(0)	0(0)	0(0)
	Tributaries	0(0)	17(0)	15(0)	4(0)
	Totals	309	1,104	230	150

*In 2005 a second removal effort was made post-spawning in October from Sheep Creek to Silver Gate.

elsewhere in the park and across the region. If left unchecked, the brook trout may drive the cutthroat to near extinction. Given the downstream proximity of the Lamar River, including Slough Creek and many other significant tributaries, the threat of the upper Soda Butte brook trout expansion cannot be overstated. To the greatest extent possible, park staff and partner agencies will need to suppress the brook trout in Soda Butte Creek each year into the foreseeable future, if the cutthroat trout of the Lamar River system are to be preserved.

Piscicide Effects on Non-target Species

An important component of our native trout restoration program is to document any long-term effects that piscicides may have on non-target organisms, such as aquatic invertebrates and amphibians. During the summer of 2007, we conducted both aquatic invertebrate and amphibian surveys in areas that are either being restored or have a high potential for restoration in the future. The primary purpose of these surveys is to better understand (1) the natural variation in aquatic invertebrate distribution and community structure; (2) the presence and extent of amphibian breeding populations; and (3) how the piscicides may impact these animals within fluvial trout restoration areas.

Macroinvertebrates in Restoration Areas

Invertebrates are an important element in aquatic food webs and occupy a wide assortment of feeding groups ranging from primary consumers (filter feeders, herbivores, scrappers, and shredders) to predators which feed on other invertebrates, larval amphibians, and young fish. In turn, various life stages of these invertebrates serve as an important food source for fish, birds, and mammals. Of the 29 sites on 16 streams we sampled during 2007 to assess invertebrate populations, 18 were located in current or proposed fish restoration areas (Ruhl and Koel 2007). We also sampled aquatic invertebrates in High Lake and Trout Lake in the northwest and northeast corners of the park, respectively. To date, only samples and data collected from Specimen Creek and High Lake have been processed.

In general, stream invertebrates in the three groups known as EPT taxa—Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)—are less tolerant of environmental stressors than are other aquatic invertebrate groups and are a major component of fish diets. Since EPT taxa are sensitive to changing environmental conditions, higher numbers are indicative of good water quality while lower numbers usually indicate poorer water quality. Conversely, aquatic invertebrates

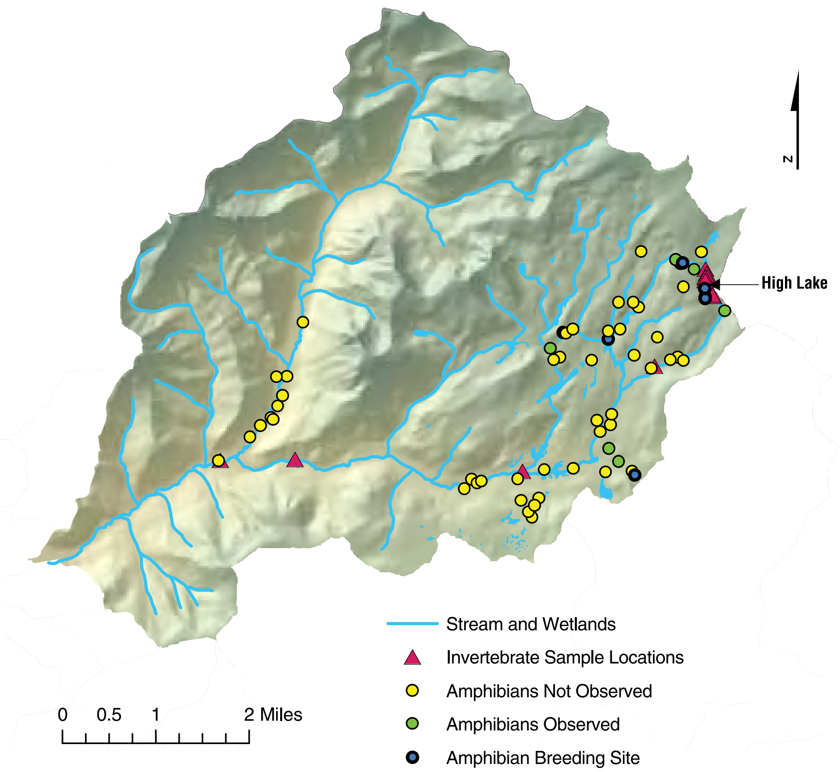

Figure 22. Invertebrate sampling locations and wetlands surveyed for amphibians in the Specimen Creek watershed, Yellowstone National Park, 2006 and 2007.

that belong to the insect order Diptera (true flies) are more tolerant of environmental stressors, with higher densities usually indicating poorer water quality or environmental stress. By assessing these aquatic invertebrate groups, we can predict the overall impacts that potential stressors may have on aquatic systems.

From 2004 to 2007 aquatic invertebrates were collected each August at three locations (sites 1–3) on East Fork Specimen Creek between High Lake and its confluence with the main stem Specimen Creek (Figure 22). In 2006 and 2007 we also sampled three sites (sites 4–6) on East Fork Specimen Creek in the immediate vicinity of High Lake. These samples were collected to assess the impact piscicides have had on aquatic invertebrate communities in the High Lake area, which was treated with rotenone in August 2006.

On East Fork Specimen Creek, the percentage of major invertebrate groups at sites 1–3 has remained relatively constant since 2004. Invertebrate groups at sites 1 and 2, which offer a wider range of habitats with variable substrate size, stream flow, and areas of aquatic plant distribution, demonstrated slightly

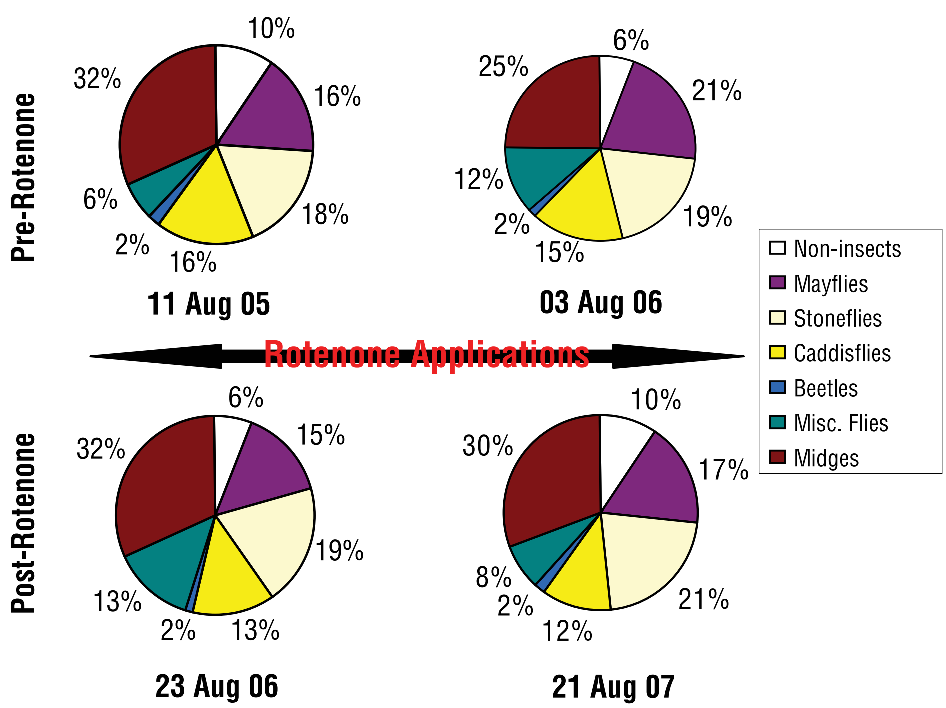

Figure 23. Percentage of major invertebrate taxa from East Fork Specimen Creek (Site 3), located 1 km downstream from High Lake, before and immediately after rotenone treatment in 2006 and one year post-treatment in 2007.

MSU water quality technician Ty Harrison and Student Conservation Association (SCA) intern and international VIP Eefje Smit collecting flow data on the outlet to Mammoth Crystal Springs.

more annual variability than the invertebrate groups at site 3, located 1 km below High Lake, which demonstrated the most stable invertebrate community between years. Prior to rotenone treatment, the invertebrate samples were comprised of 50% EPT in 2005 and 55% EPT in 2006 (Figure 23). Following rotenone treatment in 2006 and 2007, samples were comprised of 47% and 51% EPT, respectively. This work has provided strong evidence that the piscicide application and other restoration activities at High Lake did not impact invertebrates in reaches downstream in the watershed.

The invertebrate communities in both outlet and inlet stream segments in the immediate vicinity of High Lake (sites 4–6; Figure 24) were the most affected by the piscicide treatment. To evaluate short- and long-term effects, we examined the total number of taxa, the percentage of major invertebrate groups, and the percent invertebrate abundance before and after rotenone treatment. We found a total of 68 invertebrate taxa (identified from 7 samples) in 2006 prior to treatment and 53 taxa after treatment in 2007 (identified from 3 samples). Prior to treatment, 33% and 38% of the invertebrate taxa belonged to EPT groups located within outlet and inlet stream segments, respectively (Figure 24). After treatment, however, EPT taxa declined to 11% and 10% in those segments. We documented a concurrent increase in aquatic fly larvae in these streams. This clearly indicated that in the short term, at

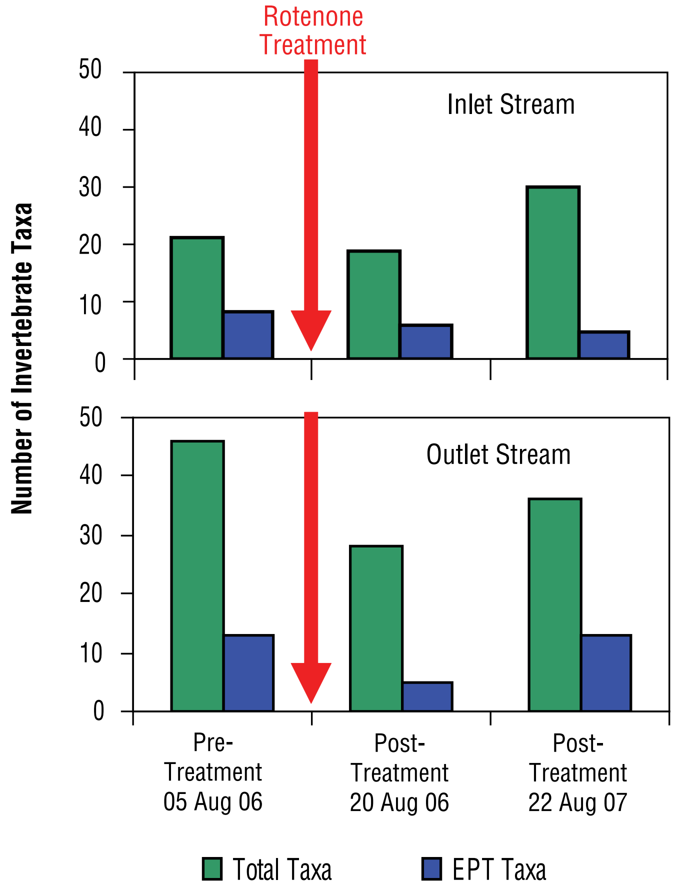

Figure 24. Total number of invertebrate taxa and total EPT taxa from High Lake inlet and outlet streams before and immediately after rotenone treatment in 2006 and one year post-treatment in 2007.

least, invertebrate communities were negatively impacted by the rotenone treatment of High Lake.

One year after treatment, invertebrate surveys indicated recovery of invertebrate populations within the High Lake outlet stream, while those in the inlet stream remained similar to conditions immediately after treatment. For example, aquatic fly larvae comprised a majority of the invertebrate community during 2006 pre- and post-treatment surveys (Figure 25). During 2007, however, densities of non-insect taxa as well as EPT taxa increased dramatically within the outlet stream. This increase was mainly attributed to four taxa: the fingernail clam (*Pisidium compressum*), two mayfly species (*Diphetor hageni* and *Paraleptophlebia* sp), and one stonefly (*Isoperla* sp). The fingernail clams, in particular, were encountered in low densities prior to treatment, yet reached densities of nearly

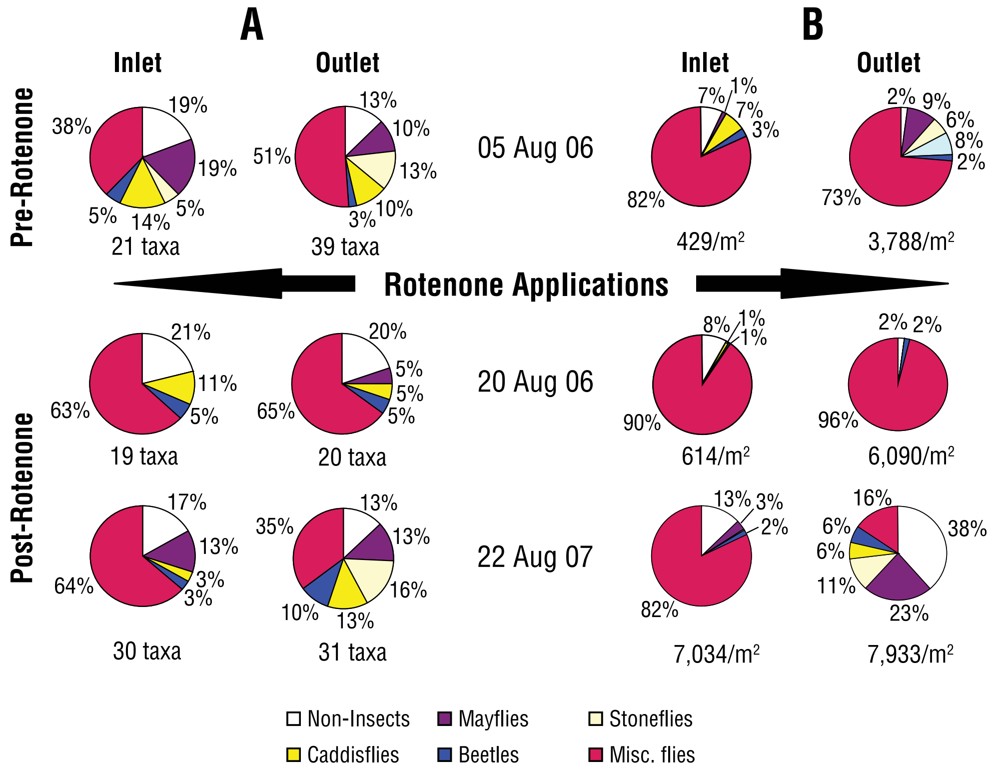

Figure 25. (A) Percentage of major invertebrate taxa and (B) percent invertebrate abundance from High Lake inlet and outlet streams before and immediately after rotenone treatment in 2006 and one year post-treatment in 2007.

...in the short term, at least, invertebrate communities were negatively impacted by the rotenone treatment of High Lake.

3,000/m² in 2007. This increase in densities could be due to natural variation within the population or, possibly, a direct response by the fingernail clams sparked by the removal of trout.

Within High Lake itself the benthic invertebrate communities were not greatly impacted by the rotenone treatment. Prior to rotenone treatment, 25 taxa were identified from 20 samples collected in High Lake bottom sediments (Figure 26), including aquatic fly larvae (16 taxa), caddisflies (2 taxa), and various non-insects (7 taxa). After rotenone treatment, a total of 22 taxa were identified from 29 samples, including aquatic fly larvae (15 taxa) and non-insects (7 taxa). Except for the absence of caddisfly larvae (2 taxa) after treatment, benthic invertebrate groups in the High Lake sediments varied little before and after treatment.

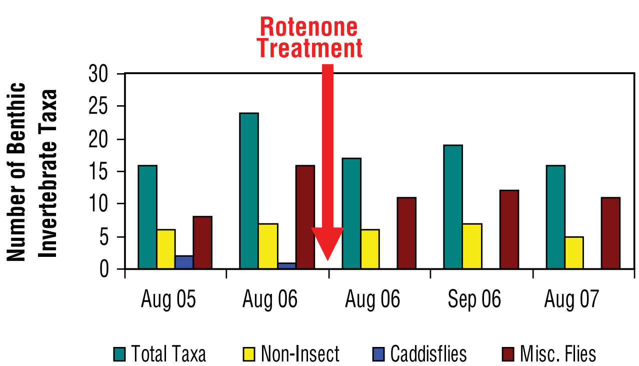

Figure 26. Total number of invertebrate taxa, non-insect taxa, caddisflies, and miscellaneous fly taxa (misc. flies) collected from the benthos of High Lake before rotenone treatment in 2005, before and immediately after rotenone treatment in 2006, and one year post-treatment in 2007.

Amphibians in Restoration Areas

Yellowstone National Park is home to four amphibian species: the Columbia spotted frog (*Rana luteiventris*), the boreal chorus frog (*Pseudacris maculata*), the boreal toad (*Bufo boreas*), and the blotched tiger salamander (*Ambystoma tigrinum*) (Koch and Peterson 1995). In May and July 2007, we investigated 122 wetlands identified by the National Wetlands Inventory (U.S. Fish and Wildlife Service 1998) for the presence of amphibians in areas targeted for native trout restoration. A majority of these wetlands were on the park's northern range (83 sites) and within the

Young-of-year boreal toads using a small puddle on the Firehole Lake Drive resulted in placement of cones to keep traffic from killing them.

Madison River (15 sites) and Specimen Creek (24 sites; Figure 22) drainages in the northwest region of the park. Of the 122 designated wetlands, 46 (38%) had adequate surface waters to warrant a survey; the other 76 (62%) were not surveyed because they were unsuitable for amphibian breeding (e.g., dry, located on slope).

The northern range surveys focused on the Blacktail Deer (Figure 27), Elk, and Rose creek drainages and the small watershed that encompasses Trout Lake. Of the 83 wetland sites, 33 provided habitat that met the amphibian search criteria. The only amphibian species not found by our surveys was the boreal toad. Evidence of breeding (larvae and/or egg masses) was documented at 14 sites, half of which contained at least two species: 10 sites were used by the blotched tiger salamanders for breeding, 7 by boreal chorus frogs, and 5 by Columbia spotted frogs.

The Madison River drainage surveys focused on Duck Creek, which originates on Mount Holmes and flows westward toward the park boundary approximately 13.5 km north of West Yellowstone, Montana. The 14 surveyed sites were located in the extensive floodplain/wetland complex that surrounds the primarily slow moving, deep channeled Duck Creek. Ten of these sites were completely dry, three had adult boreal chorus frogs, Columbia spotted frogs, and juvenile boreal toads, and one had adequate water but we were unable to find any amphibians. No evidence of amphibian breeding was found in this drainage.

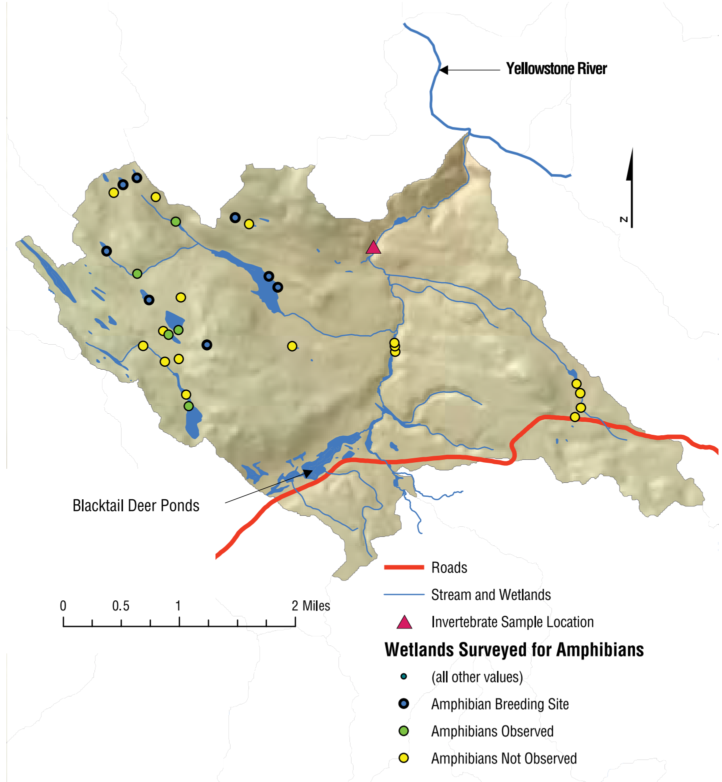

Figure 27. Invertebrate sampling locations and wetlands surveyed for amphibians in the lower portion of the Elk Creek watershed, Yellowstone National Park, 2007.

Of the 24 wetland sites we visited in the Specimen Creek drainage, 7 provided adequate habitat for amphibians (Figure 22), but only Columbia spotted frogs and boreal chorus frogs were found. Evidence of breeding (larvae and/or egg masses) was documented at four sites, all of which had Columbia spotted frogs; two of the sites also had boreal chorus frogs. High Lake, in the upper East Fork Specimen Creek drainage, is characterized by shallow margins dominated by sedge, which appears to be an important substrate for Columbia spotted frog egg laying. Before the rotenone treatment in spring 2006, spotted frog larvae were found only in the lake outlet area (Koel et al. 2007). In spring 2007, however, after the rotenone treatment, we observed adults and tadpoles all around the perimeter of the 7.1-acre lake. Research undertaken with Idaho State University will help us understand rotenone's potential impacts on amphibians and explain increased amphibian use of High Lake littoral areas immediately following removal of introduced fish, which are major predators of amphibians in mountain lakes (Knapp and Matthews 2000; Knapp et al. 2001; Pilliod and Peterson 2001).

Aquatic Ecology

Goose Lake and Goose Neck Lake (shown here) were surveyed for fishes, macroinvertebrates, and amphibians in 2007 to determine their potential for supporting pure-strain westslope cutthroat trout.

Long-term Water Quality Monitoring

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

A pair of blotched tiger salamanders at a wetland near the Gibbon River.

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 or accidental sewage spills), identify any changes that may be associated with water quality degradation, and guide resource management decisions related to water quality. In 2007, data was collected monthly at each monitoring site on core water quality parameters, including water temperature, dissolved oxygen, pH, specific conductance, and turbidity. Water samples were brought back to the laboratory for total suspended solids (TSS) analysis. In addition, 10 of the sites were sampled for various chemical parameters, including anions (sulfate, chloride, bicarbonate and carbonate), cations (calcium, magnesium, sodium, and potassium), and nutrients (total phosphorus, orthophosphate, nitrate, nitrite, and ammonia). Dissolved and total metals (arsenic, copper, iron, and selenium) in water and sediment are measured twice annually during high and low flow periods on the upper Soda Butte Creek at the park boundary near Silver Gate, Montana.

Core Water Quality Parameters

The 2007 statistics for core water quality parameters indicate spatial trends very similar to those observed from 2002 to 2006. In general, physical and chemical characteristics of water quality are related to seasonal changes,

elevation, precipitation events, and presence or absence of thermal features. Water temperature and dissolved oxygen (DO) are closely tied because colder water holds more oxygen. With the exception of the Gardner River, overall water temperatures were generally lowest and DO concentrations highest on sites within the Yellowstone River drainage, which has minimal geothermal activity compared to the Madison River drainage (Figure 28a and b). Surface water temperatures ranged between –0.2 and 25.5°C in 2007. The lowest and highest mean annual temperatures were both recorded within the Yellowstone River drainage on upper Soda Butte Creek (4.7°C; range -0.1–13.8°C) and the Gardner River (16.0°C; range 10.6–24.1°C) respectively (Figure 28a). Meanwhile, average DO concentrations remained relatively consistent among sample sites (mean for all sites ranged from 8.5 to 10.8 mg/L).

The acidity of surface water in Yellowstone, 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 deposition, geothermal contributions, and biological factors. Within-site variation of pH was quite low in

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A bull snake Pituophis catenifer sayi *captures a cutthroat trout hybrid from the Gardner River near the Boiling River visitor area.*

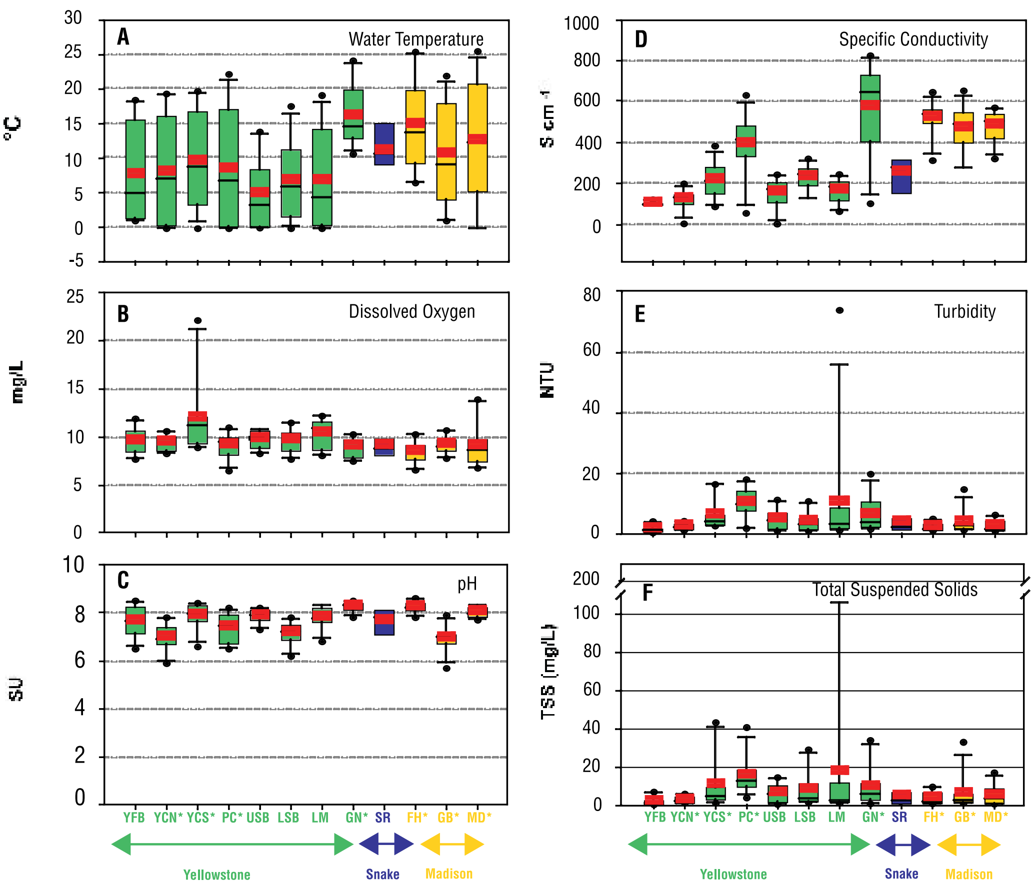

Figure 28. Box and whisker plot illustrating annual variation for selected parameters at each water quality location. Lower and upper portions of boxes represent the 25th and 75th percentile respectively: lower and upper black horizontal bars represent 10th and 90th percentile respectively. Outlying values are represented by black dots; means are indicated by solid red lines. Green, blue, and orange represent the Yellowstone, Snake, and Madison river basins, respectively (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. Snake River is not sampled during winter months.


NPS/JEFF ARNOLD

Soda Butte Creek (left) carrying sediment after a thunder shower is much more turbid than the clearer Lamar River (right) at its confluence.

2007; most differences occurred spatially across the park and among sites (Figure 28c). The Madison River, for example, receives water from the Firehole and Gibbon rivers, both of which are influenced by geothermal activity. But while the mean pH at the Firehole River was 8.21 SU (range 7.8–8.6), the Gibbon River, into which flows very acidic geothermal water, had lower pH values (mean of 6.9 SU, range


NPS/JEFF ARNOLD

MSU water quality technician Ty Harrison collecting data from the Lamar River as a part of the NPS Vital Signs Water Quality Monitoring Program.

5.7–7.9). Specific conductance, turbidity, and total suspended solids (TSS) are directly related to stream flow. Specific conductance is a measure of a solution's resistance to conducting 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 the high flow periods of May and June, and higher during the low flow periods of late summer and winter. Specific conductance was higher at stream sites that received geothermal inputs, including Pelican Creek and the Gardner River within the Yellowstone River basin and the Firehole, Gibbon, and Madison rivers within the Madison River basin (Figure 28d). Yellowstone Lake operates as a buffer to the upper Yellowstone River system, resulting in low annual variation in specific conductance, turbidity, and TSS. The Yellowstone River at Fishing Bridge (at the lake outlet) had the lowest mean specific conductance, 100 µSiemens (µS cm-1) with a range of 95–123 µS cm-1. Conversely, the Gardner River station exhibited the highest mean specific conductance, 573 µScm-1 with a range of 103–827 µScm-1. Both turbidity, which is measured in nephelometric turbidity units (NTU), and TSS concentrations, which are measured in mg/L, are measures of water clarity. For both parameters water clarity remains very good throughout the year, with more turbid conditions being observed during snowmelt and after rainfall events, which is typical of mountain streams with minimal sediment contributions (Figure 28e and f).

Chemical Constituents of Surface Waters

As part of the long-term water quality monitoring program, we began collecting water samples for chemical analysis at 10 stream sites within the Yellowstone and Madison river drainages in May 2006, and completed the first calendar year of this data collection in 2007. The added parameters include select anions, cations, and nutrients (Appendix v). Aquatic plants use these dissolved chemicals to varying

degrees for basic cellular structure, metabolism, growth, and development. In Yellowstone, dissolved concentrations of ions and nutrients are most closely related to natural factors such as geology, discharge, geothermal input, grazing, and uptake by aquatic plants, but there are also anthropogenic sources such as sewage spills, runoff from paved road surfaces, and acid mine drainage. Generally, dissolved ion concentrations in Yellowstone waters are relatively low, with higher concentrations observed during low flow conditions and lower concentrations during high flow conditions.

Relative concentrations of major anions and cations were calculated for each site and a unique pattern of relative dissolved ion concentrations were observed between the Yellowstone and Madison River drainages (Figure 29). For the most part, relative concentrations of bicarbonate (HCO_3^{2-}) ions were dominant at all water quality stations. However, concentrations of other major ions seemed to vary among watersheds. The Lamar River drainage, within the Yellowstone River basin, had higher concentrations of calcium (Ca^{2+}) ions than the Yellowstone River mainstem, which had higher concentrations of sulfate (SO_4^{2-}) ions. In addition to bicarbonate ions, both sodium (Na^+) and chloride (Cl^-) were present in approximately equal proportions within the Madison River basin (Figure 29). Both phosphorus and nitrogen concentrations remained very low for all sites sampled. Mean total phosphorus concentrations were highest on the Firehole River (0.23 mg/L, with a range between 0.18 and 0.30 mg/L). Orthophosphate, nitrate, nitrite, and ammonia were very low; most concentrations were below the analytical detection limits.

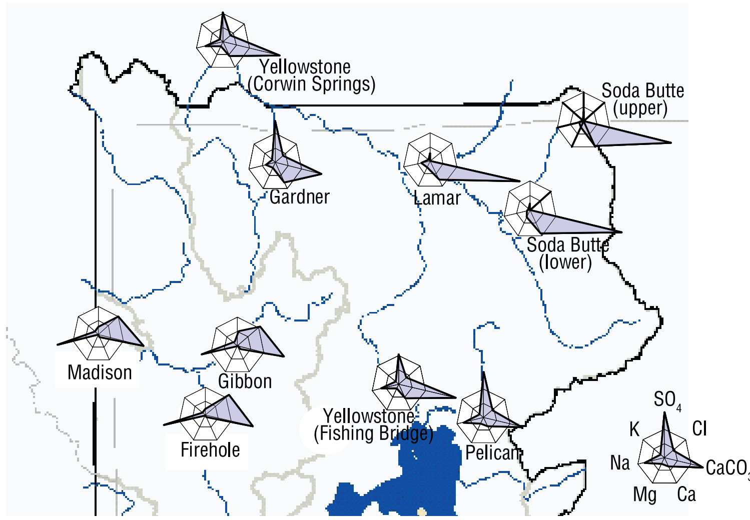

Figure 29. Average annual percent ion concentration of seven measured ions from water quality sites on rivers and streams in Yellowstone National Park. The concentric heptagons represent the 10th and 20th percentiles respectively from the center with remaining percentiles not shown. (SO4 = sulfate, Cl = chloride, CaCO3 = bicarbonate, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium).

Regulatory Monitoring on Soda Butte Creek

In conjunction with routine water quality monitoring, we sampled dissolved and total metals in water and sediments on Soda Butte Creek near the park's northeast boundary. The state of Montana has listed Soda Butte Creek upstream of the Northeast Entrance as "water quality impaired" because of elevated metal concentrations from the McClaren mine tailings that are located near Cooke City and within the Soda Butte Creek floodplain. On June 14 and September 20 (during periods of high and low stream flow, respectively), we collected water and sediment in both the morning and evening to capture diurnal variations in arsenic, copper, iron, and selenium. Total and dissolved arsenic, copper, and selenium were below analytical detection limits in all water samples. Levels of dissolved and total iron concentration in water did not exceed the state of Montana's aquatic-life standards for any sample event. Dissolved iron

NPS/JEFF ARNOLD

Student Conservation Association (SCA) intern and international VIP Eefje Smit collecting water quality data from Soda Butte Creek.

was below detection limits, while total iron had recorded values of 0.393 and 0.535 mg/L in June and 0.536 and 0.55 mg/L in September. Total hardness was near 41 mg/L in June and near 91 mg/L in September.

In the sediment samples, arsenic and selenium were below detection limits on both sample days. Concentrations for both copper and iron tended to be lower in June than in September: copper (12.25 and 24.55 mg/kg respectively) and iron (17,050 and 25,600 mg/kg respectively). Concentrations of arsenic and copper in sediments were well below the probable effect concentrations listed by Ingersoll and MacDonald (2002), at 33 mg/kg and 149 mg/kg respectively. There are no recognized standards for iron and selenium in sediments.

Yellowstone Lake Limnology

Yellowstone Lake is the largest high alpine lake in the contiguous United States and the most prominent body of water in Yellowstone National Park. Understanding Yellowstone Lake limnology is an important element in comprehending the ecology of lake trout and aids park fisheries biologists with the lake trout suppression program. Water temperature, dissolved oxygen, specific conductance, and turbidity measurements were sampled monthly from May through October 2007 at seven sites located throughout the Yellowstone Lake basin (Figure 1). In addition, with weather permitting, temperature profile data was collected from the West Thumb and South Arm area of Yellowstone Lake. Water samples were collected at each location for analysis of total suspended solids (TSS) and volatile suspended solids.

Whirling disease, caused by the exotic parasite *Myxobolus cerebralis*, is responsible for severe declines in wild trout populations in the Intermountain West…

Avian Piscivores as Whirling Disease Vectors

Whirling disease, caused by the exotic parasite *Myxobolus cerebralis* (Myxozoa: Myxosporea), is responsible for severe declines in wild trout populations in the Intermountain West, including a decline in native cutthroat trout in Yellowstone National Park (Koel et al. 2005). Movement of infected hatchery fish has been blamed for the spread of *M. cerebralis* in Colorado and its introduction in Wyoming (Bartholomew and Reno 2002). The vector for dissemination to many waters of the Intermountain West, including the relatively pristine and highly protected waters of Yellowstone, is unclear. Obvious possible vectors include the movement of myxospores by anglers and their gear (Gates 2007) or by fish-eating wildlife, especially those capable of traveling long distances in a short time, such as birds.

PHOTOS BY USDA/APHIS

A great blue heron is fed a rainbow trout in the USDA/APHIS aviary at Fort Collins, CO (top); a double-crested cormorant enjoys his tank while waiting for feeding time at the aviary.

Although the specific mechanism resulting in transmission was unclear, in an early study by Taylor and Lott (1978), trout were infected with *M. cerebralis* in ponds exposed to waterbirds. El-Matbouli and Hoffman (1991) demonstrated that myxospores can pass through the gastrointestinal tracts of northern pike (*Esox lucius*) and mallard (*Anas platyrhynchus*) without loss of infectivity. However, it remained unknown if myxospores remain viable after passage through wildlife species that specifically prey on trout, especially avian piscivores and other animals that can range widely among drainages. Research initiated by Barrows et al. (1999) documented the evacuation rates of trout

by white pelicans (*Pelicanus erythrorhynchos*) and bald eagles but did not examine the myxospore transfer through these birds or subsequent viability.

Beginning in 2005, park staff partnered with Montana State University's Department of Ecology and the USDA Animal and Plant Health Inspection Service's National Wildlife Research Center (NWRC) to determine the potential of highly mobile avian piscivores, including American white pelicans, great blue herons (*Ardea herodius*), great egrets (*Ardea alba*), and double-crested cormorants (*Phalacrocorax auritus*) as dispersal vectors for *M. cerebralis*. Our specific objectives were to determine if *M. cerebralis* can be detected after it has passed through these bird species' gastrointestinal tracts and, if so, whether it remains viable.

In May 2005, rainbow trout (six weeks post hatch) were infected by *M. cerebralis* by exposure to triactinomyxons (TAMs) at the Montana Water Center's Wild Trout Laboratory in Bozeman. In winter/spring 2006, biologists at the NWRC Mississippi Field Station (Mississippi State University) captured six each of American white pelicans, double-crested cormorants, great blue herons, and great egrets and transported them to an aviary at Fort Collins, Colorado, for disease challenges. Three birds of each species were simultaneously fed 10 infected trout; the other three were given certified disease-free placebos. Fecal material was collected prior to the experimental feeding and each day for 10 days afterward. A one-gram fecal sub-sample from each bird was sent to Pisces Molecular, Colorado, for genetic analysis to detect *M. cerebralis* DNA. Another 1-gram sub-sample was used to test for infectivity in *Tubifex tubifex* in the ecology laboratory at Montana State University.

Through analysis of fecal samples spiked with known concentrations of myxospores, we determined that the lowest detectable limit of our PCR method was 250 myxospores per gram of fecal material. We found *M. cerebralis* DNA in the feces of all 12 birds that had been fed infected fish, but only the great blue herons' feces induced TAM production by *T. tubifex* held in laboratory cultures. Thus, our study confirms the ability of herons to vector *M. cerebralis* among aquatic habitats in the Greater Yellowstone Ecosystem and elsewhere. Our more equivocal results for the other three bird species may have been caused by an unknown aspect of our experimental protocol or real differences in the effects of these bird species' gastrointestinal tracts on myxospores. Replication of this work may improve our understanding of the ability (or lack thereof) of pelicans, cormorants, and egrets to vector *M. cerebralis*.


USDA/APHIS

A great blue heron ready to select one of the rainbow trout placed in the pool at the USDA/APHIS aviary.

...our study confirms the ability of herons to vector *M. cerebralis* among aquatic habitats in the Greater Yellowstone Ecosystem.


NPS/TODD KOEL

Research conducted by NPS, MSU, and USDA/APHIS documented the ability of avian piscivores to move whirling disease within Yellowstone. Here, great blue herons and American white pelicans search for trout along the margin of the Yellowstone River near Alum Creek, a whirling disease infected stream.

Angling in the Park

Yellowstone adopted a Drought Fishing Restriction Strategy in 2007 that outlined criteria and options for restrictions on fishing in an effort to preserve native and wild trout.

Drought Fishing Restriction Strategy

Geothermal features naturally affect the temperature regimes of several popular Yellowstone fishing waters, such as the Firehole, Gibbon, and Madison rivers. Although the trout in these streams are considered "coldwater" species, they have behaviorally adapted to deal with these conditions. In recent years, however, regional weather patterns have resulted in extremely low flows and high stream temperatures in the park. These changes have heightened effects on fish living in geothermally-influenced streams and threaten to stress native and wild trout in many other park waters where they are not accustomed to such conditions. During three of the past six years (2002, 2003, and 2007, see below), low flows and high water temperatures have necessitated placing additional restrictions on angling to protect trout populations from stress. Given predictions of a warming climate, drought conditions in Yellowstone may persist long term, and actions to protect trout may become routine.

Yellowstone streams vary in temperature but are always coldest at dawn and warmest at dusk. The relatively high elevation and cool nighttime air temperatures cause stream temperatures to drop overnight, especially in smaller streams. It is not uncommon for the temperature of a park stream to range 25°F or more during a 24-hour period. However, the larger rivers are much slower to cool down, and fishes in these waters get little relief from extended heat during the summer season. There is also much less variation between daytime and nighttime temperatures in smaller streams that are influenced by geothermal features.

Temperature limits vary among trout species, with rainbow and brown trout tolerating somewhat higher temperatures than do cutthroat trout. The cumulative impact of sustained high stream temperatures is that cold-water adapted trout become extremely stressed. In general, trout mortality is high in waters >68°F (20°C) and complete in waters >73°F (22.7°C). Above this temperature, trout almost certainly will die, especially if exposed for extended periods. Angling of heat-stressed trout, which often congregate in deep pools seeking shade and cooler water, significantly adds to their stress. Trout that would be capable of revival and release following a fight when caught in cold water are more likely to die when caught in warm water. Because of this, Yellowstone adopted a Drought Fishing Restriction Strategy in 2007 that outlined criteria and options for restrictions on fishing in an effort to preserve native and wild trout. When stream flows decline below long-term averages, and/or stream temperatures approach 73°F (22.7°C) for three consecutive days, the park may impose either of the following restrictions:

A) Time-of-Day Restriction: Fishing begins at 5 AM and ends at 2:00 PM each day. No fishing allowed after 2:00 PM.

B) Full Closure: All fishing on the designated waters will be prohibited. This restriction is appropriate for waters with extremely low flows that threaten the fishery resources (e.g., excessive angling pressure concerns). Full closures may be implemented in priority waters that meet the thresholds and in which Time-of-Day Restrictions are inadequate, and in other waters if conditions warrant.

The decision regarding which restriction to apply will depend on the threat to the fisheries as well as the existing and projected fishing pressure.

NPS/BRIAN ERTEL

High temperatures resulted in a trout die-off on the Firehole River in 2007.

Extreme Heat Forces Angling Restrictions

By the third week in June 2007, temperatures on the Gibbon and Firehole rivers were already exceeding 22.7°C each day. By the first week of July, daily temperatures were exceeding 77°F (25°C) and 82°F (28°C) in the Gibbon and Firehole rivers, respectively (YVO, 2007). On July 6, the same day the park issued a Fishing Advisory, we learned of a significant trout die-off on the Firehole River. We found hundreds of dead fish along the river all the way from Midway Geyser Basin downstream to Firehole Cascades. Dead trout were also found in Nez Perce Creek from the road bridge downstream to its confluence with

the Firehole River. All of the fish were 2–14" brown or rainbow trout in varying stages of decay. It was felt that the fish kills within these geothermally-influenced streams were anomalies, and were very surprised when three days later the Fisheries Program ecologists conducting water quality monitoring found evidence of a large fish die-off on Pelican Creek near the road viaduct and upstream in the location of the historical fish weir. The dead fish along the stream margin and bottom included longnose dace, longnose suckers, and redside shiners. Fish that were still alive were lethargic and unresponsive. None of the fish found were cutthroat trout.

The July 6 Fishing Advisory asked anglers for voluntary cooperation in refraining from fishing between noon and 6 PM on several priority waters. However, because heat and dry conditions continued, mandatory restrictions announced on July 21 limited fishing on these waters to 5:00 AM to 2:00 PM. By late July the flows within the park, particularly those across the Yellowstone River drainage, had declined to a mere fraction of their normal levels. The low flows occurred from Soda Butte Creek downstream through the Lamar River and mainstem Yellowstone River at the park's north boundary (Figure 1). These conditions were also seen far upstream on Slough Creek at the park boundary and Silvertip Ranch area. Although stream flows remained low through August, cooling nighttime temperatures brought much needed relief to streams. On August 22, with daily peak temperatures rapidly declining and remaining well below 73°F (22.7°C), the fishing restrictions were lifted.


NPS/BILL VOIGT

Anglers on Grayling Creek participate in the Yellowstone Fly Fishing Volunteer program.

Trends from Volunteer Angler Report Cards

Angling remains a popular pastime for those visiting, living near, and working in Yellowstone National Park. Of the record 3,151,342 visitors to the park in 2007, 47,069 obtained the special use fishing permit required for fishing in park waters and a volunteer angler response (VAR) card. These cards, which have been handed out since 1973, provide anglers an opportunity to share their fishing success and opinions about the park's fishing opportunities with park managers. The response rate of almost 3,000 angler outings is a decrease from recent years. Exit gate surveys, in which some visitors are interviewed as they leave the park, also provide information about how many visitors fished. This year's gate surveys revealed that nearly 2.4% of the visitors who purchased a permit did not fish, while 0.5% of visitors fished without a permit; this resulted in an estimated 46,318 anglers fishing during the 2007 season.

Parkwide angler use (total number of days anglers spent fishing) was 389,360 days in 2007, which was 36% more than in 2006. Based on the 2007 VAR data, we estimate that anglers landed 998,318 fish and creeled 51,752, releasing more than 95% of the fish they caught. Anglers fished for an average of 2.79 hours a day during a typical outing and on an average of 1.71 days during the season. Although visitors who fished only one day comprised 63% of fishermen, 82% of all anglers caught fish. Anglers reported being satisfied with their overall fishing experience (76%), with the number of fish caught (64%), and with the size of fish

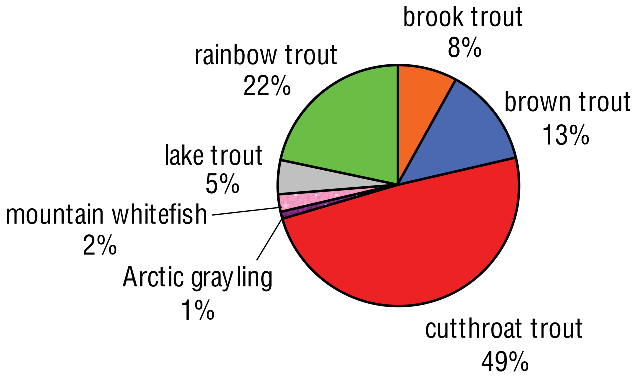

Figure 30. Percentage of each species in parkwide, angler-reported catch during the 2007 fishing season.

Native cutthroat trout remained the most sought after and caught fish species again in 2007, comprising 50% of all fish caught.

(66%), representing little change from previous years.

The 2007 VAR cards reported the lengths of 20,988 fish. The overall mean length of fish caught in the park was 11.4 inches, with 38% of them longer than 12 inches and 26% longer than 14 inches. Average fish lengths increased in 2007 for all but cutthroat and rainbow trout. Lake trout had the greatest average length (17.5", a 0.5" increase from 2006), followed by whitefish (12.1", a 0.7" increase), cutthroat (12.0", a 0.3" decrease), brown trout (11.3", a 0.5" increase), rainbow trout (10.1", no change), grayling (9.9", a 1.6" increase) and brook trout (7.5", a 0.5" increase).

Native cutthroat trout remained the most sought after and caught fish species again in 2007, comprising 50% of all fish caught (Figure 30). Rainbow trout were the second most caught fish, comprising 21% of angler catch, followed by brown trout (13%), brook trout (8%), lake trout (5%), mountain whitefish (2%) and grayling (1%). Native fish species (cutthroat, whitefish, and grayling) comprised 53% of all reported fish caught.

An estimated 7,764 anglers, or about one out of every seven anglers in the park, fished Yellowstone Lake, making it again the most popular place to fish. Anglers caught an estimated 84,411 cutthroat trout in the lake in 2007, an increase from 2005 and 2006. The reported number of cutthroat trout caught per hour also increased, from 0.41 in 2006 to 0.57 in 2007. However, the average reported size of cutthroat trout decreased slightly from 454 mm (17.9") in 2006 to 444 mm (17.5") in 2007 (Figure 31). Extremely large cutthroat trout continue to be caught each year on Yellowstone Lake; in 2007 the relative abundance of fish >20 inches long (27% of the total catch) was nearly equal that of fish 18–20 inches long (28% of the total catch). Unlike the size distribution of cutthroat trout caught during the fall netting assessment, cutthroat trout 18–20 inches long have comprised the majority of the angler catch since 2003 (Figure 32). The cutthroat trout most often caught by anglers measured 14–16 inches in 2000, 16–18 inches in 2001, and 18–20 inches during 2003–2007. Similar sizes of lake trout have been reported by anglers on Yellowstone Lake. In 2007, the majority of lake trout caught were in the 16–20 inch (40–50 cm) size classes (Figure 32). The lake trout suppression program (discussed above) has been effective at ensuring that most lake trout do not live to larger sizes. A fishing guide at the Bridge Bay marina on Yellowstone Lake speculated that the recent increases in lake trout catches could be due to local anglers targeting them and having better knowledge of angling tactics designed to catch lake trout, such as downriggers and weighted fishing line. Anglers in Yellowstone Lake reported good catches of lake trout in 40 to 70 feet of water, especially in the West Thumb, Breeze Channel and areas near Frank Island.

Mercury in Lake Trout and Rainbow Trout

Although Yellowstone's waters are among the most pristine in the world, mercury (Hg) is present from both natural and unnatural sources. Natural sources include the park's iconic geothermal features (Hall et al. 2006; King et al. 2006), which are typically associated with streams and lakes. However, atmospheric deposition of inorganic Hg is an additional source of contamination (Krabbenhoft et al. 1999; Krabbenhoft et al. 2002) from sources that can be great distances away (Sorensen et al. 1994; Glass and Sorensen 1999). Methylmercury (MeHg) is the most common form of organic Hg (Hg bound to carbon) and the form that most easily accumulates in organisms (USGS 2008). Inorganic Hg deposited from the

atmosphere in rain or snow is transformed into MeHg within aquatic systems by sulfur-reducing bacteria found in the anoxic (low oxygen) environment of bottom sediments. Within these environments, MeHg can persist for long periods, allowing bottom-dwelling organisms to accumulate them and pass them up the food chain to fish. Since concentrations of MeHg increase at each level in the food chain, concentrations in top predators may be a million or more times that found in the water where they live (EPA 2007).

Methylmercury is a neurotoxin, meaning that it has the potential to harm the nervous system, especially that of an unborn baby or young child. In fact, MeHg is considered the most toxic and widespread contaminant effecting aquatic systems in the United States (Krabbenhoft 1999). Over 80% of all fish consumption advisories nationwide are due, at least in part, to Hg, and 49 states have issued fish consumption advisories due to elevated MeHg levels (EPA 2007).

Since the presence of lake trout in Yellowstone Lake was confirmed in 1994, the park has required that all lake trout caught there be harvested or otherwise killed. In addition, the 2006 changes to the park's angling regulations included a liberalization of harvest limits for non-native trout (Koel et al. 2006*b*). Encouraging the harvest of introduced fish has compelled us to find out more about the possible health risks associated with their consumption. During 2007 we collected 24 lake trout from Yellowstone Lake and 27 rainbow trout from the Lamar, Gardiner, and Gibbon rivers and had them analyzed for total mercury by the Environmental Research Laboratory at the University of Minnesota–Duluth. Two samples were also analyzed for MeHg, which confirmed that most of the mercury was in the MeHg form (>90%).

The lab results indicated that consumption advisories are appropriate for Yellowstone. Because MeHg levels vary across water bodies and increase dramatically in a fish as it grows, consumption advisories are typically specific for a given species and water body. Mercury concentrations in the lake trout from Yellowstone Lake ranged from 38 to 90 ng/g

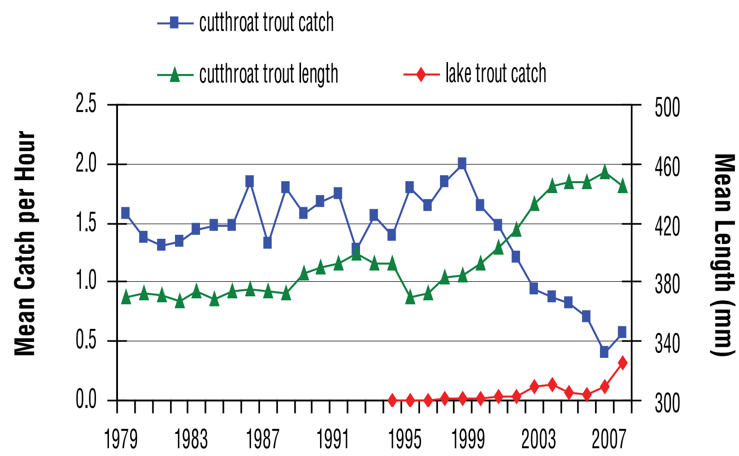

Figure 31. Angler-reported catch rates of Yellowstone cutthroat trout and lake trout and the mean length of angler-reported cutthroat trout caught on Yellowstone Lake in 2007.

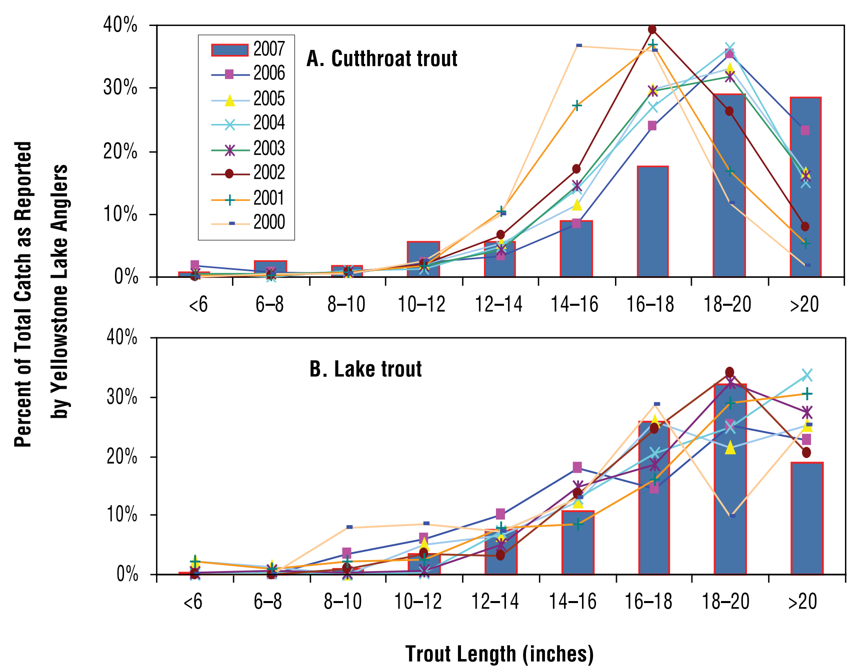

Figure 32. Percentage of angler-reported catch among length classes for (A) Yellowstone cutthroat trout and (B) lake trout from Yellowstone Lake, 2000–2007.

(wet weight) in fish <50 cm long, to 527–599 ng/g for fish >80 cm (Figure 33). However, no statistically significant difference was found between the mercury concentrations in lake trout from the West Thumb and those from the main basin of Yellowstone Lake. Consumption guidelines based on thresholds developed by the U.S. Environmental Protection Agency are given as the recommended safe number of meals per month for fish of the indicated size (EPA

2007). Safe consumption of the lake trout most commonly caught on Yellowstone Lake, which are 40–50 cm long, allows for up to 12 meals per month (Figure 33). However, fewer meals are recommended for larger lake trout, and those that are very large (>470 mm) should not be consumed more than once per month.

The rainbow trout analyzed contained lower concentrations of mercury than the large lake trout. However, the levels varied from one river to another, with the Lamar River trout having the lowest mercury levels (36 ng/g), and those from the Gibbon River the highest (185 ng/g), perhaps due to the abundant geothermal influences found there (Figure 34). Safe consumption of these rainbow trout allows for up to 12 meals per month (Figure 34) in these rivers, but large fish (30–40 cm) should be eaten no more than three times per month. Although no large fish were caught from the Gibbon River for us to analyze, model predictions indicate that any rainbow trout exceeding approximately 20 cm should be consumed no more than twice each month.

The mercury concentration for a standard sized fish (60 cm) from Yellowstone Lake (183 ng/g) was lower than that from other large lakes at similar latitude (J. Sorensen, University of Minnesota, personal communication, 2007; Figure 35). Lake Superior had the highest mean mercury concentration (285 ng/g), whereas Lac La Croix, a large northern Minnesota lake, and a group of eight lakes located in northern Alberta and Saskatchewan (Evans et al. 2005); had moderate levels. This evidence suggests that Yellowstone fishes are safer to consume than those found in many other large northern lakes.

The significant differences in mercury concentrations found in fish from the three rivers included in this survey clearly indicate that they are being affected by environmental variables such as geothermal features or total annual precipitation. More detailed sampling on the Gibbon and Gardner rivers could reveal which river reaches are the highest in mercury and what factors are responsible. Unfortunately, only smaller fish were sampled from the Gibbon River and an extensive extrapolation of those data was required to estimate consumption guidelines for the bigger fish. We need to analyze more fish of larger sizes to complete that data set and to analyze lake trout from other lakes to create consumption guidelines specific to those waters.

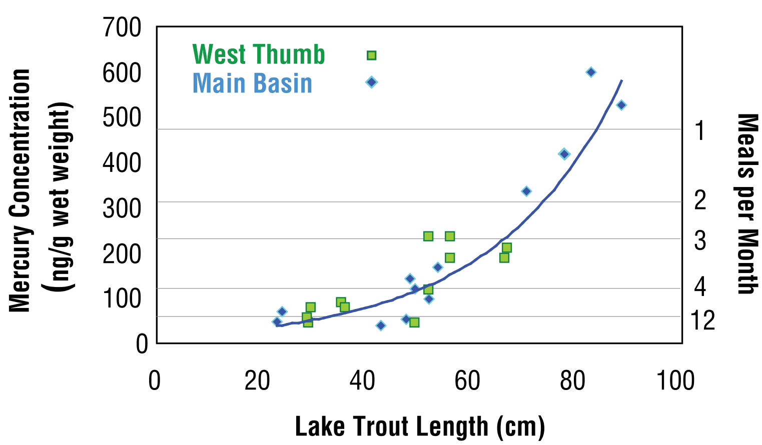

Figure 33. Mercury concentration of 24 lake trout of various lengths collected from the West Thumb and main basin of Yellowstone Lake in 2007. Recommended number of meals per month as provided by the U.S. Environmental Protection Agency are given on the alternate y-axis (EPA 2007).

Aquatic Nuisance Species Prevention

Yellowstone's world-class fisheries are threatened by introductions of exotic and non-native aquatic nuisance species (ANS) that displace native species, such as cutthroat trout and many native macroinvertebrates upon which Yellowstone fishes depend for growth and survival. ANS 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. 2006*a*) are already present in park waters. The park again placed high priority on ANS prevention in 2007. Staff were assigned to contact boaters and anglers in both Yellowstone and Grand Teton national parks to increase awareness of the issue (Fey et al. 2007). Contacts with boaters, anglers, the general public, NPS

staff, and concessions staff more than tripled, increasing from 828 in 2006 to 3,541 in 2007.

Due to the looming threat of additional ANS introductions, of particular interest is the origin of equipment arriving here, especially boats which may be carrying water in bilges or livewells. Regarding this, Fey et al. (2007) states:

"Though over half of the boats entering Yellowstone National Park (1,748 of 2,641)… came from the surrounding states of Montana, Idaho, and Wyoming; many came to the greater Yellowstone area from waters in 42 of our 50 States. Some (of the visitors) were from as far away as Australia, Canada, Mexico and Germany. The greater Yellowstone area is in effect an international destination for recreational boaters and anglers; and along with them is the potential for spreading invasive ANS."

Given that hundreds of ANS exist in the United States and more are introduced each year (<http://nas.er.usgs.gov>), the threat to park waters will persist into the foreseeable future.

For fisheries, it is the spread of Viral Hemorrhagic Septicemia (VHS) that is especially worrisome. Historically considered the most serious of viral diseases for freshwater salmonids reared in Europe, it has evolved into a problem for marine finfish and most recently has become a fast-spreading disease in wild, freshwater fish across the Great Lakes, where it has caused a significant number of large-scale fish mortalities (GLC 2007; USGS 2008). This contagious virus is active in cold water (<15°C) and causes severe internal and external hemorrhaging of the fish. Once introduced into a wild fishery, it is essentially impossible to eliminate or control. As VHS is spread largely by the movement of fish, eggs, urine, feces, and sexual fluids within water, methods to prevent its introduction to Yellowstone are similar to those of other ANS.

Although our efforts to prevent additional ANS invasion are far above those of just a few years ago, a new paradigm is required in Yellowstone regarding the way people and equipment are allowed to move among water bodies. Unless risk of introduction is reduced to zero, ANS will eventually populate all accessible, suitable habitats across the park. In that case, they will be here to stay, and will impact biodiversity and ecosystem processes beyond that which park managers can repair. The Fisheries Program will continue to work closely with park Resource Protection Specialists and others across the ecosystem to guide research, provide scientific information, actively pursue funding, and support other means for the prevention of ANS introductions.

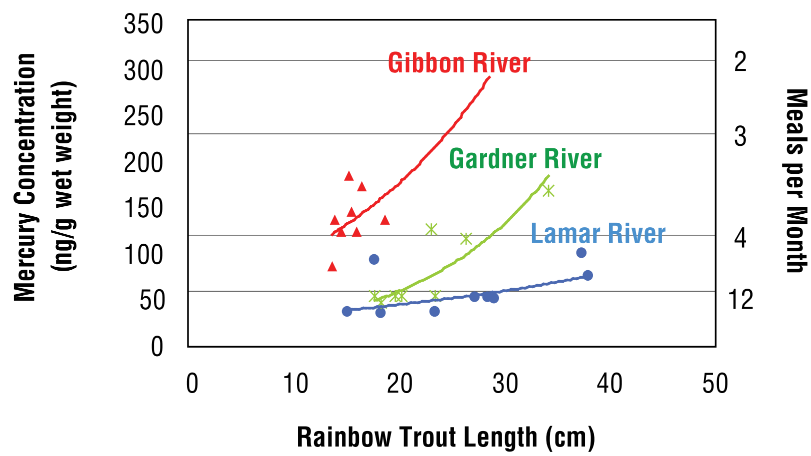

Figure 34. Mercury concentration of 27 rainbow trout of various lengths collected from the Gardner, Gibbon, and Lamar rivers in 2007. Recommended number of meals per month as provided by the U.S. Environmental Protection Agency are given on the alternate y-axis (EPA 2007).

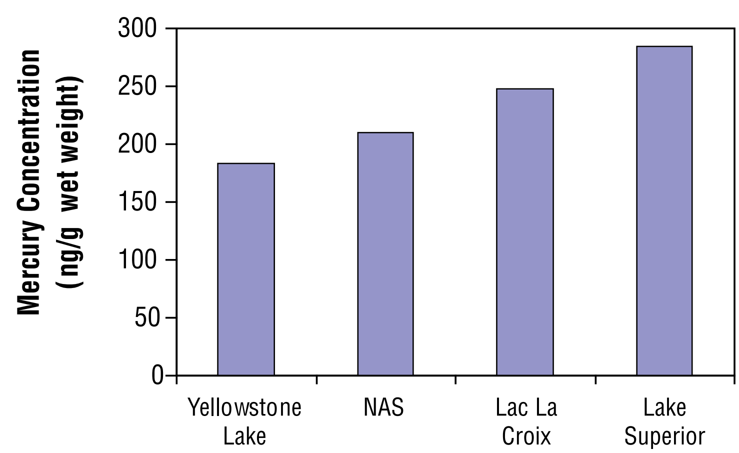

Figure 35. Comparison of mercury concentrations in 60-cm lake trout from Yellowstone Lake in 2007; eight lakes located in northern Alberta & Saskatchewan (Evans et al. 2005); and Lac La Croix (northern Minnesota) and Lake Superior (John Sorenson, University of Minnesota, unpublished data).

Public Involvement

Sixth Year of Fly Fishing Volunteers

Led by volunteer coordinators Timothy Bywater and Bill Voigt, field work for the 2007 season began in early June with the fly fishing volunteers focusing on distribution of pure and hybridized cutthroat trout in Slough Creek and documenting the effectiveness of a waterfall on Grayling Creek as a barrier to upstream passage by trout. In addition, to determine the effectiveness of a natural cascade on Elk Creek as a barrier to upstream fish movement, brook trout were captured upstream of the cascades, marked by clipping a fin, and then moved downstream to a location below the cascades near the Yellowstone River. Effectiveness of the barrier was then assessed by angling for brook trout upstream and examining for clipped fins. Elk Creek above the cascades provides excellent habitat for removal of the non-native brook trout and reintroduction of Yellowstone cutthroat trout.

This year, the volunteer fly fishing program also focused on several small lakes. Samples were taken to understand the degree of hybridization of cutthroat trout at Trout Lake and to determine species presence in Goose Lake and its potential for westslope cutthroat trout stocking. The program also developed a list of lakes in the park that would be good candidates for native cutthroat trout stocking.

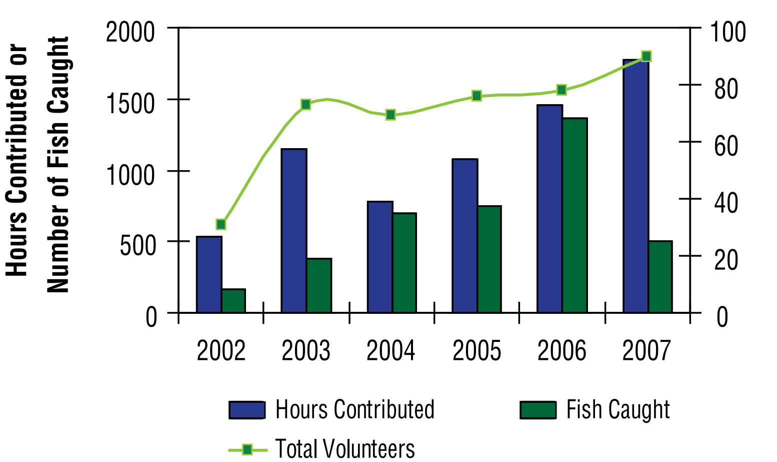

Figure 36. Total number of fly fishing volunteers, and the hours contributed and number of fish caught by them from streams and lakes within Yellowstone National Park, 2002–2007.

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Artificial beaver dams set up for research on willows were examined for their potential to restrict passage of trout by fly fishing volunteers (top); fly fishing volunteers sample the Gibbon River (bottom).

During the 2007 field season, 90 volunteers participated in the program, contributing 1,776 hours to the park's fisheries—the most volunteer involvement we have experienced since this program began in 2002 (Figure 36). Information collected from a total of 3,853 fish caught by the Fly Fishing Volunteer Project has been used by the Fisheries Program to guide research and management within the park. This project is funded by the Yellowstone Park Foundation and is expected to continue at least through 2009.

Long-term Volunteer Assistance

The Fisheries Program 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 Fisheries Program activities as possible. Given that 10,000s of hours of assistance have been provided by volunteers over the years, there is


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NPS/BILL VOIGT

A focus on Artic grayling by the fly fishing volunteer program has resulted in greater understanding of the biology of this native species (top). Fly fishing volunteers led by coordinator Bill Voigt on a trip to acquire genetic samples from cutthroat trout in the upper Slough Creek watershed (bottom).

no question that all aspects of our program have greatly benefited from both long- and short-term volunteer support.

Educational Programs

Fisheries Program 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 Fisheries Program, 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 NPS biologists and other regional managers of aquatic systems.

Projects by Graduate Students

Graduate student: Julie Alexander (Doctor of Philosophy candidate).
Committee co-chairs: Drs. Billie Kerans and Todd Koel, Department of Ecology, Montana State University.
Title: Detecting *Myxobolus cerebralis* infection in *Tubifex tubifex* of Pelican Creek.
Status: Field studies completed, lab work, analyses, and writing on-going.

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.
Status: Field studies completed, analyses, and writing on-going.

Graduate student: Hilary Billman (Master of Science candidate).
Committee chair: Dr. Charles Peterson, Department of Biological Sciences, Idaho State University.
Title: Effects of fish restoration on amphibian populations in Yellowstone National Park and southwestern Montana. Status: Field studies initiated.

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.
Status: Field studies completed, lab work, analyses, and writing on-going.

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.
Status: Analyses and writing on-going.

Information collected from a total of 3,853 fish caught by the Fly Fishing Volunteer Project has been used by the Fisheries Program to guide research and management within the park.

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 (*Oncorhynchus clarkii bouvieri*) with environmental gradients at three spawning tributaries to Yellowstone Lake.
Status: Field studies and lab work completed, analyses and writing on-going.

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.
Status: Project completed in August 2007.

Graduate student: John Syslo (Master of Science candidate).
Committee chair: Dr. Christopher Guy, U.S. Geological Survey Cooperative Fisheries Research Unit, Department of Ecology, Montana State University.
Title: Lake trout suppression program data analysis, modeling, and guidance to improve efficiency.
Status: Field studies initiated.

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.
Status: Field studies, lab work, and analyses are completed and writing is on-going.


NPS/BILL VOIGT

Rainbow trout collected by the fly fishing volunteers in 2007.

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 (http://fwp.mt.gov/wildthings/concern/yellowstone.html), and an MOU concerning the recovery of fluvial Arctic grayling (http://fwp.mt.gov/wildthings/concern/grayling.html).

Cutthroat Trout Broodstock Development

In previous years, Wyoming Game and Fish Department has 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-zero Yellowstone cutthroat trout from the broodstock in Wyoming (LeHardys Rapids origin) are often provided for whirling disease exposure studies in the park.

The park has verified two genetically pure westslope cutthroat trout populations. In 2007 gametes from the population located in Last Chance Creek were incorporated into the upper Missouri River westslope cutthroat trout broodstock at the Sun Ranch in the Madison Valley, Montana.

Acknowledgments

Much-appreciated administrative support for the Fisheries Program in 2007 was provided by Barbara Cline, Montana Lindstrom, Melissa McAdam, and Becky Wyman. Trudy Haney of the contracting office also worked especially hard for us with contracting of the Specimen Creek fish barrier and modifications due to the Owl Fire.

Special thanks to the Wyoming Game and Fish Department for help on Yellowstone Lake by providing the assistance of five seasonal technicians and several other senior staff, including Rob Gipson, Bill Wengert, Mark Smith, and Jason Burckhardt, who helped with gillnetting and electrofishing, and Andy Dux who assisted with underwater videography. The U.S. Fish and Wildlife Service, Idaho Fishery Resources Office in Ahsahka once again allowed us to use their electrofishing boat for removal of spawning lake trout. We greatly appreciate their support and assistance.

We received much appreciated support and guidance for our cutthroat trout restoration activities from Lee Nelson, Don Skaar, and Ken Staigmiller, Montana Fish, Wildlife and Parks; and Dale White, Gallatin National Forest.

Special thanks to Emily Renns and Austin McCullough of Montana Fish, Wildlife and Parks for helping us determine the suitability of upper Grayling Creek for fluvial Arctic grayling. Julie Alexander of Montana State University and Troy Davis and Dan Quinn of Yellowstone's Wildlife Program provided much appreciated assistance with fish and habitat surveys on the upper Yellowstone River.

Diane Eagleson and John Varley 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.

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.

Many other people from within Yellowstone National Park contributed to the success of Fisheries Program activities in 2007; 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 from Fire Cache; Phil Anderson, Greg Bickings, Earl McKinney, Bruce Sefton, Art Truman, Mark Vallie, 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.

NPS/TODD KOEL

Fisheries biologist Pat Bigelow with research advisor Dr. Wayne Hubert, USGS Wyoming Cooperative Fisheries and Wildlife Research Unit, University of Wyoming.

NPS/TODD KOEL

NPS/TODD KOEL

MTFWP fisheries biologist Lee Nelson spawned westslope cutthroat trout at Last Chance Creek in June 2007 (left). Dale White, Gallatin National Forest, measures topography of Specimen Creek near Highway 191 to determine the potential of a fish barrier in this area (right).

Special thanks to our dedicated technicians and volunteers for their contributions to our program. The accomplishments of 2007 would not have occurred without your hard work and tireless efforts!

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- 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.

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NPS/BRIAN ERTEL

Fisheries horse Ethan takes a break in the backcountry with supervisory fisheries biologist Dr. Todd Koel.

NPS/BRIAN ERTEL

NPS/TODD KOEL

MSU fisheries restoration specialist Mike Ruhl and NPS supervisory fisheries biologist Dr. Todd Koel with fisheries horses Pat, Sammy, and Scotty on the back side of Turret Mountain in the Teton Wilderness, Wyoming (left). Dan Reinhart of Yellowstone's Resource Protection led efforts to identify hazard trees in the burned area of East Fork Specimen Creek (right).

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Appendices

Appendix i. Fish Species List

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

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

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

NPS/JEFF ARNOLD

Student Conservation Association (SCA) intern Lindsey Belt and MSU water quality technician Ty Harrison in the lab at Lake.

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

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

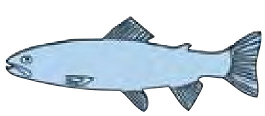
The Yellowstone Fisheries and Aquatic Sciences Program staff in July 2007. Seated (left to right): Pat Bigelow, Becky Adams, Hallie Ladd, Jeff Arnold, Lindsey Belt, Audrey Squires, Stacey Sigler, Brad Olszewski. Standing (left to right): Nicole Legere, Phil Doepke, George Monroe, Chelsey Young, Bill Voigt, John Syslo, Patrick Smith, Cody Burnett, Brian Ertel, Robert McKinney, Ty Harrison, Mike Ruhl, Derek Rupert, Todd Koel.

Appendix iii. Long-term Volunteers, 2007

Name
Belt, Lyndsay
Burnett, Cody
Giorgi, Connor
Ladd, Hallie
McKinney, Robert
Metler, Brad
Millar, Allison
Monroe, George
Smit, Eefje
Smith, Patrick
Voigt, JoAnn

Appendix iv. Seasonal Staff, 2007

Name
Adams, Rebecca
Billman, Hilary
Bywater, Timothy
Harrison, Ty
Helmy, Olga
Legere, Nicole
Olszewski, Brad
Rupert, Derek
Romankiewicz, Christopher
Squires, Audrey
Sigler, Stacey
Voigt, Bill
Young, Chelsey



Fisheries volunteer Eefje Smit, summer 2007.

Appendix v. Chemical Characteristics of Yellowstone National Park Surface Waters and Sediment in 2007.*

		Anions			Cations				Nutrients				
									Phosphorus		Nitrogen		
Stream/River	**Statistic**	**SO_4**	**Cl**	**Alkalinity**	**Ca**	**Mg**	**Na**	**K**	**Total**	**Ortho_P**	**Nitrate**	**Nitrite**	**Ammonia**
Yellowstone River Fishing Bridge	Mean	16.6	6.7	38.0	6.8	3.5	12.9	2.6	-	-	-	-	-
	Minimum	7.6	4.3	31.0	4.8	2.2	8.6	1.6	-	-	-	-	-
	Maximum	102.0	26.7	95.0	20.6	14.3	48.0	11.9	0.09	0.5	0.2	-	0.9
	Std. dev.	27.0	6.3	18.0	4.4	3.4	11.1	2.9	-	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Yellowstone River Corwin Springs	Mean	30.0	10.6	61.2	15.7	4.9	19.1	4.1	0.07	-	-	-	-
	Minimum	6.5	2.0	34.0	7.6	2.4	5.3	1.3	0.03	-	-	-	-
	Maximum	46.4	16.6	76.0	22.7	7.1	29.2	6.5	0.10	0.2	0.3	-	0.2
	Std. dev.	13.7	4.9	13.8	5.0	1.5	7.9	1.7	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Pelican Creek	Mean	75.3	19.4	67.4	15.4	10.3	35.6	9.1	0.10	-	-	-	0.4
	Minimum	7.7	1.0	17.0	3.7	2.1	3.7	1.6	-	-	-	-	-
	Maximum	119.0	30.3	94.0	23.0	15.9	53.9	14.0	0.15	0.3	0.3	-	0.9
	Std. dev.	38.6	10.1	27.5	6.1	4.5	17.4	4.3	0.03	-	-	-	0.3
	N. obs.	12	12	12	12	12	12	12	12	12	12	12	12
Soda Butte Creek at park boundary	Mean	8.1	-	84.3	23.9	5.5	4.2	0.4	0.05	-	-	-	-
	Minimum	5.1	-	44.0	11.4	2.5	3.1	0.2	-	-	-	-	-
	Maximum	10.9	-	109.0	32.3	7.2	5.3	0.5	0.10	0.4	-	-	-
	Std. dev.	2.0	-	21.3	7.0	1.6	0.6	0.1	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11
Soda Butte Creek near confluence with Lamar River	Mean	7.2	-	114.8	28.9	9.5	3.9	1.5	0.07	-	-	-	-
	Minimum	3.9	-	64.0	15.2	4.5	2.5	0.7	0.04	-	-	-	-
	Maximum	9.0	-	147.0	36.8	12.7	4.6	2.1	0.17	0.4	-	-	0.1
	Std. dev.	1.7	-	27.6	7.4	2.8	0.6	0.5	0.04	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	10	12	12	12	10
Lamar River	Mean	6.5	-	79.0	18.1	6.1	7.3	1.3	0.08	-	-	-	-
	Minimum	1.5	-	34.0	7.2	2.3	2.5	0.6	-	-	-	-	-
	Maximum	9.8	-	104.0	23.9	8.2	9.9	1.7	0.21	0.2	-	-	-
	Std. dev.	2.6	-	24.6	5.9	2.1	2.5	0.4	0.06	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11
Gardner River	Mean	123.6	31.7	151.8	65.7	18.0	30.3	11.5	0.08	-	-	-	-
	Minimum	32.7	7.4	77.0	27.8	6.5	8.2	3.2	0.05	-	-	-	-
	Maximum	227.0	55.6	216.0	95.3	29.1	53.2	20.5	0.11	0.2	0.2	-	-
	Std. dev.	50.2	12.6	35.5	18.2	5.9	12.0	4.6	0.02	-	-	-	-
	N. obs.	12	12	12	12	12	12	12	11	12	12	12	11

*Table of reporting limits provided in the annual report for 2006 (Koel et al. 2007).