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Westslope cutthroat trout

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Title page art courtesy Mimi Matsuda.
Front cover captions (left to right): John Syslo, USGS Montana Cooperative Fisheries Research Unit and Adam Lucas, Student Conservation Association (SCA) volunteer, examine a gillnet used for monitoring of cutthroat trout and lake trout on Yellowstone Lake (NPS/Jay Fleming); SCA volunteer Jessica Dugan with a cutthroat trout from Yellowstone Lake (NPS/Brian Ertel); native fish restoration biologist Michael Ruhl (right), SCA volunteer, Saalem Adera, and fisheries technician Mike Consolo stocking westslope cutthroat trout eggs at East Fork Specimen Creek (NPS/Todd Koel).
Back cover captions (left to right): NPS fisheries biologist Pat Bigelow leading efforts to suppress lake trout on Yellowstone Lake (NPS/Todd Koel); contract netting boat *Sheepshead* removing lake trout from Yellowstone Lake (NPS/Todd Koel); National Park Service aquatic ecologist Jeff Arnold with a cutthroat trout from Yellowstone Lake (NPS/Brian Ertel).
Background: Moonlight on Yellowstone Lake (NPS/J. Schmidt, 1977).
Opposite page: High Lake, at the headwaters of East Fork Specimen Creek, is now home to an abundance of genetically unaltered westslope cutthroat trout (NPS/Jay Fleming).

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

Contents

NPS/B. ERTEL

Yellowstone Lake.

Background

NPS YELL-36232

Hayden Survey camping near Yellowstone Lake in 1871.

Significant threats to the long-term persistence of native fish in Yellowstone National Park have emerged over the past two decades. Nonnative, predatory lake trout and exotic whirling disease were introduced to the vast, seemingly secure Yellowstone Lake ecosystem, home to the largest remaining concentration of cutthroat trout. In the early 2000s the impacts of an expanding lake trout population and whirling disease coincided with that of drought, resulting in a precipitous decline in cutthroat trout. Cascading effects through the ecosystem have been documented. Grizzly bears are now seldom seen on cutthroat trout spawning tributaries, and few ospreys prey on cutthroat trout near the lake's surface or nest in adjacent trees. As measured by the frequency with which Yellowstone cutthroat trout are caught, angler success on Yellowstone Lake is less than one-fourth of what it once was.

Coinciding with the cutthroat trout decline in Yellowstone Lake were changes in another previous stronghold for this species in the park, the Lamar River. Rainbow trout, which were intentionally introduced by park managers in the early 1900s and propagated at the Trout Lake hatchery near lower Soda Butte Creek, historically remained concentrated in the Yellowstone River below the falls at Canyon and the lower Lamar River, primarily downstream of the Lamar River and Slough Creek cascades. In the early 2000s, however, anglers began reporting catches of rainbow trout upstream more frequently. During the summer of 2002, a cadre of the park's Fly Fishing Volunteers returned from the first meadow of Slough Creek with a rainbow trout in hand. As rainbow trout hybridize with cutthroat trout, this confirmation of their spread raised concerns about the security of the cutthroat trout in the upper Lamar River system. Since then, rainbow trout and rainbow trout–cutthroat trout hybrids have been caught as far upstream as the third meadow of Slough Creek (at the park's north boundary) and in upper Soda Butte Creek upstream of Ice Box Canyon.

Yellowstone's native fish have underpinned natural food webs, had great local economic significance, provided unparalleled visitor experiences, and defined much of the park's 20th century historical context. To address recent and historical losses and reverse declining trends in native fish populations and loss of ecosystem function, the National Park Service has sought to take actions that will ensure their recovery. Scientific peer review continue to provide guidance for future efforts on Yellowstone Lake. An environmental compliance process culminating in a parkwide Native Fish Conservation Plan/Environmental Assessment was recently completed. By implementing the aggressive conservation actions described in the plan, the National Park Service aims to reduce long-term extinction risk and restore the ecological role of native species, including fluvial Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout, while ensuring sustainable native fish angling and viewing opportunities for visitors.

This report documents the conservation actions, long-term monitoring, and assessments made to conserve Yellowstone's native fish by the National Park Service and collaborators during 2011. This and previous annual reports are available in electronic format at the Yellowstone National Park website (http://www.nps.gov/yell/planyourvisit/fishing.htm).

2011 Summary

The need to greatly increase lake trout (*Salvelinus namaycush*) suppression efforts on Yellowstone Lake, as well as to implement cutthroat trout and Arctic grayling (*Thymallus arcticus*) recovery efforts elsewhere in the park, led to the completion of a Native Fish Conservation Plan/Environmental Assessment for Yellowstone National Park (National Park Service 2010). Following a long public review period, substantive comments were incorporated into a decision document (Finding of No Significant Impact) signed by Intermountain Region Director John Wessels on May 18, 2011. Implementation of the conservation actions described in the plan began immediately.

Following guidance from external scientific panel reviews of the cutthroat trout conservation program on Yellowstone Lake (August 2008 and June 2011), private sector netters were contracted to assist in the lake trout suppression efforts. From June through October 2011, National Park Service and contracted crews captured a total of 221,563 lake trout, including the first documented from Yellowstone Lake weighing over 30 lbs. (a 30 lb. 4 oz. male) and three other lake trout weighing more than 27 lbs. Gillnets were the primary gear used; however, the eight large live entrapment nets deployed by contractors again demonstrated that large adult lake trout could be removed from shallow water habitats with little or no harm to the cutthroat trout that are also present there. In addition, a network of receivers (listening devices) placed throughout Yellowstone Lake recorded the movements of 159 lake trout that had been caught in the entrapment nets and had sound-emitting tags implanted. This information will be used to identify specific spawning locations where suppression efforts can be focused in future years.


NPS/B. KLEIN

Fish Program Leader Todd Koel presenting the Native Fish Conservation Plan at a public meeting in Cody, Wyoming.

Progress toward cutthroat trout recovery and the achievement of desired conditions for Yellowstone Lake, as defined in the program's adaptive management strategy, was assessed via continued long-term monitoring efforts. A rebound in juvenile cutthroat trout was detected in the Yellowstone cutthroat trout (*Oncorhynchus clarkii bouvieri*) assessment gillnetting conducted in September using gear which begins capturing them at approximately age two. The average catch in September 2011 (17.6 cutthroat trout per net, many of which were juveniles) was the highest since 1987 and a dramatic improvement over the 5.2 cutthroat trout per net in 2010. It exceeds the primary desired condition for Yellowstone Lake (15 cutthroat trout per net). The abundance of juvenile cutthroat trout is an initial indicator that they are responding positively to the expanded efforts to suppress lake trout. Yellowstone cutthroat trout begin spawning at three to four years old, thus this group of young fish should be detected via monitoring of spawning tributaries beginning in 2013–2014.

Westslope cutthroat trout (*O. c. lewisi*) recovery efforts focused on East Fork Specimen Creek and the Goose Lake chain of lakes (Firehole River drainage) in 2011. Restocking efforts on East Fork Specimen Creek were continued despite a long period of spring snowmelt and a protracted westslope cutthroat trout spawn. Approximately 1,300 eggs were collected from Geode Creek, reared to eyed-stage at the Sun Ranch Hatchery, and then stocked in incubators along the East Fork Specimen Creek with more than 1,000 additional eggs provided by Montana Fish, Wildlife and Parks. Most of the incubators hatched eggs into the stream and in one case fry were observed dispersing from an incubator. In July, westslope cutthroat trout from previous stockings were observed spawning in the inlet streams of High Lake for the first time since the East Fork Specimen Creek project began. In September, the Goose Lake chain of lakes and connecting streams were treated with liquid rotenone to remove introduced rainbow trout (*O. mykiss*). Initial investigations indicated that the treatment was successful; however, extensive evaluations will be conducted in 2012 to ensure that complete removal was achieved. Stocking of the Goose Lake system to create a genetically-unaltered westslope cutthroat trout brood from upper Missouri River system sources will begin as early as 2013.


NPS/J. FLEMING

NPS fisheries crew electrofishing Geode Creek to obtain adult westslope cutthroat trout for spawning and stocking of eggs in Specimen Creek.

Ecological monitoring and assessment of the park's aquatic systems continued in 2011. The quality of the surface waters was monitored monthly at 11 sites near the confluences of major streams and rivers. In April, water quality was also sampled at five additional sites across the northern region of the park. Discharge was monitored weekly during August and September at two sites on Reese Creek (a 303(d) listed stream). The physical and chemical characteristics of Yellowstone Lake were monitored seasonally at seven sites to assist the targeting of nonnative lake trout. The water quality sampling effort in Yellowstone during 2011 involved a total of 154 site visits, 478 activities, and 4,250 results that included field observations, multiprobe measurements, and laboratory analysis. Monitoring continued to emphasize assessment of the possible impacts of rotenone on non-target species (amphibians and aquatic invertebrates) during native fish restoration projects. In addition, due to the recent discovery of red-rimmed melania (*Melanoides tuberculata*) in the Boiling River swimming area of the Gardner River, 42 sites were surveyed in the upper Snake River drainage to determine whether this snail or other exotic species had invaded similar habitats; red-rimmed melania was not found at any of them.

The Fly Fishing Volunteer Program continued to be an integral mechanism for communicating information and raising public awareness of issues facing Yellowstone's native fishes. Throughout the 2011 field season, 40 volunteers participated in the program, contributing 2,050 hours to the park's fisheries, which advanced many of the actions outlined in the Native Fish Conservation Plan/Environmental Assessment. The volunteers assisted with westslope cutthroat trout conservation activities on Grayling Creek and with sample collection for cutthroat trout genetics in the Lamar River, Slough Creek, Soda Butte Creek, and Trout Lake. When Pelican Creek, which had been closed to angling for seven years due to whirling disease, was reopened in 2011, fly-fishing volunteers were among the first to visit it with fly rods. They caught many juvenile cutthroat trout, suggesting that the population in Pelican Creek, the second largest tributary to Yellowstone Lake, may be recovering from effects of the devastating disease.

Native Fish Conservation Plan

To implement aggressive actions that will ensure recovery of native fish and restore natural ecosystem function, a Native Fish Conservation Plan/Environmental Assessment (National Park Service 2010) and Finding of No Significant Impact were completed in 2011. Goals of the plan include:

- reduction in the long-term extinction risk for fluvial Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout;
- restoration and maintenance of the important ecological role of native fishes; and
- creation of sustainable native fish angling and viewing opportunities for the public.

The Environmental Assessment was made available for tribal consultation and public review and comment during a 45-day period ending January 31, 2011. Opportunities to comment were available through the park planning website, by US mail, and at public meetings hosted by the National Park Service in Bozeman, Montana, and Cody, Wyoming. Of the 2,998 pieces of correspondence received on the Environmental Assessment during the public comment period, approximately 48% (1,435) were form letters (13 versions). Of the 10,280 comments selected by compliance staff for further analysis, 728 unique substantive comments were analyzed within the Finding of No Significant Impact.

Most of the correspondence (approximately 67%, mostly form letters) favored all aspects of the preferred alternative, which is to implement large-

scale suppression of lake trout on Yellowstone Lake via National Park Service crews and private sector, contract netters. The preferred alternative describes in detail the development of benchmarks for lake trout suppression and an adaptive management strategy for actions on Yellowstone Lake and in streams and lakes elsewhere across the park, and calls for the development and implementation of robust monitoring and continued scientific review through collaboration with partners. For details see the Environmental Assessment and Finding of No Significant Impact at http://parkplanning.nps.gov/projectHome.cfm?projectID=30504.

Adaptive Management for Native Fish Conservation

Adaptive management is an integral component of the Fisheries & Aquatic Sciences Program. The adaptive management approach includes statistically valid long-term monitoring to evaluate the effectiveness of conservation actions, such as efforts to suppress lake trout on Yellowstone Lake. The adaptive management approach was chosen because of the varied environments and stressors impacting native fish across the park and the uncertainty of the possible response by native fish to management action. For example, although initial science indicates lake trout expansion in Yellowstone Lake could be curtailed by inflicting an annual total mortality of 60% (see Native Fish Conservation Plan/Environmental Assessment, Appendix A), it is not known for how long this level of mortality would need to be maintained or if the effort could eventually be reduced without resulting in a lake trout resurgence. Similarly, the rate of cutthroat trout recovery in Yellowstone Lake after the population is released from lake trout impacts is uncertain. It may be years before a positive Yellowstone cutthroat trout response is detected and decades before Yellowstone cutthroat trout regain their ecological role in the ecosystem. Performance metrics such as the abundance of spawning cutthroat trout in tributary streams and angler success will therefore be closely monitored to track system responses to conservation actions.

The park's surface waters are considered in two domains for purposes of native fish conservation actions: (1) the Yellowstone Lake, river, and tributaries upstream of the Upper Falls at Canyon; and (2) all other streams, rivers, and lakes within park boundaries (fig. 1). A hierarchical series of "desired conditions" has been developed for each of these domains (see tables 5 and 6 in Native Fish Conservation Plan/Environmental Assessment). From a scientific perspective, each desired condition represents a hypothesized outcome for native fish given the initial state of the system and the conservation actions applied. Monitoring will be conducted to determine if performance metrics are met and conservation actions influence native fish as predicted. If this is the case, hypothesized outcomes for native fish will have also been met and the desired condition achieved.

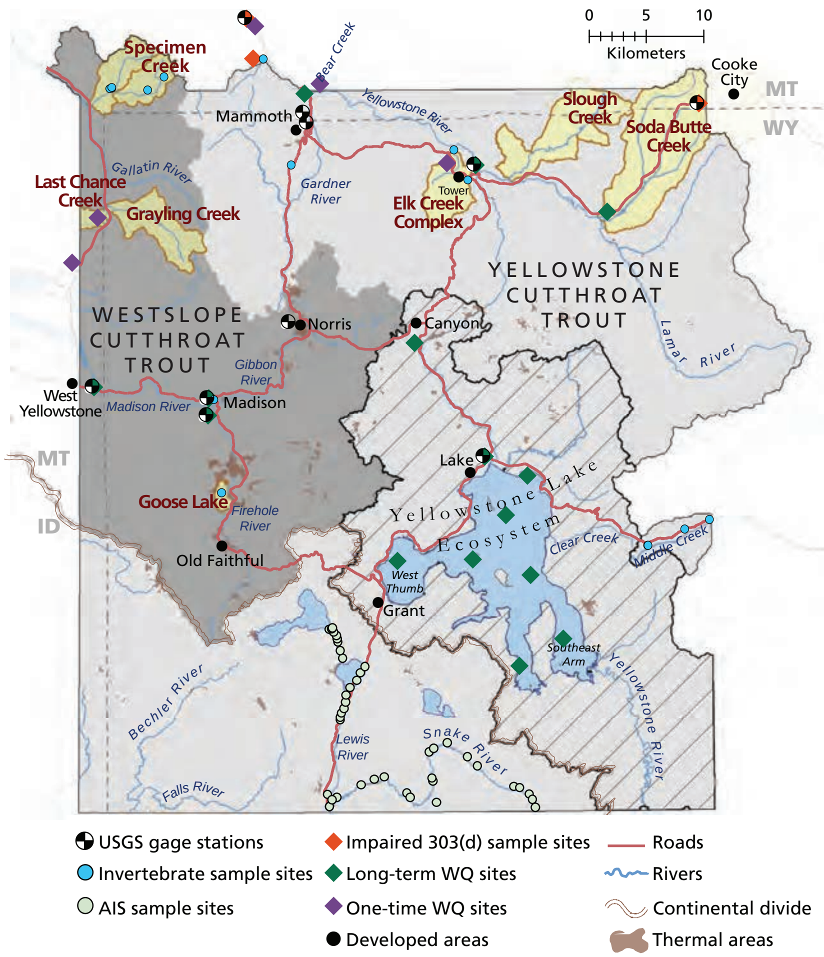


Figure 1. Major surface waters, historical distribution of cutthroat trout within Yellowstone National Park, and sites established for long-term water quality monitoring and status assessments of macroinvertebrates and aquatic invasive species. Stream restoration efforts in 2011 were made at watersheds highlighted in pale yellow-green .

NPS/J. FLEMING

Yellowstone cutthroat trout spawning in tributary to Trout Lake.

Conservation Actions to Restore Yellowstone Lake

Lake trout, intentionally stocked in Lewis and Shoshone lakes in 1890 by the US Fish Commission and introduced into Yellowstone Lake by an unknown source, are a serious threat to the native Yellowstone cutthroat trout population. The National Park Service has worked to suppress the lake trout population since the species was first documented in Yellowstone Lake in 1994. Although more than 830,000 lake trout have been netted from the lake, catches have increased each year. In 2008 and 2011, the National Park Service convened a scientific review panel to provide critical evaluations of the lake trout suppression efforts and guidance for improving them. Population modeling suggested that the lake trout removal effort expended in 2010 (Koel et al. 2012) must be doubled in order to curtail further population growth. To meet this goal, the National Park Service added the use of private sector, contract netters. Following a pilot study in which contract netters were successfully incorporated in a limited effort during abbreviated seasons in 2009 and 2010, the contract netters were used during nearly the full netting season in 2011.

Lake Trout Suppression

The start of the 2011 gillnetting season was delayed due to the unusually late ice-off on Yellowstone Lake. Netting began on June 9, after the lake was sufficiently ice-free to allow safe travel, and ended on October 19. National Park Service and contract crews put forth a total of 26,777 units of effort (one unit of effort is 100 m of gillnet set over one night). The contract netting crew also used eight large deep-water entrapment nets from June 8 to September 19. Most of the netting was done in the central and western regions of Yellowstone Lake (fig. 2).

The number of lake trout netted and the catch per unit effort have been increasing annually, with more than 221,500 lake trout caught in 2011 (fig. 3). Estimated biomass of lake trout netted has increased exponentially, with 109,000 kg (3.2 kg/ha of lake area) netted in 2011 (fig. 4). When focused on adults, the maximum sustainable harvest experienced at other lakes is typically less than 1.0 kg/ha (Martin and Olver 1980).

NPS/T. KOEL

Hickey Brothers fisheries, LLC gillnetter Adam Lohmeyer aboard the *Kokanee*.

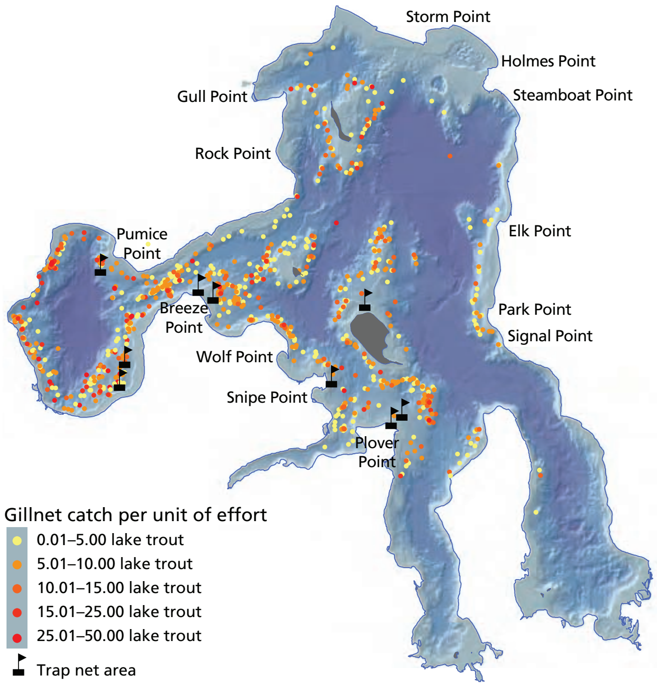


Figure 2. Spatial extent of total effort on Yellowstone Lake by gillnets and large live entrapment nets in 2011. Color shade indicates the number of lake trout caught per 100 meters of gillnet per night.

Lake Trout Gillnetting

Most gillnetting was done in water 20–60 m deep, where small-mesh gillnets (25, 32, and 38 mm) caught predominantly the smaller juvenile lake trout residing at those depths. In 2011, small-mesh gillnets were used for 22,603 units of effort (84% of total gillnet effort) resulting in the capture of 184,857 lake trout (fig. 5) weighing approximately 61,700 kg (fig. 6).

Large-mesh gillnets (44, 51, 57, and 64 mm) were deployed primarily in water more than 20 m deep to target large, adult lake trout. In 2011 large-mesh gillnets were used for 4,174 units of effort (16% of total gillnet effort), resulting in the capture of 25,189 lake trout (fig. 5) weighing an estimated 29,800 kg (fig. 6). The mean length of the females (492 mm) was slightly longer than that of males (469 mm). The largest catches in large-mesh gillnets were made at Carrington Island, Breeze Channel, and the West Thumb geyser basin (fig. 2).

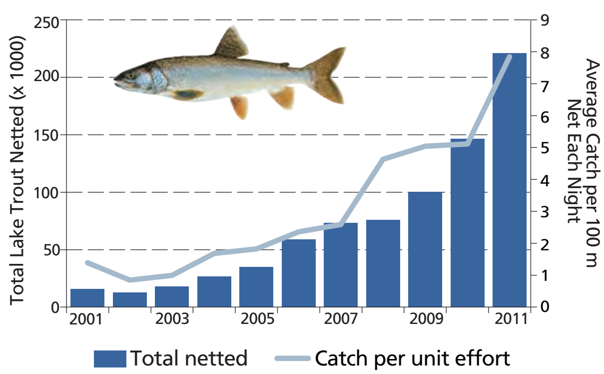


Figure 3. Total number of lake trout netted from Yellowstone Lake by all gear types and average number caught per 100m net per night by small and large mesh gillnetting, 2001–2011.

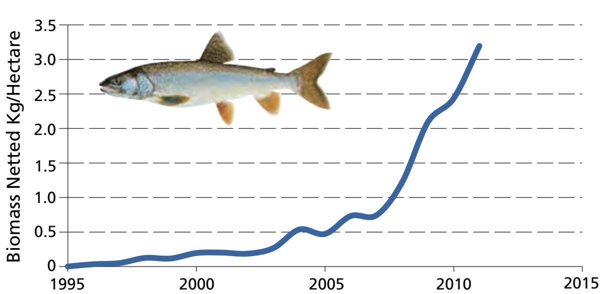


Figure 4. Total estimated lake trout biomass netted from Yellowstone Lake by all gear types, 1995–2011.

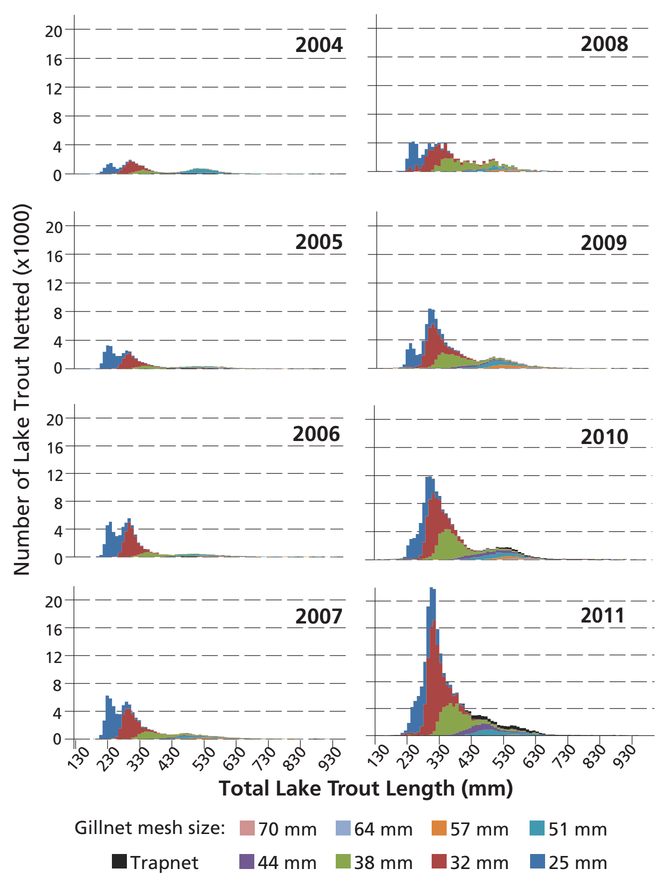


Figure 5. Length-frequency distributions of lake trout removed by gillnets and live entrapment nets, 2004–2011.

Lake Trout Live Entrapment Netting

From June 8 to September 19, 2011, contract netters placed eight large live entrapment nets in shallow areas near the shore where both lake trout and cutthroat trout were present. These nets consisted of a series of mesh lead (or guide) lines up to 275 m long and funnel-shaped tunnels which directed fish into a box constructed of heavy mesh (fig. 7) that is 12 m by 6 m and up to 12 m in height, enabling the capture of many lake trout of large size. These nets were lifted and checked approximately every three days; the cutthroat trout were sorted from the lake trout and released unharmed. The trap nets also permitted the live capture of large lake trout for research use (see *Sonic Tracking to Locate Spawning Areas*).

An important feature of adding trap nets to the suppression program was an increased ability to remove large female lake trout from the population, thus impacting population reproductive potential. Total catch by trap nets was 10,962 lake trout in 2011, of which the mean total length for females and males was 551 mm and 500 mm, respectively. Of these, 53% were female, 42% were male, and 5% were either undetermined or not examined.

The top three producing trap nets in both number and biomass of lake trout were in West Thumb (fig. 2), where each net caught an average of 21 lake trout per night with an average biomass of 28 kg. The trap nets in the Breeze Channel/Main Basin areas each caught an average of 10 lake trout per night with an average biomass of 19 kg.

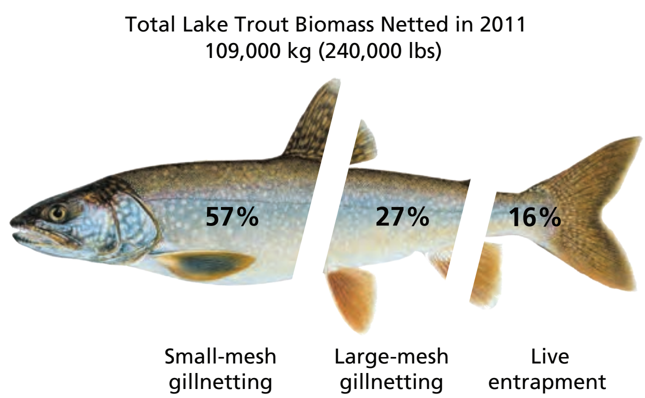


Figure 6. Estimated proportions of the total lake trout biomass removed from Yellowstone Lake by small-mesh (25, 32, and 38 mm) and large-mesh (44, 51, 57, and 64 mm) gillnets and live entrapment netting in 2011.

NPS/P. BIGELOW

Lake trout suppression boat ***Sheepshead*** operated by Hickey Brothers Fisheries, LLC lifting a large deep-water trapnet on Yellowstone Lake.

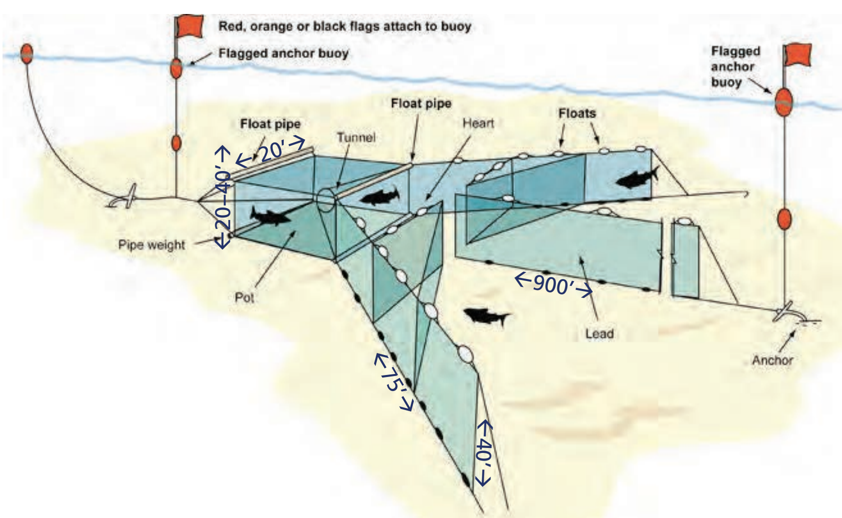


Figure 7. Diagram of large live entrapment net used by contract netters on Yellowstone Lake in 2011.

NPS/T. KOEL

Buoys used to mark locations of gillnets on Yellowstone Lake.

Sonic Tracking to Locate Spawning Areas

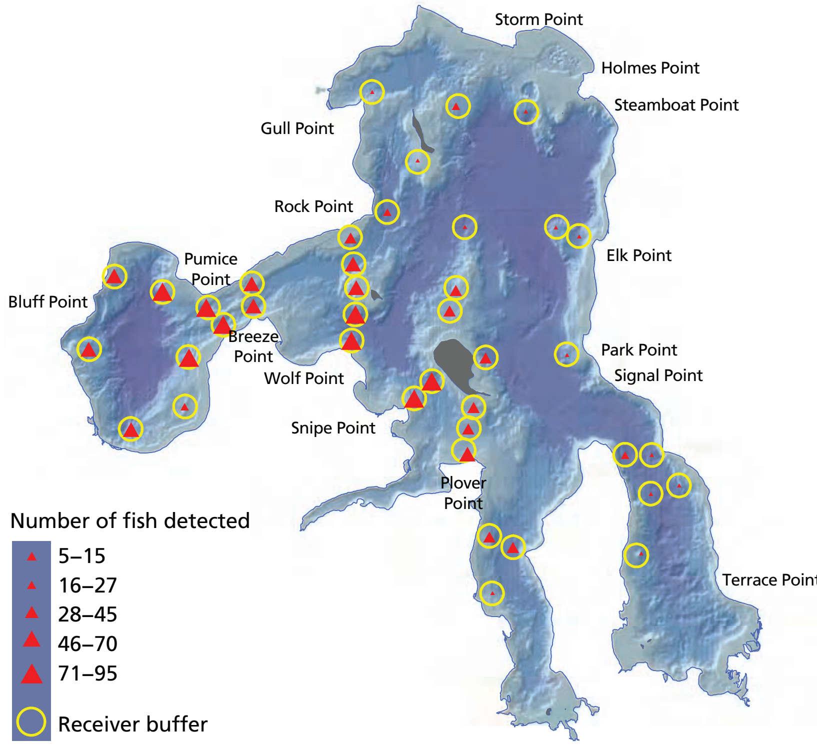


Figure 8. Spatial distribution and tag detection range (yellow circles) of acoustic receivers used to track lake trout movements and locate spawning areas on Yellowstone Lake. Size of triangle corresponds to the number of unique fish detected (5–95) during fall, 2011.

In August 2011, the National Park Service and US Geological Survey launched a pilot study with support from Trout Unlimited, the National Parks Conservation Association, and the Greater Yellowstone Coalition to surgically implant 159 lake trout with transmitters or tags and deploy 40 stationary acoustic receivers. The receivers were distributed throughout the lake, but more concentrated in areas believed to be more heavily used by lake trout (fig. 8). At suspected passage points, receivers were positioned to form an acoustic curtain so that as fish moved through the area, at least one receiver would record its presence.

Initial results from this work show a great deal of movement of lake trout around the lake. More than 65% of the tagged lake trout traveled through the Breeze Channel at least once between August 23 and October 13 (fig. 8). This included fish tagged in the main basin and Southeast Arm that moved westward toward West Thumb, as well as those tagged in West Thumb moving eastward into the main basin. During a three-day period (September 18–21), 51 (36%) of the tagged fished moved through the Breeze Channel area. Many of the tagged lake trout were recaptured during suppression efforts. It is anticipated that this research will lead to the identification of precise spawning locations, increasing the efficiency of suppression efforts.

Science Panel Review of the Yellowstone Lake Program

Upon completion of the Native Fish Conservation Plan/Environmental Assessment (National Park Service 2010), the National Park Service reconvened the scientific review panel in June 2011 to evaluate the effectiveness of the current program, review the relevance of the 2008 recommendations (Gresswell 2009), provide continued guidance and recommendations for restoring the cutthroat trout in Yellowstone Lake, and identify significant knowledge gaps concerning the lake. The panel was able to incorporate new information in their evaluation, including the suppression plan and benchmarks set forth in the plan/Environmental Assessment, lake trout population modeling (Syslo et al. 2011), the results of private-sector contracted netters using commercial techniques, and additional data from National Park Service suppression efforts.

The 2011 science review panel concluded that to obtain a rapid positive response in the cutthroat trout population, the lake trout suppression efforts should be greatly increased (Gresswell et al. 2012). While emphasizing that increased suppression should remain a top priority, they prioritized other research needs for Yellowstone Lake, with the highest priority assigned to a telemetry study to identify lake trout spawning areas within Yellowstone Lake. This was initiated in August 2011 as described in the previous section.

Monitoring Performance Metrics on Yellowstone Lake

Progress toward cutthroat trout recovery and achievement of desired conditions for Yellowstone Lake, as defined in the program's adaptive management strategy (Koel et al. 2011), is assessed through four long-term monitoring efforts: (1) a lakewide population assessment of cutthroat trout conducted via gillnetting in shallow waters in September, (2) cutthroat trout spawner assessments using weirs/traps or by making visual counts on tributary streams from May through July, (3) cutthroat trout catch success reported by lake anglers during the fishing season, and (4) lakewide assessments of cutthroat trout and lake trout conducted via distribution gillnetting at three depth strata in August.

Lakewide Cutthroat Trout Population Assessment

The cutthroat trout population in Yellowstone Lake has been monitored through annual sampling at the same 11 sites since 1969 (fig. 9). Using 55 variable mesh gill nets and approximately 24-hour net sets, 970 cutthroat trout were captured in 2011. The average catch was 17.6 cutthroat trout per net, the highest since 1987 and a dramatic increase over the lowest catch of 5.2 cutthroat trout per net in 2010. It exceeds the performance metric for the program's adaptive management strategy, in which the primary desired condition is 15 cutthroat trout per net (fig. 10a). The mean total length of

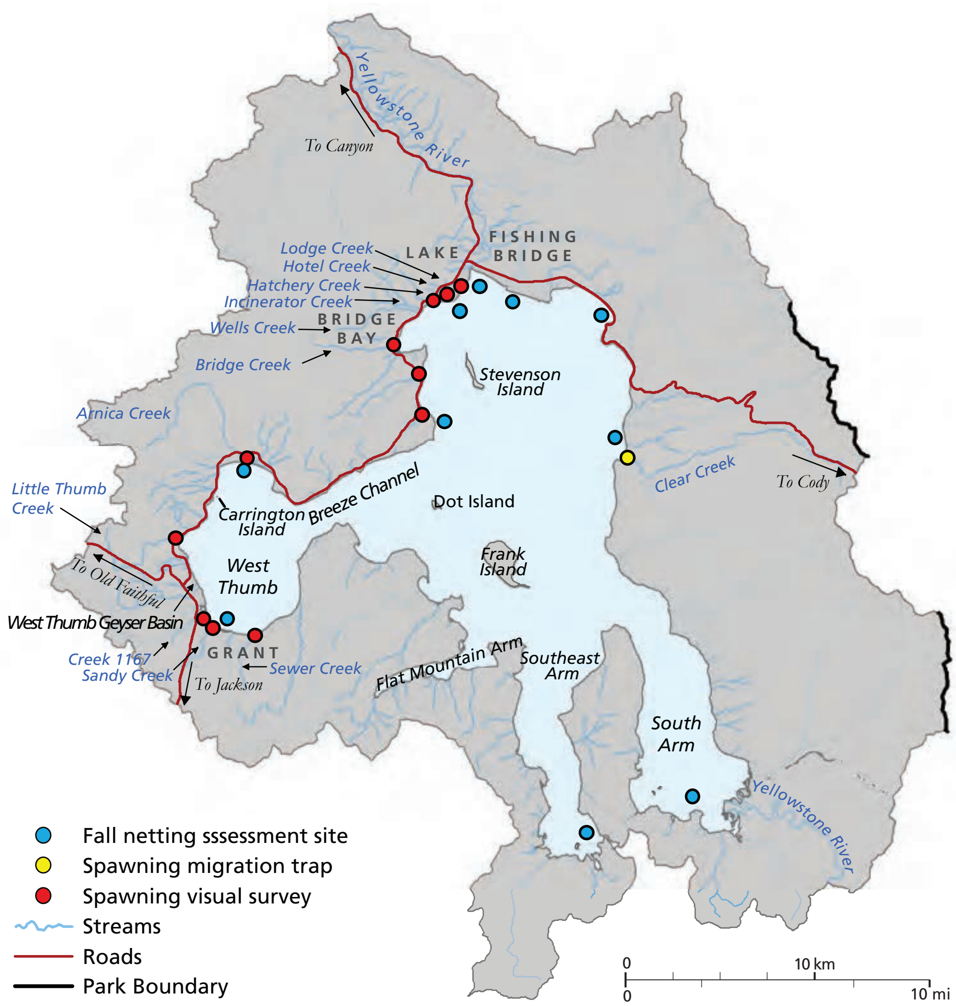


Figure 9. Cutthroat trout long-term monitoring sites for the fall netting assessment on Yellowstone Lake and by a migration trap and visual surveys on tributary spawning streams.

cutthroat trout, which had held relatively steady over the last decade (292–372 mm), dropped to 245 mm (range 142–596 mm) the lowest ever observed by this monitoring method. The decrease in mean length can be attributed to the increase in the number of fish captured that were 100–200 mm (fig. 11). Historically, fish in that size range composed only 7–16% of the catch, but in 2011 they accounted for more than 40%. The abundance of small fish detected by this lakewide population assessment is an initial indicator that the cutthroat trout are responding positively to our expanded efforts to suppress lake trout.

Cutthroat Trout Tributary Spawner Assessment

Long-term monitoring of tributary streams has indicated a substantial decline in the abundance of adult spawning cutthroat trout. From 1988 to 2007, the number of upstream migrating cutthroat trout counted at the trap and weir at Clear Creek (fig. 9) decreased from nearly 55,000 to just over 500 (Koel et al. 2008), while their mean total length increased from 393 mm to 523 mm. Cutthroat trout have not been assessed at Clear Creek since then because the trap and weir were seriously damaged by high spring flows in 2008. Concepts and designs for a new structure have been developed through collaboration with Montana State University's Department of Civil Engineering. Environmental compliance for the project was included in the Native Fish Conservation Plan/Environmental Assessment National Park Service 2010). Contracting and work to regain our capacity to monitor cutthroat trout at Clear Creek are expected in 2012 and 2013.

NPS/T. KOEL

Students from Montana State University's Department of Civil Engineering assess damaged supporting structures at the Clear Creek weir site, while firefighters (left) look on.

In addition to the previous Clear Creek weir and trap counts, the abundance of spawning cutthroat trout was visually estimated by walking the same reaches of stream banks of 9 to 11 tributaries along the west side of the lake between Lake and Grant each year starting in 1988 (Reinhart and Mattson 1990; Reinhart et al. 1995; fig. 2). These surveys have also indicated a significant decline in spawning-age cutthroat trout in Yellowstone Lake (fig. 10b). More than 70 cutthroat trout would typically be observed during a single visit to one of the streams in the late 1980s, compared to only one or two on average in recent years. The secondary and primary desired conditions for Yellowstone Lake are an average of 40 and 60 spawning cutthroat trout observed per stream visit, respectively.

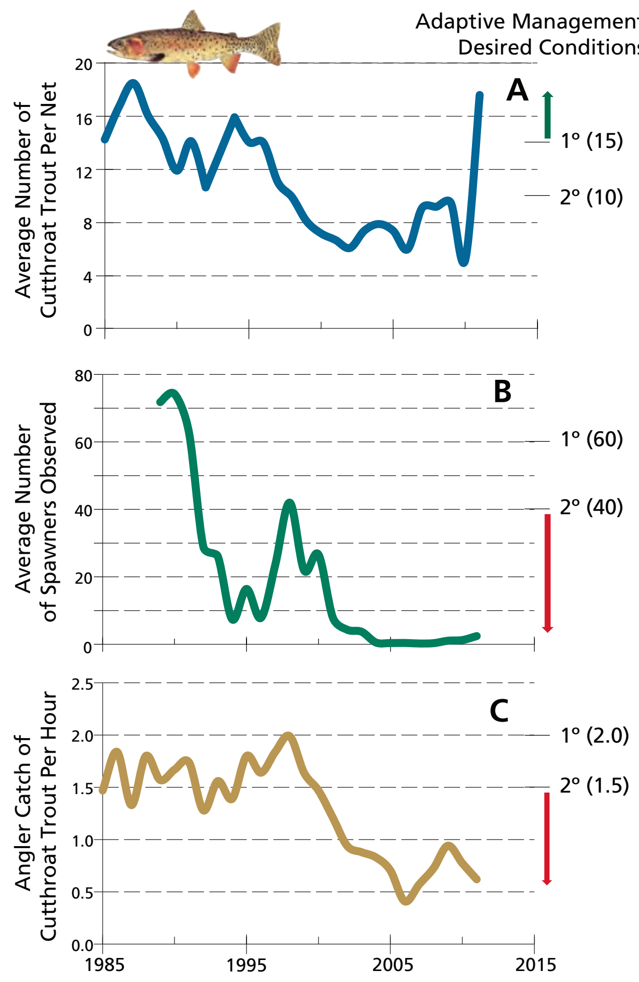


Figure 10. Metrics monitored to assess the effects of conservation actions on Yellowstone Lake include the average number of cutthroat trout that are (A) caught per net during the fall netting assessment, (B) observed during visual surveys of spawning streams, and (C) caught per hour by lake anglers, 1985-2011. Primary and secondary desired conditions are from the Native Fish Conservation Plan (Koel et al. 2010).

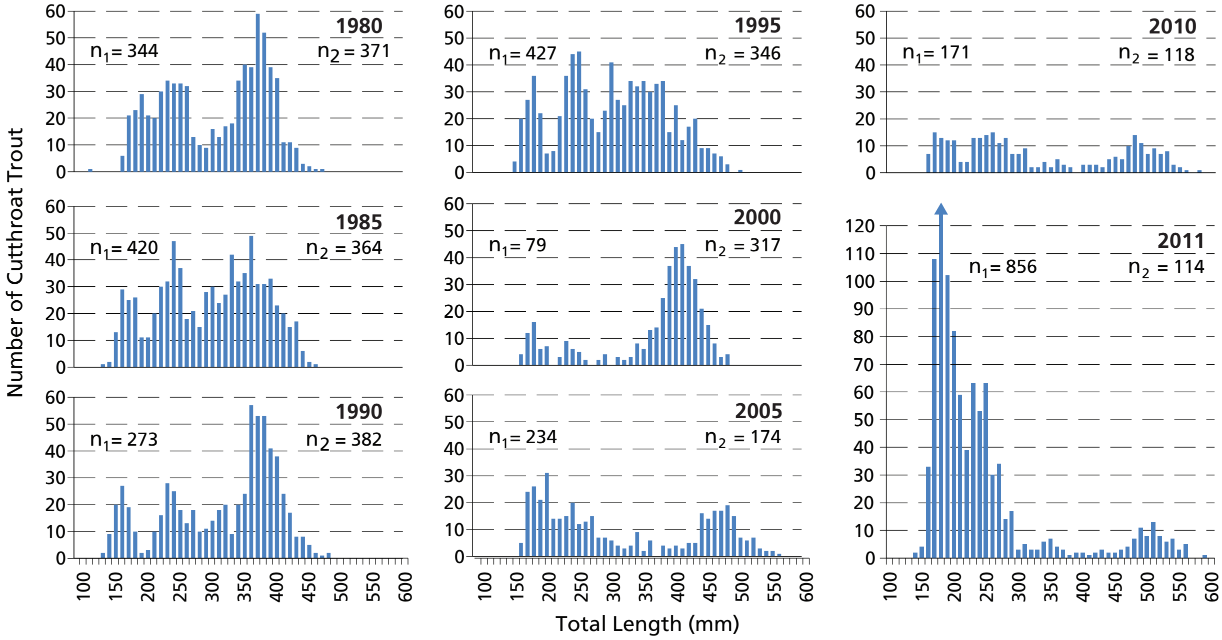


Figure 11. Length-frequency distributions of cutthroat trout from the fall netting assessment on Yellowstone Lake with total number of cutthroat trout <325 mm (n_1) and >325 mm (n_2) at five-year intervals (1980–2010) and in 2011.

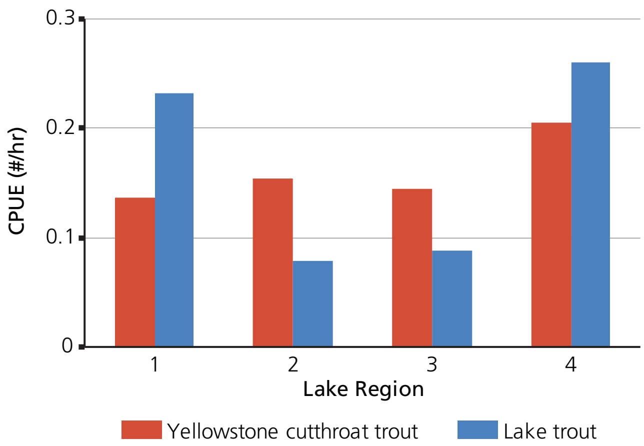
Cutthroat Trout Angler Success

Since 1979, park visitors who purchase a fishing permit have been given a card on which to report the waters fished, time spent, and species and sizes of fish caught (Jones et al. 1980). About 5% of these anglers (or approximately 4,000 a year on average) have completed and returned the cards to the park's fisheries program. About one-third of them fished in Yellowstone Lake, where the average catch rate for cutthroat trout was as high as two fish per hour in the 1990s. It declined dramatically in the early 2000s and was only 0.6 per hour in 2011 (fig. 10c). The secondary and primary desired conditions are an average of 1.5 and 2.0 cutthroat trout caught per hour of angling. Similar to trends noted by other monitoring methods, the cutthroat trout caught by anglers have increased in size over the last 15 years. The mean length of angler caught cutthroat trout in 2011 was 447 mm—incredibly large in comparison to cutthroat trout caught just 15 years ago, which averaged 380 mm. Although the catch rate is far below the desired condition, an angler could expect to catch at least one (likely very large) cutthroat trout for every two hours of fishing on Yellowstone Lake.

Distribution Netting of Cutthroat Trout and Lake Trout

After the presence of lake trout in Yellowstone Lake was confirmed in 1994, a monitoring plan was developed to determine their spatial distribution in the lake (Ruzycki et al. 2000), but inconsistency in the methods used reduced the usefulness of the data collected from 2001 to 2009. Beginning in 2010, with guidance from the USGS Montana Cooperative Fishery Research Unit, the Ruzycki (2000) monitoring plan was enhanced to ensure that both lake trout and cutthroat trout were monitored to inform adaptive management. The distribution netting program is now designed to (1) evaluate the distribution of cutthroat trout and lake trout in Yellowstone Lake, (2) measure the recruitment of cutthroat trout into the Yellowstone Lake ecosystem, (3) assess the age and size class structure of cutthroat trout and lake trout, and (4) determine lake trout mortality from the suppression program.

The distribution netting program partitioned Yellowstone Lake into four regions based on hypothesized lake trout densities in 1997 (Ruzycki 2004). Including islands but excluding the non-motorized zones in the South and Southeast Arms, the 181 km of Yellowstone Lake shoreline was divided into 1-km units for selection of sites. In August 2011, 24 of these potential sites were sampled (12 fixed and 12 random), with 6 sites located in each region (fig. 12). Both large mesh (57–89 mm) and small mesh (19–50 mm) gillnets were used. Each net was 75 m long and 2.4 m in height, with five panels (15 m each) of varying mesh size. One large-mesh and one small-mesh net were set parallel to each other, 100 m apart, perpendicular to shore, within three depth strata at each site: (1) in



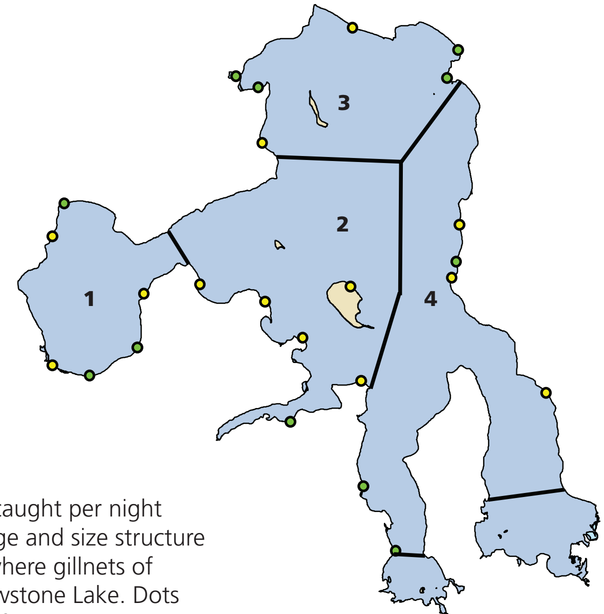


Figure 12. Catch-per-unit-effort (CPUE) was the average number of fish caught per night during summer gillnetting in 2011 to evaluate the distribution and the age and size structure of cutthroat trout and lake trout populations. The map shows the sites where gillnets of various mesh sizes were set at three depth strata in four regions of Yellowstone Lake. Dots indicate net placements at random (green) and fixed (yellow) sites in the four regions.

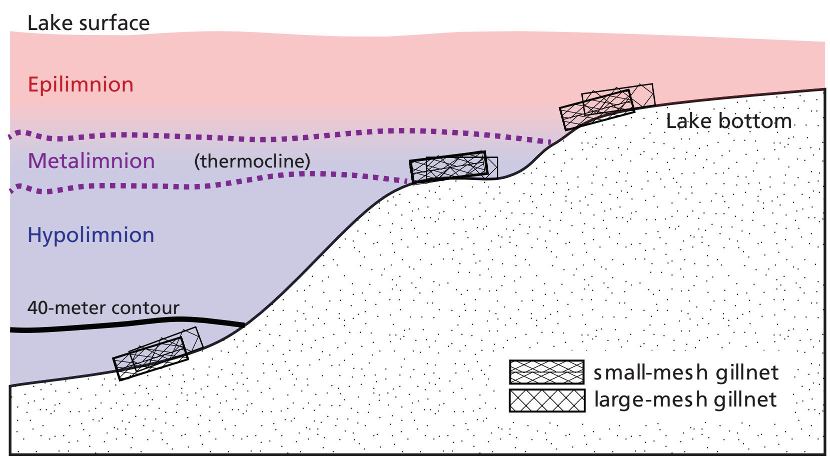


Figure 13. Profile of three depth strata sampled at each site during summer distribution netting for cutthroat trout and lake trout on Yellowstone Lake.

the epilimnion above the thermocline (≈ 2–15 m), (2) in the metalimnion at or immediately below the thermocline (≈15–25 m), and (3) in the hypolimnion in deep water (≈40–50 m; fig. 13).

The distribution nets caught a total of 512 cutthroat trout and 509 lake trout in 2011. The cutthroat trout had a mean total length of 450 mm, compared to 458 mm in 2010 (fig. 14); 73% were 430–570 mm, and 13% were 150–240 mm, an encouraging sign that younger fish are entering the population. Most of the lake trout (73%) were immature fish, 170–350 mm (fig. 15). The mean total length for lake trout was 321 mm, comparable to that in 2010 (322 mm).

Catch per unit effort for the distribution netting program is expressed as the number of fish caught each hour the net was set. The catch per unit effort for cutthroat trout and lake trout varied among sites and lake regions, but was highest for both cutthroat trout and lake trout in region 4 (east shore and southern arms) with 0.21 and 0.26 catch per unit effort, respectively (fig. 12). The highest catch per unit effort was 0.33 for cutthroat trout (sites 77 and 115) and 0.51 for lake trout (site 79). Catch per unit effort was lowest for cutthroat trout in region 1 (West Thumb, 0.14) and for lake trout in region 2 (main basin, 0.08).

NPS/J. ARNOLD

National Park Service crews setting nets to evaluate distribution of cutthroat and lake trout in Yellowstone Lake.

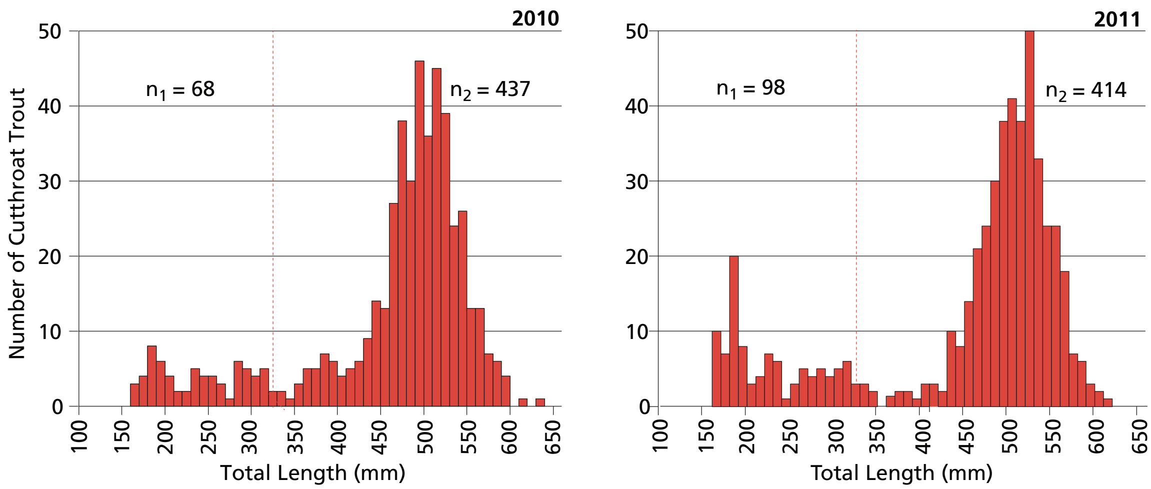


Figure 14. Length-frequency distributions of cutthroat trout from the summer distribution netting on Yellowstone Lake with total number of cutthroat trout <325 mm (n_1) and >325 mm (n_2), 2010 and 2011.

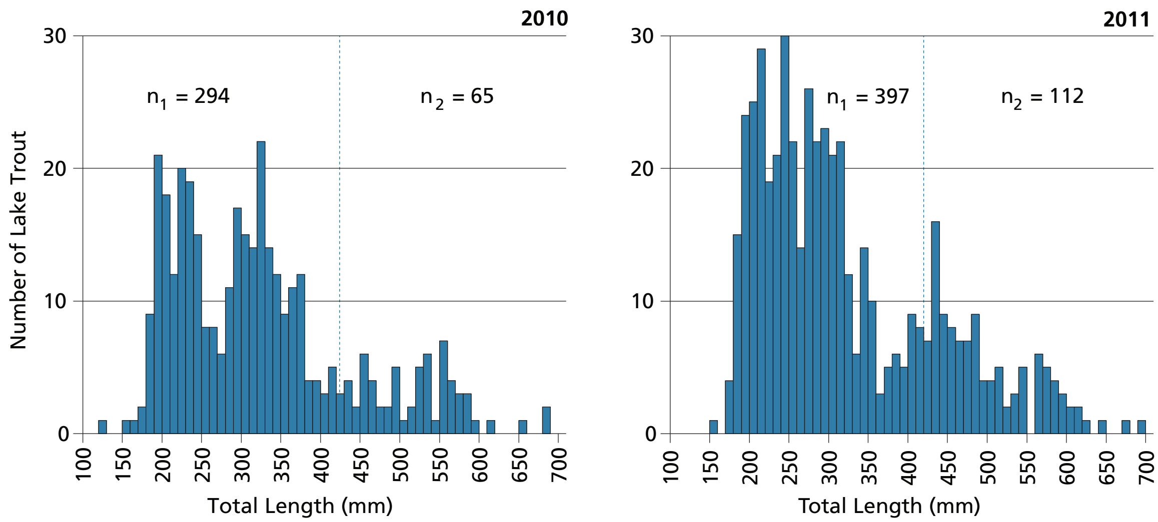


Figure 15. Length-frequency distributions of lake trout from the summer distribution netting assessment on Yellowstone Lake with total number of lake trout <420 mm (n_1) and >420 mm (n_2), 2010 and 2011.

NPS/JAY FLEMING

Montana State University doctoral candidate John Syslo (left), SCA volunteer Adam Lucas, and National Park Service fisheries technician Brian Ertel using gillnets to monitor fish populations on Yellowstone Lake.

NPS/J. FLEMING

Arctic grayling in the Gibbon River system, Yellowstone National Park.

Cutthroat Trout and Grayling Conservation in Streams

Westslope Cutthroat Trout Restoration on East Fork Specimen Creek

The East Fork Specimen Creek westslope cutthroat trout restoration project is nearing completion. Since its inception in 2006 (Koel and York 2006), progress has been made each year to construct a fish barrier, eliminate nonnative fish, and introduce westslope cutthroat trout to High Lake and the East Fork Specimen Creek. In 2011, one of the highest runoff years in memory, a long period of spring snowmelt caused no apparent damage to the fish barrier but prolonged westslope cutthroat trout restocking efforts.

Approximately 1,300 eggs were collected from Geode Creek in June, reared to eyed-stage at the Sun Ranch Hatchery, and then stocked in incubators along the East Fork Specimen Creek in July. In addition, Montana Fish, Wildlife and Parks made available more than 1,000 westslope cutthroat trout eggs from Muskrat Creek (Elk Horn Mountains) that were stocked in the East Fork Specimen Creek in July and August (table 1). Most of the incubators appeared to successfully hatch eggs into the stream and in one case fry were observed dispersing from an incubator. Westslope cutthroat trout from previous stockings were observed spawning in the inlet streams of High Lake in July for the first time since the project began.

The East Fork Specimen Creek project will include a final year of westslope cutthroat trout reintroductions in 2012, followed by periodic monitoring of the westslope cutthroat trout populations, genetic integrity, and fish barrier performance. However, as described in the Native Fish Conservation Plan/Environmental Assessment (National Park Service 2010), the long-term goal is to integrate this project into a larger westslope cutthroat trout restoration in the Specimen Creek drainage (fig. 16) in order to improve the resilience of this isolated population to threats such as wildfire.

The National Park Service contracted with DJ&A, P.C., an engineering and planning firm in Missoula, Montana, in the fall of 2011 to conduct detailed topographic mapping and provide a conceptual design for a large fish barrier on the lower mainstem

Table 1. Total number of westslope cutthroat trout stocked into the East Fork Specimen Creek watershed, 2007–2011

Body of Water	Year	Eggs	Fish
High Lake	2007	1,377	1,144
	2008	3,130	890
	2009	838	930
East Fork Specimen Creek	2010	4,503	—
	2011	2,246	—

of Specimen Creek near the trail head and Highway 191 bridge (fig. 16). A barrier in this location would prevent nonnative brown trout, rainbow trout, and other species from moving upstream into Specimen Creek from the Gallatin River. If an acceptable design can be developed, efforts to restore westslope cutthroat trout to the remaining portion of the East Fork Specimen Creek, North Fork Specimen Creek, and mainstem Specimen Creek will likely commence in the near future.

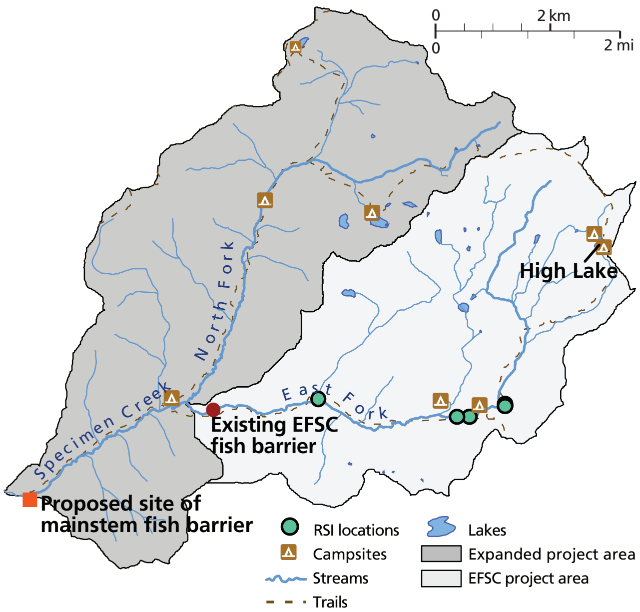


Figure 16. East Fork Specimen Creek (EFSC) westslope cutthroat trout restoration area in the Specimen Creek watershed in northwestern Yellowstone National Park, with locations of remote site incubators for reintroduction of westslope cutthroat trout embryos in 2011.

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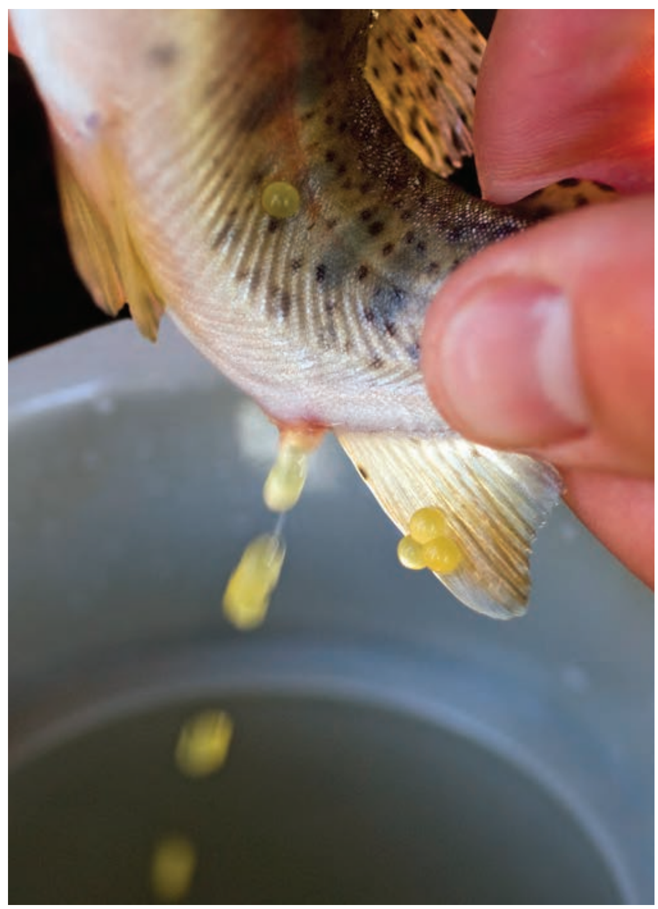


NPS/J. FLEMING

Left: Remote site incubator used for stocking westslope cutthroat trout to East Fork Specimen Creek. Right from top: Westslope cutthroat trout from Geode Creek; barrier constructed on East Fork Specimen Creek to prevent upstream movement of nonnative fish; eggs collected from Geode Creek westslope cutthroat trout.

NPS/J. ARNOLD

Fisheries crews use rotenone to remove nonnative rainbow trout from Goose Lake.

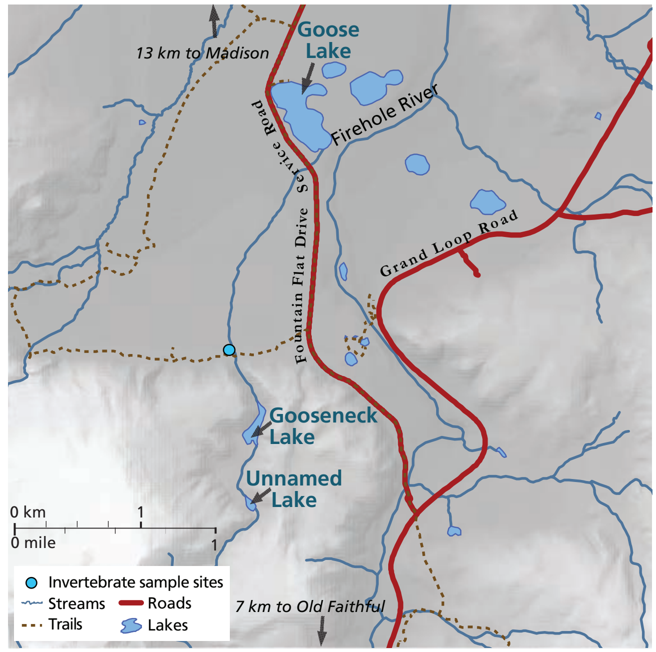


Figure 17. Goose Lake chain of lakes near (but not connected to) the Firehole River in west-central Yellowstone National Park. Rotenone was used to remove rainbow trout from the Goose Lake chain in September 2011 to develop a westslope cutthroat trout brood source.

Westslope Cutthroat Trout Brood Development at Goose Lake

Locating appropriate brood sources is integral to native fish restoration in Yellowstone. The ideal brood stock for use in Yellowstone would be easily accessible, secure from disease, self-sustaining, genetically diverse, abundant, of traceable origin, and pose no risk to existing wild populations. None of the broods from existing sources meet all of these criteria; however, the opportunity to create such a brood exists in the Goose Lake chain of lakes in the park.

Goose Lake and two other small, historically fishless lakes connected to it (figs. 1 and 17) lie within the Firehole River drainage, but are not connected to the river by surface waters. Their proximity to the Fountain Flat Drive service road makes the lakes easily accessible much of the year. Yellow perch (*Perca flavescens*), stocked in Goose Lake early in the 20th century, were eradicated from the lake in 1938 with rotenone, the first known use of piscicide for fisheries management in a national park. The lake was then stocked with nonnative rainbow trout which established a self-sustaining population.

In September 2011, the Goose Lake chain of lakes and connecting streams were treated with liquid rotenone to remove the rainbow trout. Initial investigations indicate that the treatment was successful; however, extensive monitoring will be conducted in 2012 to ensure a complete removal was achieved. Stocking the system with westslope cutthroat trout from upper Missouri River system sources to create the Goose Lake brood is scheduled to begin by 2013.

Native Fish Community Restoration on Grayling Creek

Since 2007, park fisheries personnel have worked with Montana Fish, Wildlife and Parks biologists to assess Grayling Creek for a possible fluvial Arctic grayling and westslope cutthroat trout restoration project (fig. 1; Koel et al. 2008). The proposed plan includes modification of the waterfall near Highway 191 to create a complete barrier to upstream fish movement. With much of the fish survey work and several years of invertebrate and amphibian monitoring completed, DJ&A, P.C., is analyzing possible barrier designs. Barrier construction is expected to begin on Grayling Creek within the next two years, followed by chemical removal of nonnative fish and introduction of fluvial Arctic grayling and westslope cutthroat trout. Collaboration among the National Park Service; Gallatin National Forest; Montana Fish, Wildlife and Parks; and other organizations will continue as the project moves into the implementation phase.

Site on Slough Creek for future construction of a barrier to prevent the spread of nonnative rainbow trout upstream.

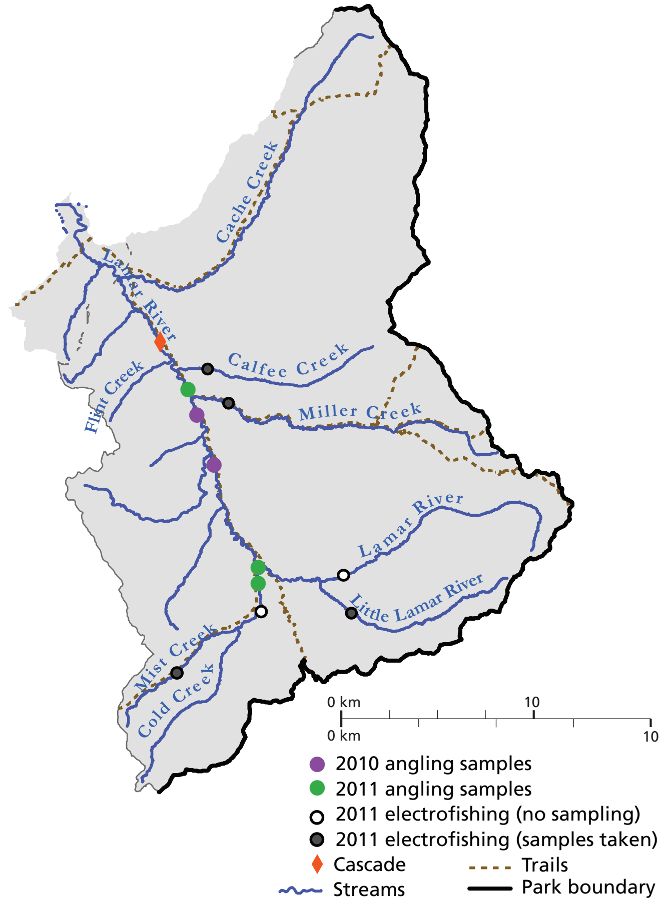


Figure 18. Sites in the Lamar River watershed upstream of the confluence with Soda Butte Creek sampled to assess Yellowstone cutthroat trout genetic integrity, 2010–2011.

Yellowstone Cutthroat Trout on the Northern Range

The efforts invested in understanding the status and trends of Yellowstone cutthroat trout across the northern reaches of the park over the past decade have identified several restoration opportunities in small streams and lakes as well as threats from nonnative trout in three of the region's largest and most important Yellowstone cutthroat trout fluvial populations: Slough and Soda Butte creeks and the Lamar River upstream of Cache Creek. Fish barriers are needed on Slough and Soda Butte creeks to halt the upstream movement of rainbow trout before plans to mitigate for nonnative fish can be developed. The canyon on Slough Creek upstream of the campground and Ice Box Canyon on Soda Butte Creek were surveyed in fall 2011 by DJ&A, P.C., which is now working on possible fish barrier designs and preliminary cost estimates for barriers on the two creeks.

When the Lamar River was sampled in 1993, no rainbow trout genetics were found in cutthroat trout upstream of Soda Butte Creek (Koel et al. 2010, Appendix iii). The Fly Fishing Volunteers (see below) collected genetic samples from cutthroat trout caught there in 2010 and 2011, and electrofishing and angling were used in 2011 in extremely remote reaches of the drainage (fig. 18). Staff plan to investigate a cascade on the Lamar River near Flint Creek in 2012 to determine if it may be a barrier to upstream fish movement that would preserve the upper Lamar River's Yellowstone cutthroat trout.

Soda Butte Creek Brook Trout Removal

Nonnative brook trout in the headwaters of Soda Butte Creek have been moving downstream into the park where they could out-compete the cutthroat trout and become the dominant fish in this stream system. The National Park Service, Gallatin National Forest, and Montana Fish, Wildlife and Parks have spent approximately one week each summer for more than a decade electrofishing and removing brook trout from Soda Butte Creek upstream of Ice Box Canyon (fig. 19).

Electrofishing in 2011 removed 106 brook trout (table 2). Similar to previous years, almost all (96%) of the brook trout were found between Sheep Creek (near Silver Gate) and the first road bridge inside the park. Only two brook trout were found between that bridge and Ice Box Canyon. Electrofishing of tributaries in and outside the park found no brook trout.

These removal efforts are preventing an increase in the brook trout population of upper Soda Butte Creek and greatly reducing the potential for downstream dispersal of brook trout into the Lamar River and other tributaries. Comparison among years is difficult as effort has changed over the past four seasons. However, in the two sections sampled with equivalent effort in the park, brook trout catches declined significantly from 2010. Also, the low number of young-of-year fish (10) found in the sample area in 2011 is an encouraging sign that the removals are limiting spawning and recruitment.

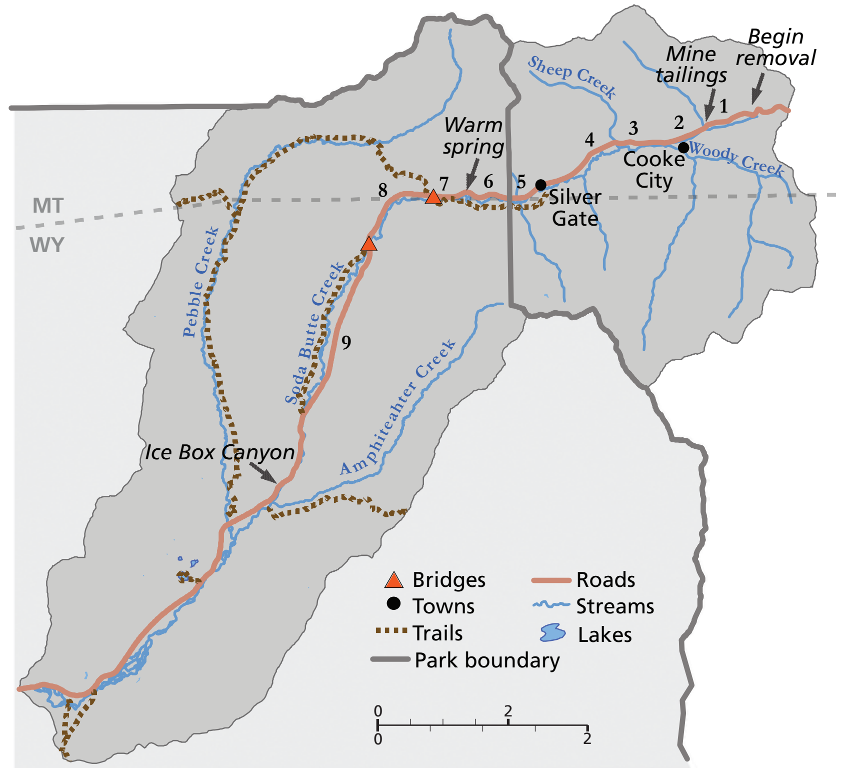


Figure 19. Soda Butte Creek watershed in northeastern Yellowstone National Park and the Gallatin National Forest with reaches (1–9) annually electrofished to remove nonnative brook trout.

Table 2. Total (including young-of-year) brook trout removed by electrofishing from Soda Butte Creek in Gallatin National Forest, State of Montana, and Yellowstone National Park, 2004–2011

Site #	Removal Reach	2004	2005	2006	2007	2008	2009	2010	2011
1	Hwy 212 to McClaren Mine Tailings	19(1)	3(0)	0(0)	0(0)	0(0)	NS	NS	NS
2	McClaren Mine Tailings to Woody Creek	15(0)	17(0)	3(0)	3(0)	2(0)	NS	NS	NS
3	Woody Creek to Sheep Creek	8(2)	43(0)	16(0)	0(0)	1(0)	NS	NS	2(0)
4	Sheep Creek to Silver Gate	251(79)	932(51)	142(6)	45(8)	5(0)	6(0)	NS	30(1)
5	Silver Gate to Yellowstone Park Boundary	9(3)	80(9)	54(2)	48(19)	13(0)	30(2)	16(0)	22(2)
6	Yellowstone Park Boundary to Warm Creek	7(0)	11(0)	0(0)	50(27)	23(2)	56(10)	43(2)	15(0)
7	Warm Creek to Road Bridge	0(0)	1(0)	0(0)	0(0)	3(1)	51(12)	68(29)	35(6)
8	Road Bridge I to Road Bridge II	NS	NS	NS	NS	0(0)	1(0)	7(0)	2(0)
9	Road Bridge II to Ice Box Canyon	NS	NS	NS	NS	0(0)	0(0)	NS	0(0)
T	Tributaries	0(0)	17(0)	15(0)	4(0)	1(0)	8(0)	NS	NS
	Total	309	1,104	230	150	48(3)	152(24)	134(31)	106(10)

NS = Not sampled.

Aquatic Ecological Monitoring and Assessment

Long-term Water Quality Monitoring

Monitoring water quality continues to be a high priority for Yellowstone, with standardized data collected at fixed sites since 2002. This long-term data is used to evaluate overall ecosystem health, ascertain impacts of potential stressors (e.g., road construction activities, accidental sewage spill), identify changes that may be associated with water quality degradation, and guide resource management decisions related to water quality. As in past years, the 2011 monitoring was conducted in cooperation with the Vital Signs Monitoring Program of the Greater Yellowstone Inventory and Monitoring Network, which includes Yellowstone National Park, Grand Teton National Park (with John D. Rockefeller, Jr. Memorial Parkway), and Bighorn Canyon National Recreation Area.

Of the 18 long-term monitoring sites in Yellowstone (Appendix ii), 11 are on streams (sampled in January and April through October) and 7 are on Yellowstone Lake (sampled June through October). In April, water quality was sampled at an additional five sites across the northern region of the park. In August and September, discharge was monitored weekly at two sites on Reese Creek (a 303(d) listed stream, see below).

Core water quality parameters were collected during each site visit, including water temperature, dissolved oxygen, pH, specific conductivity, and turbidity. Water was also collected and processed for total suspended solids, volatile suspended solids, and fixed suspended solids. Dissolved anions (chloride, sulfate, and total alkalinity), dissolved cations (calcium, magnesium, potassium, and sodium), and nutrients (nitrate, nitrite, ammonia, and total phosphorus) were analyzed using samples from 10 stream sites (five long-term sites and five one-time event sites).

All water quality data were entered into the NPSTORET (storage and retrieval) database, which is part of the national STORET database, a repository for water quality, biological, and physical data used by state environmental agencies, the Environmental Protection Agency, and other federal agencies, universities, and private citizens. The water quality sampling effort in Yellowstone during 2011 for 27 sites involved a total of 154 site visits, 478 activities, and 4,250 results that included field observations, multiprobe measurements, and laboratory analysis.

Core and Chemical Water Quality Parameters

In general, physical and chemical characteristics of water quality in the park are related to seasonal changes, elevation, precipitation events, and the presence or absence of thermal features. Statistics for 2011 core water quality parameters indicate spatial trends very similar to those observed from 2002–2010 (fig. 20).


NPS/T. KOEL

Adam Lucas, Student Conservation Association volunteer, collects a water sample from Soda Butte Creek.

Table 3. The waters of Yellowstone

Area of Yellowstone National Park[1]	3,468.4 mi^2 (8,983 km^2)
Water surface area[2,3]	~ 5% of park area
Number of named lakes[1]	150
Surface area of named lakes[1]	24.7 mi^2 (63.9 km^2)
Number of lakes with fish[2]	~45
Yellowstone lake surface area[1]	131.8–135.9 mi^2 (341–352 km^2)
Number of named streams[3]	278
Total stream length[3]	3,496,329 m (2,172.52 mi)
Number of streams with fish[2]	~200

[1]Yellowstone Spatial Analysis Center data 2010. [2]Varley and Schullery 1998.
[3]GRYN Water Quality Report 2009

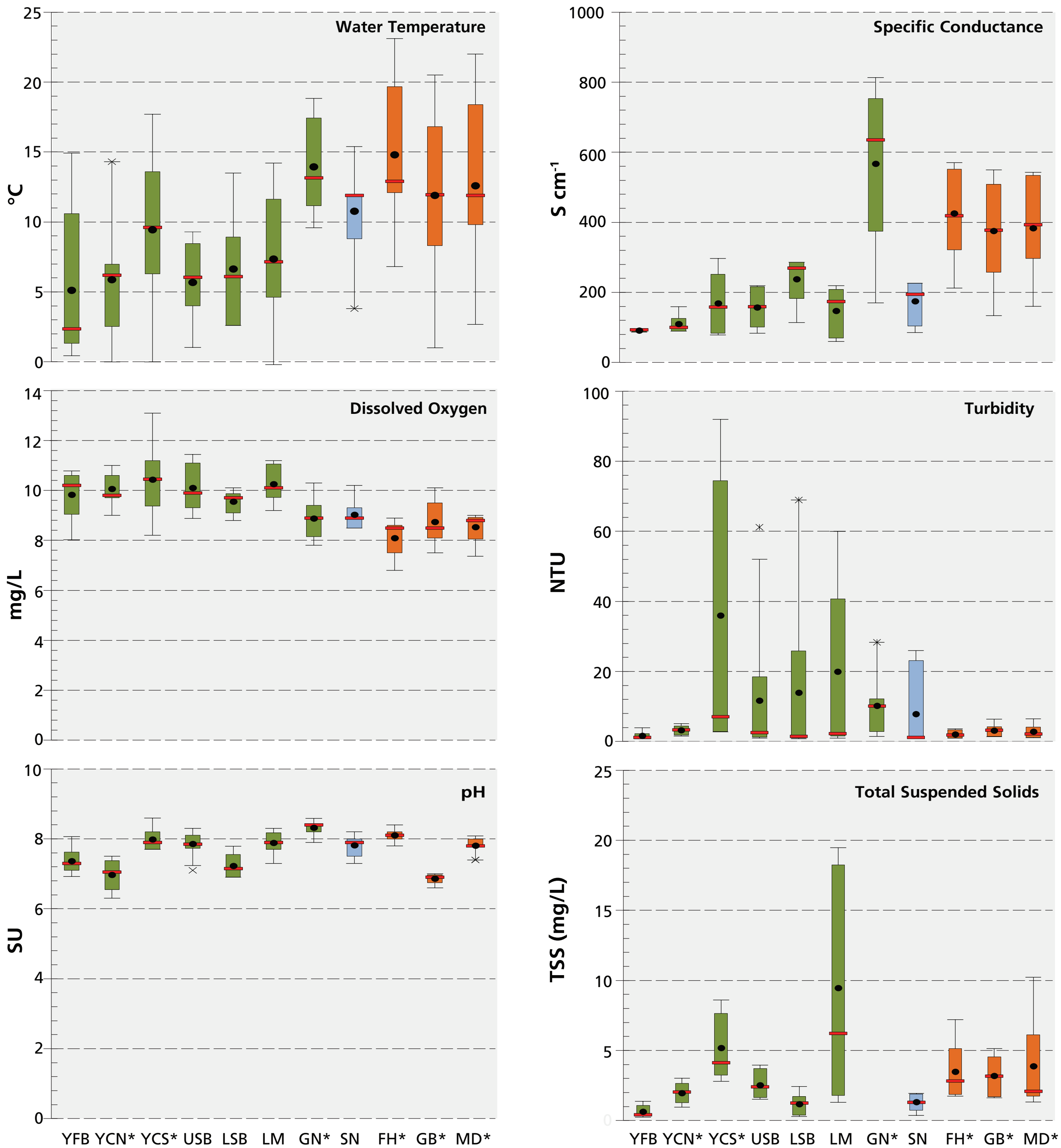


Figure 20. Box and whisker plots, illustrating annual variation for selected parameters at each water quality monitoring site. Lower and upper portions of boxes represent the 25th and 75th percentiles; lower and upper black horizontal bars represent the 10th and 90th percentiles. Outlying values are represented by black dots; means are indicated by solid red lines. The Snake River is not sampled during the winter.

Water samples for chemical analysis (ions and nutrients) have been collected at 10 stream sites within the Yellowstone, Madison, and Snake River drainages since 2006. Due to budget constraints in 2011, however, chemical analysis occurred at only five sites: one in each of the three major river drainages (Yellowstone, Madison, and Snake rivers) near the park boundary, one on the Yellowstone River at the Yellowstone Lake outlet, and one on the Lamar River near its confluence with the Yellowstone River (fig. 1).

With one exception, all monitored sites met or surpassed national and state water quality standards for all standard core and chemical parameters (anions, cations, and nutrients) on all collection days. The exception was the Yellowstone River near Canyon, where pH was 6.3 in January when discharge was low. The Environmental Protection Agency secondary drinking water standard for pH is 6.5–8.5 standard units. There are several thermal areas upstream of this site that have acidic runoff and most likely contributed to the low pH value recorded.

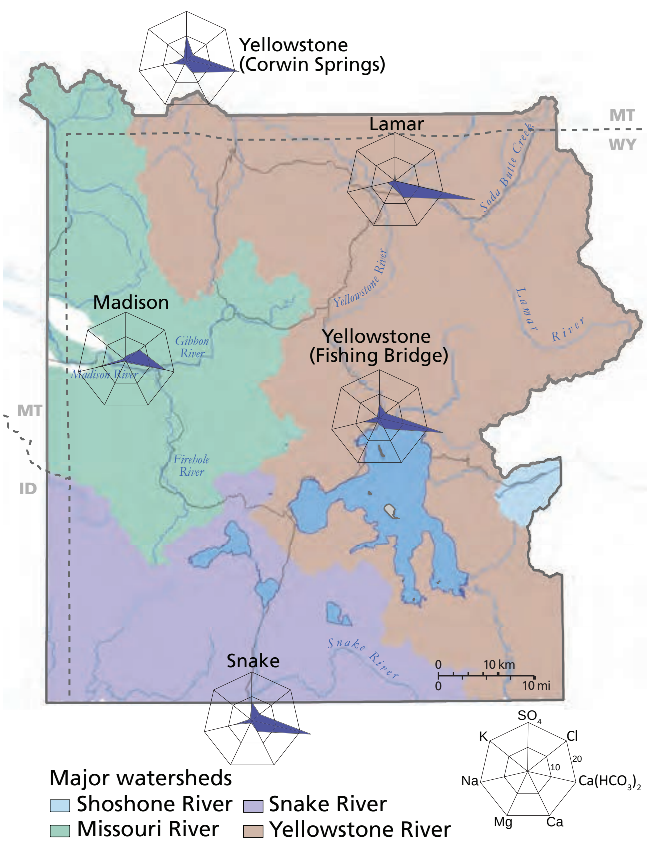


Figure 21. Average annual percent concentration of seven ions from sites on rivers in Yellowstone National Park. The concentric heptagons represent the 10th and 20th percentiles from the center. (SO_4 = sulfate, Cl = chloride, $Ca(HCO_3)_2$ = bicarbonate, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium).

The calculation of relative concentrations of major anions and cations for each site revealed a pattern among the water quality sites and river drainages (fig. 21). While relative concentrations of bicarbonate (HCO_3^{2-}) ions were dominant at all water quality stations, concentrations of other major ions varied among watersheds. Both sites on the Yellowstone River (Corwin Springs and Fishing Bridge) and the one site on Snake River had relatively equal proportions of sulfate, sodium, chloride, and calcium compared to the other ions that were analyzed. In contrast, calcium was the dominant ion within the Lamar River, and sodium and chloride ions were present in approximately equal proportions within the Madison River. Across the park, phosphorus and nitrogen concentrations were very low, as were nitrate, nitrite, and ammonia, with most sites below the detection limits.

Monitoring of 303(d) Listed Streams

Three stream segments in the Yellowstone River drainage listed as 303(d) impaired by the state of Montana were monitored as regulatory streams (fig. 1):

1. Reese Creek downstream of the water diversion structure (dewatering),
2. Soda Butte Creek upstream of the park boundary (contamination by metals), and
3. Yellowstone River upstream of Corwin Springs (sediment and arsenic).

Reese Creek. The lowermost reach of Reese Creek is on Montana's 303(d) list because historical irrigation practices often dewatered the stream during mid-summer and fall, making it unsuitable for sustaining trout. As Reese Creek supports both resident and migratory (spawning) cutthroat trout from the Yellowstone River, monitoring of discharge during the summer is important to conserve these native fish populations and overall biological integrity. To ensure that an adequate amount of water remains in lower Reese Creek, the National Park Service has been measuring stream flows and estimating discharge each year during months when water is diverted from the stream by neighboring landowners for irrigation north of the park in the Gardiner Basin.

Discharge was estimated at the Reese Creek mainstem immediately above the uppermost diversion structure and the channel of uppermost diversion ditch during eight visits in 2011. The difference in discharge between these two sites is the amount of water entering the main channel of Reese Creek below the uppermost diversion. The adjudicated water rights stipulate that Reese Creek is to have a minimum flow of 1.306 ft^3/sec from April 15 to October 15. Due to the high snowpack of the 2010–2011 winter, stream discharge remained

high through July and stream discharge monitoring occurred from August 2 to September 21. During this period, discharge on Reese Creek ranged from 4.27 to 7.43 ft^3/sec, well above the stipulated minimum.

Soda Butte Creek. In-stream metals contamination in Soda Butte Creek is a result of historical mining in the vicinity of Cooke City, Montana, upstream of the park boundary. Mine tailings persist within the floodplain in this area, contributing to its 303(d) listing (impaired and only partially supporting of aquatic life and coldwater fisheries). Partner agencies initiated a three-year effort to relocate mine tailings away from the floodplain in 2011, an activity that poses a risk of heavy metal contamination of the stream. Because of this, the National Park Service conducted intensive monitoring weekly from June to October and had the samples analyzed for arsenic, copper, iron, selenium, and zinc. Metal concentrations of all samples were below the analytical detection limit, except that total iron exceeded aquatic life and drinking water standards in 8 and 10 of the samples, respectively (fig. 22).

Yellowstone River Upstream of Corwin Springs. The Yellowstone River upstream of Corwin Springs was first listed on Montana's 303(d) list in 2006 due to sedimentation and arsenic levels exceeding drinking water standards. Data to support this initial listing were collected 1999–2001 (Miller et al. 2004). To determine the current level of arsenic in the river, the National Park Service sampled water during the low flow period (late April to early May) at six sites between Corwin Springs and Bear Creek: three sites on the Yellowstone River mainstem and three on connecting tributaries. Water collected from all six sites exceeded the Environmental Protection Agency drinking water standard of 0.01 mg/L total arsenic. The highest total arsenic concentration was 0.132 mg/L recorded at the Gardner River site, 13 times the drinking water standard (fig. 23). The high total arsenic values observed in the Yellowstone River drainage may be due to natural geological or geothermal influences on water chemistry in this region of the park.

NPS/J. ARNOLD

Adam Lucas, Student Conservation Association volunteer, checks the clarity of Yellowstone Lake using a secchi disk.

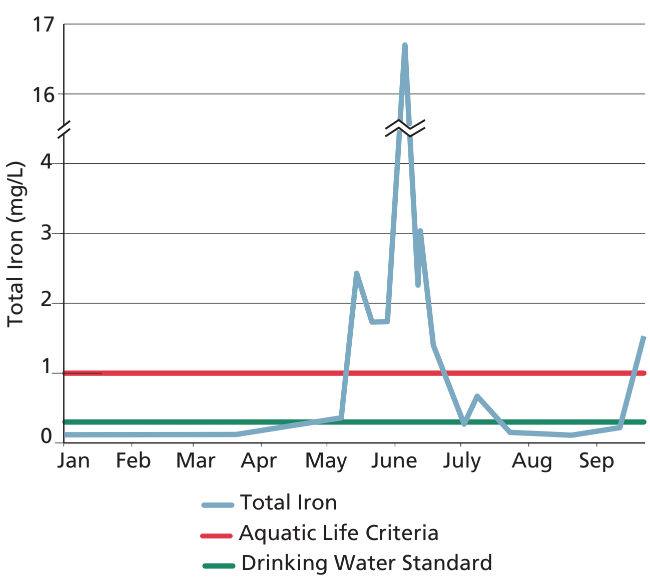


Figure 22. Total iron concentrations in Soda Butte Creek during 2011 compared to aquatic life and drinking water standards.

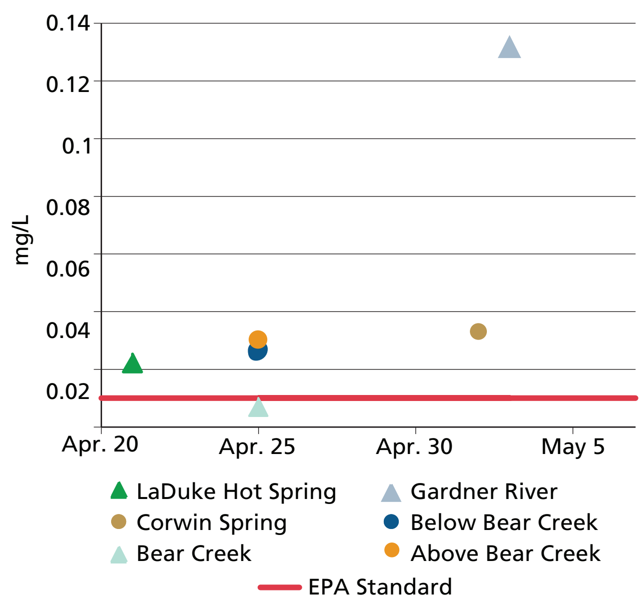


Figure 23. Total arsenic concentrations in the Yellowstone River near Corwin Springs, MT.

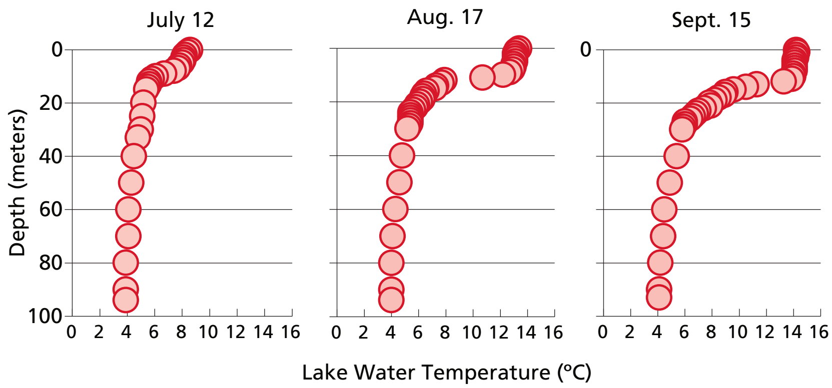


Figure 24. Water temperature depth profiles measured in the West Thumb of Yellowstone Lake during summer 2011.

Yellowstone Lake Limnology

Understanding the basic limnology of Yellowstone Lake promotes cutthroat trout conservation by enhancing the efficiency of the lake trout suppression program. Monthly water temperature, dissolved oxygen, specific conductance, and turbidity measurements were recorded at seven sites from June to October 2011 (fig. 1). Surface water chemical characteristics were homogenous throughout the lake except for the Southeast Arm, likely due to the upper Yellowstone River, which enters there and delivers sediments from the upper portion of the watershed during snowmelt. As a result, this area of the lake tends to exhibit higher turbidity and lower specific conductance during spring runoff.

Water temperature affects the distribution and movement patterns of Yellowstone Lake fishes. Higher than average snowpack and cold air temperatures resulted in a June 9 ice-off date in 2011, one of the latest on record. A gradual warming trend contributed to slow snowmelt which kept the lake's tributaries at flood stage for most of July and into August. The lake's surface level peaked in early July at a near-record high. The large influx of cold water along with cool summer temperatures led to a later than usual and less pronounced summer stratification. In early August (at the beginning of the distribution netting) the lake had yet to stratify, but by mid-August the thermocline had developed at a depth of 11 to 12 meters (fig. 24).

Health Assessments via Macroinvertebrate Surveys

Macroinvertebrates were sampled at 16 sites in three watersheds in 2011: four in the Shoshone, five in the Yellowstone, and seven in the Missouri (fig. 1). The four sites in the Shoshone River watershed are part of long-term monitoring on Middle Creek, where runoff from road construction on Sylvan Pass resulted in the deposit of sediments in Mammoth Crystal Springs, a small tributary to Middle Creek. Mitigation measures are being planned to remove sediment from the spring. Macroinvertebrate data will be used to monitor the stream's recovery and the effectiveness of the sediment removal project.

Sampling sites in the Yellowstone and Missouri river watersheds were within current or proposed native fish restoration areas. To assess rotenone's impact on the stream invertebrate community, aquatic invertebrate surveys were conducted before and after CFT Legumine formulation was used to remove nonnative fish from the Goose Lake chain of lakes in September 2011. The invertebrate samples were sent to an independent contractor for analysis.

Aquatic Invasive Species Surveys

After the discovery of red-rimmed melania (*Melanoides tuberculata*) in the Boiling River swimming and soaking area of the Yellowstone River (Koel et al. 2012), 42 sites in the upper Snake River drainage were surveyed in 2011 to determine whether this snail or other exotic species had invaded similar habitats. The selected sites in Summit Creek, Lewis River Channel, Lewis Lake, Lewis River, Snake River, and Harebell Creek (fig. 1) are thermally-influenced and/or receive high visitor use, such as areas that are popular for swimming, soaking, or fishing, or are located near road pullouts.

The survey was conducted by walking the perimeter of a 20 x 20 m site with a d-frame net, collecting substrate, and visually examining it for evidence of aquatic invasive species. The survey took a total of about nine hours with a mean survey time of 11 minutes per site. All snails as well as other questionable specimens were collected and preserved in alcohol; suspect plants were collected and stored in water. Measurements and observations of the physical habitat were recorded for each site. Water quality data including pH, conductivity, and water temperature were collected at many sites.

Only one of the 42 surveyed sites had aquatic invasive species present: New Zealand mudsnails (*Potamopyrgus antipodarum*) were found below the Lewis and Snake River confluence, an area that was first identified as having the mudsnails in 2005. Red-rimmed melania were not found at any of the Snake River drainage sites within the park.

Amphibians in Native Fish Restoration Areas

A total of 120 wetlands were surveyed for the presence of amphibians in June and July of 2011 in areas where native fish restoration projects are planned: the Elk, Grayling, and East Fork Specimen Creek drainages as well as the small watershed that encompasses the Goose Lake complex (fig. 1).

Elk Creek Drainage. Since amphibian sampling in the lower Elk Creek drainage began in 2006, 48 wetlands have been sampled at least once a year. The three species found in this drainage are the boreal chorus frog (*Pseudacris maculata*), the blotched tiger salamander (*Ambystoma tigrinum melanostictum*), and the Columbia spotted frog (*Rana lutieventris*). Of the 48 wetland sites sampled, 12 (25%) were identified as breeding areas, 12 (25%) had only adults observed, and 24 (50%) had no amphibians (fig. 25). None of the 12 breeding areas were directly connected to Elk Creek or its tributaries, and therefore they are not expected to be treated with piscicide during native fish restoration activities. Annual surveys will be conducted at the 24 sites where amphibians have been observed to better understand how they use these areas for breeding and foraging.

Grayling Creek Drainage. During surveys in 2009 and 2011, breeding by three amphibian species was documented in the Grayling Creek drainage: the boreal chorus frog, the blotched tiger salamander, and the Columbia spotted frog. Of the 74 wetland sites surveyed, 12 (16%) were identified as breeding areas, 5 (7%) had only adults observed, and 57 (77%) had no amphibians (fig. 26). Future plans are to continue surveys at the known breeding areas and at additional wetland sites not previously sampled.

East Fork Specimen Creek. Annual amphibian monitoring at High Lake and two nearby fishless wetlands within the East Fork Specimen Creek drainage has occurred since rotenone was used in 2006 (fig. 16). Columbia spotted frog tadpoles were documented in all three locations whereas boreal chorus frog tadpoles were found only in adjacent wetlands. Subsequent

NPS/J. FLEMING

Student Conservation Association volunteer Adam Lucas and National Park Service fisheries technician Kole Stewart survey for amphibians in the Grayling Creek watershed.

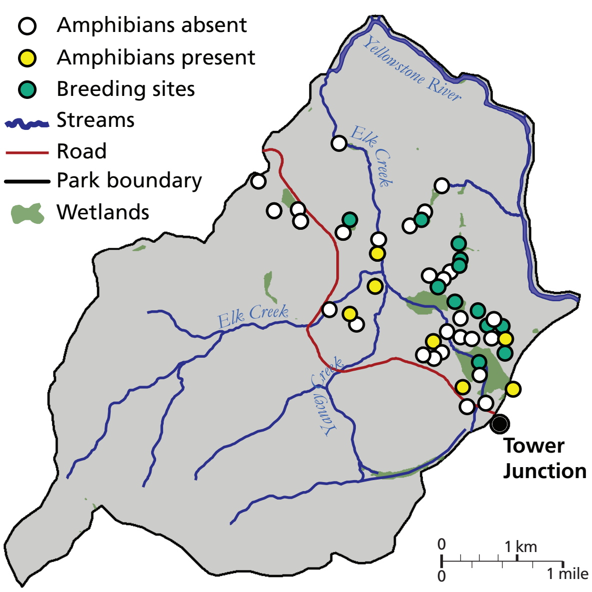


Figure 25. Survey sites (n = 48) within the Elk Creek watershed where amphibians were absent (50%), present (25%), or present and breeding (25%) in 2011.

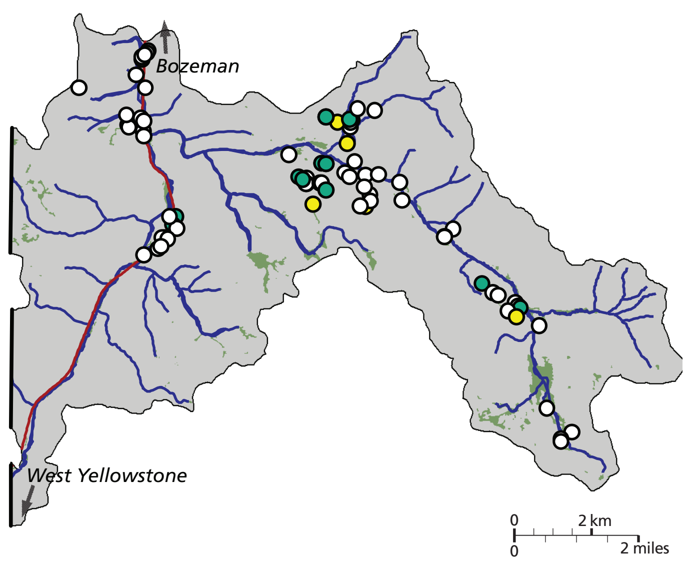


Figure 26. Survey sites (n = 74) within the Grayling Creek watershed where amphibians were absent (77%), present (7%) or present and breeding (16%) in 2011.

surveys have found that these wetlands remain important breeding areas for these species. However, since there has been no change in breeding patterns or abundance, no further amphibian monitoring of the High Lake area is planned.

Goose Lake Chain of Lakes. No larval or adult amphibians were found when Goose Lake was surveyed for amphibians in 2007, 2008, 2010, and 2011. The presence of rainbow trout, which are known to feed on larval amphibians, could be the reason for their absence. Immediately after Goose Lake was treated with rotenone to remove the rainbow trout in late September 2011 (see above), 157 larval blotched tiger salamanders of varying sizes were found on the lake surface and in shallow shoreline areas. Given the 37-acre size of Goose Lake, this was a relatively low number. However, salamander larvae are not typically found in systems that contain fish.

In Yellowstone, larval salamanders may overwinter two or more years before transforming into adults (Koch and Peterson 1995). Because different size classes of salamanders were recovered, most were thought to have been larval forms. Because adult (terrestrial) salamanders were not affected by the piscicide treatment, re-colonization of Goose Lake should occur fairly rapidly. Salamanders migrating from several small, fishless lakes in the immediate vicinity of Goose Lake could aid in population recovery. Monitoring will continue to assess long-term effects of the fish restoration activities on amphibian communities.

NPS/J. FLEMING

National Park Service fisheries technician Kole Stewart surveying for amphibians in the Grayling Creek watershed.

NPS/J. FLEMING

NPS/J. FLEMING

Top: boreal chorus frogs remain numerous in the East Fork Specimen Creek drainage after several rotenone treatments to remove nonnative trout. Bottom: spotted frog in the Grayling Creek drainage.

Fly-fishing volunteer on Riddle Lake.

Public Involvement

Volunteer Angler Report Card Trends

Angling remains a popular pastime for those visiting, living near or working in Yellowstone National Park. Among the nearly 3.4 million visitors to the park in 2011, 46,231 obtained the permit required for fishing in park waters as well as a volunteer angler report card. These cards provide anglers an opportunity to share their fishing success and opinions about the fishing in the park with park managers. Responses in 2011 contributed only 3,476 usable angler outings to our database, lower than in recent years although 2011 park visitation was the second highest in the park's history. In 2011, anglers spent a total of 218,618 days fishing in the park, a 15% decrease from 2010. An estimated 44,724 anglers landed 487,822 and creeled 27,193 fish, releasing more than 94% of the fish caught. They fished for an average of 2.8 hours a day during a typical outing and an average of 1.7 days during the season. Most anglers (64%) fished only one day and 80% of these anglers caught fish. Anglers reported being satisfied with the overall fishing experience (76%), with the number of fish caught (58%) and with the size of fish (66%); this is a slight decrease in satisfaction in all three categories from 2010.

The cards indicated the lengths of 14,243 caught fish: 46.5% were longer than 305 mm (12 inches) and 35.3% were longer than 356 mm (14 inches). Lake trout had the greatest average length, 441 mm (17.4 inches), and were the most likely to be kept (60% were retained). The release of native fishes (cutthroat trout, arctic grayling and mountain whitefish) is required by park regulation, and 99.99% of them were released. The average length of cutthroat trout and mountain whitefish was 350 mm (13.8 inches); brown trout, 285 mm (11.2 inches) with 1.7% kept; rainbow trout, 266 mm (10.5 inches) with 1.8% kept; grayling 240 mm (9.4 inches); and brook trout, 171 mm (6.1 inches) with 3.2% kept.

Native fish compose 49% of all fish caught in the park, with cutthroat trout remaining the most sought after and caught species in 2011, composing 44% of all fish caught (fig. 27). Rainbow trout were the second

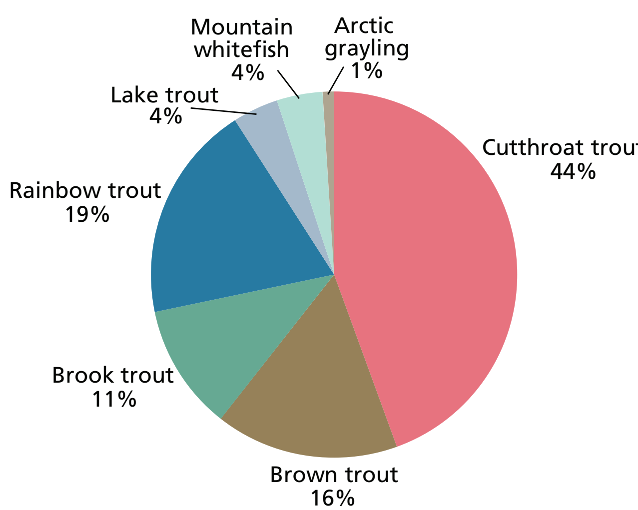


Figure 27. Native cutthroat trout remained the most sought after and caught fish species by anglers again in 2011, comprising 44% of all fish caught in the park.

most frequently caught fish species (19% of angler catch) followed by brown trout (16%), brook trout (11%), lake trout (5%), mountain whitefish (4%) and grayling (1%).

Fly Fishing Volunteers

The Fly Fishing Volunteer Program continued to be an integral mechanism for communicating information and raising public awareness of issues facing Yellowstone's native fishes. Throughout the 2011 field season, 40 volunteers participated in the program, contributing 2,050 hours to the park's fisheries that advanced many of the native fish conservation actions outlined in the Native Fish Conservation Plan/ Environmental Assessment. The Fly Fishing Volunteers assisted westslope cutthroat trout conservation by capturing trout at several locations in Grayling Creek for fish barrier testing. The volunteers also helped with sample collection for cutthroat trout genetics in the Lamar River, Slough Creek, Soda Butte Creek, and Trout Lake.

Pelican Creek, the second largest tributary to Yellowstone Lake, which had been closed to angling for seven years due to concerns about the spread of whirling disease (Koel et al. 2006), was reopened in 2011. Fly-fishing volunteers, who were among the first to visit the stream with fly rods following the closure, caught many juvenile cutthroat trout, suggesting that the population may be recovering from effects of the devastating disease.

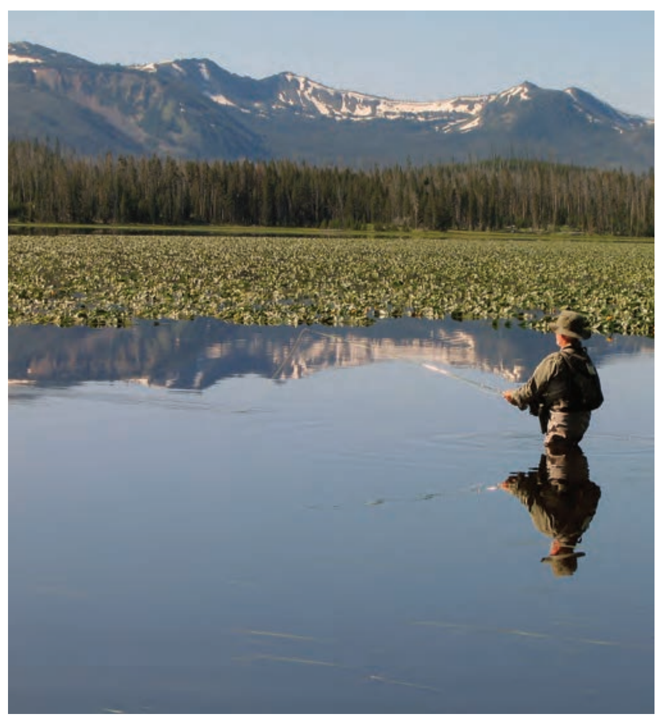
Long-term Volunteer Assistance

The fisheries program recruits volunteers through the Student Conservation Association (SCA) and other sources (see Appendix iii) to work a full-time schedule for 12 or more weeks while living in park housing at Lake or Mammoth Hot Springs. Typically, one group of SCA volunteers participates from mid-May through early August, and a second group from early August through late October. Our goal is to have the volunteers gain experience with as many fisheries program activities as possible. Given the thousands of hours of assistance have been provided by volunteers over the years, 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. Park staff also provided American Red Cross first aid and CPR certification for fisheries employees and volunteers.

NPS/W. VOIGT



NPS/S.HAMSTRA

Left: nonnative rainbow trout removed by angling from Trout Lake in an effort to preserve the genetic integrity of the native cutthroat trout. Right: fishing volunteer on Riddle Lake.

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 National Park Service biologists and other regional managers of aquatic systems.

Projects by Graduate Students

Graduate Student: Tonya Chamberlain (MS candidate).
Committee chair: Dr. Amy Krist, Department of Zoology and Physiology, University of Wyoming.
Title: An investigation of life history shifts in zooplankton in Yellowstone Lake following the introduction of lake trout.
Status: Field studies, analyses and writing on-going.

Graduate student: John Syslo (Doctor of Philosophy candidate).
Committee chair: Dr. Christopher Guy, U.S. Geological Survey Cooperative Fisheries Research Unit, Department of Ecology, Montana State University.
Title: Response of Yellowstone cutthroat trout to nonnative predator removal in the Yellowstone Lake ecosystem, Yellowstone National Park.
Status: Field studies, analyses and writing ongoing.

Interagency Workgroups

Yellowstone National Park staff participate 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 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).

NPS/W. VOIGT

Rich Hamstra (right) with three Fly Fishing Volunteer Program participants, also assisted Bill and Joann Voigt with VIP coordination during the entire 2011 season.

NPS/C. MOZELESKI

Trout Lake in the Soda Butte Creek drainage, where nonnative rainbow trout are being removed by anglers.

Acknowledgements

Much appreciated administrative support for the Fisheries Program in 2011 was provided by Barbara Cline, Alana Darr, Kevin Franken, Montana Lindstrom, and Melissa McAdam. Bianca Klein and Linda Mazzu from the Branch of Environmental Compliance provided tremendous support and guidance for the National Environmental Policy Act (NEPA) process leading to a Native Fish Conservation Plan/Environmental Assessment.

Diane Eagleson, Todd Kipfer, and Cathy Whitlock of the Montana Institute on Ecosystems graciously provided essential staff support for stream restoration and coordination of the Fly Fishing Volunteer Program. We also appreciate the support and guidance for our cutthroat trout restoration activities from Lee Nelson, Don Skaar, and Ken Staigmiller of Montana Fish, Wildlife and Parks; and Dale White of Gallatin National Forest.

Special thanks to Robert Gresswell, Phaedra Budy, Chris Guy, Michael Hansen, Michael Jones, Pat Martinez, Cory Suski, and Jack Williams for participating in the June 2011 Science Review of the Yellowstone Lake operations and for providing guidance and recommendations for improvements.

William and Joanne Voigt once again did an outstanding job coordinating the Fly Fishing Volunteer Program and safely guided volunteers from across the country to waters within the park.

Many other people contributed to the success of Fisheries Program activities. We would like to especially thank Ben Cunningham, Tim McGrady, Alison McGrady, and Wally Wines from Corral Operations; Wendy Hafer from the Fire Cache; Greg Bickings, Bruce Sefton, Lynn Webb, and Dave Whaley from the Lake Garage; Dan Reinhart from Resource Management; Brad Ross, and Kim West from the South District Rangers; and Bonnie Whitman, Michael Keator, and Jamie Hanson from the West District Rangers.

The Student Conservation Association (SCA) and Montana Conservation Corps (MCC) have enabled many people to participate in the day-to-day activities of the Fisheries Program. Our projects would not be completed without the dedicated support of the SCA and MCC.

The Fisheries Program is supported through Yellowstone Center for Resources base funding and a portion of the fees collected from anglers who purchase fishing permits. In 2011, additional funding was received from these sources:

- Yellowstone Park Foundation, through the Fisheries Fund Initiative and Fly Fishing Volunteer Program
- National Fish and Wildlife Foundation
- Greater Yellowstone Network, Vital Signs Monitoring Program of the National Park Service
- Recreational Fee Demonstration Program of the Federal Lands Recreation Enhancement Act
- Greater Yellowstone Coordinating Committee
- Park Roads and Parkways Program of the Federal Highway Administration
- Trout Unlimited; Greater Yellowstone Coalition; and National Parks Conservation Association
- U.S. Geological Survey, Biological Resources Division, Biological Research for the Parks

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.

This report is made possible only by the dedicated work of the Science Communication Office, Yellowstone Center for Resources. Special thanks to Mary Ann Franke, Emily Yost, and Janine Waller for making this report a reality.

NPS/T. KOEL

US Geological Survey research scientist Robert Gresswell assists National Park Service fisheries technician Brian Ertel with surgical implantation of a sonic tag in a lake trout.

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Appendices

Appendix i. Fish Species List

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

Family	Common Name	Scientific Name	Status	Missouri	Snake	Yellowstone
Salmonidae	Yellowstone cutthroat trout	*Oncorhynchus clarkii bouvieri*	Native	I	N	N
	westslope cutthroat trout	*Oncorhynchus clarkii lewisi*	Native	N	—	—
	finespotted Snake River cutthroat trout	*Oncorhynchus clarkii behnkei**	Native	—	N	—
	rainbow trout	*Oncorhynchus mykiss*	Nonnative	I	I	I
	mountain whitefish	*Prosopium williamsoni*	Native	N	N	N
	brown trout	*Salmo trutta*	Exotic	I	I	I
	eastern brook trout	*Salvelinus fontinalis*	Nonnative	I	I	I
	lake trout	*Salvelinus namaycush*	Nonnative	—	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*	Nonnative	—	—	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/T. KOEL

NPS fisheries biologist Pat Bigelow, Yellowstone Superintendent Dan Wenk, and SCA volunteer Jackie Schulz process gillnets aboard the *Freedom.*

Appendix ii. Water Quality Stations Sampled in 2011

Water quality stations sampled in 2011.

Drainage	Station ID	Location
Yellowstone River Drainage	YELL_YS616.4M	Yellowstone River at Yellowstone Lake outlet
	YELL_YS549.7M*	Yellowstone River at Corwin Springs, Montana
	YELL_YS600.5M	Yellowstone River at Canyon
	YELL_SB015.7A*	Soda Butte Creek at park boundary
	YELL_SB001.5M	Soda Butte Creek near Lamar Ranger Station
	YELL_LM000.5M	Lamar River near Tower Ranger Station
	YELL_GN002.9M	Gardner River near Gardiner, Montana
	YELL_RC000.9A*	Reese Creek lower diversion
	YELL_RC000.9B*	Reese Creek upper discharge mainstem
	YELL_BC000.1M†	Bear Creek near confluence with Yellowstone River
	YELL_LD000.1M†	La Duke Hot Springs
	YELL_YS560.0M†	Yellowstone River above Bear Creek
	YELL_YS559.9M†	Yellowstone River below Bear Creek
	YELL_EK002.8M†	Elk Creek near Tower Junction
	YELL_YL001.0M–007.OM	Yellowstone Lake sites 1–7
Madison River Drainage	YELL_FH001.8C	Firehole River near Madison Junction
	YELL_GB000.2M	Gibbon River near Madison Junction
	YELL_MD133.2T	Madison River near park boundary
	YELL_GY004.5M†	Grayling Creek near park boundary
	YELL_GY011.4M†	Grayling Creek site 2
Snake River Drainage	YELL_SN999.9M	Snake River at old Flagg Ranch

* Stream site appears on state 303(d) reports

† One-time sampling event at select stream site

NPS/T. KOEL

Wildfire near the mouth of Clear Creek and the NPS fisheries program cabin on Yellowstone Lake.

NPS/J. FLEMING

Fisheries crews document the upper extent of fish distribution in the Grayling Creek watershed.

NPS/B. ERTEL

SCA volunteers Jessica Dugan and Jaclyn Schultz hold a large lake trout removed from Yellowstone Lake, 2011.

Appendix iii. Seasonal Staff and Long-term Volunteers, 2011

Seasonal Staff

- Consolo, Michael
- Drescher, Earl
- Gleason, Carrie
- Holden, William
- Rosin, April
- Schreibvogel, Rance
- Stewart, Kole
- Voigt, William

Long-term Volunteers

- Adera, Saalem
- Daly, Christopher
- Detjens, Colleen
- Dugan, Jessica
- Fleming, Jay
- Hamstra, Richard
- Kinna, Taylor
- Lucas, Adam
- Owensby, Dylan
- Schultz, Jaclyn
- Tedesco, Domenic
- Voigt, Joann

NPS/B. ERTEL

Fisheries program staff during May 2011 orientation included (from L to R) April Rosen, Saalem Adera, Rance Schreibvogel, Pat Bigelow, Kole Stewart, Carrie Gleason, Mike Consolo, Phil Doepke, Brian Ertel, Jeff Arnold, Mike Ruhl, Earl Drescher, Adam Lucas, Jay Fleming, Chris Daly, Todd Koel, and Dominec Tedesco.