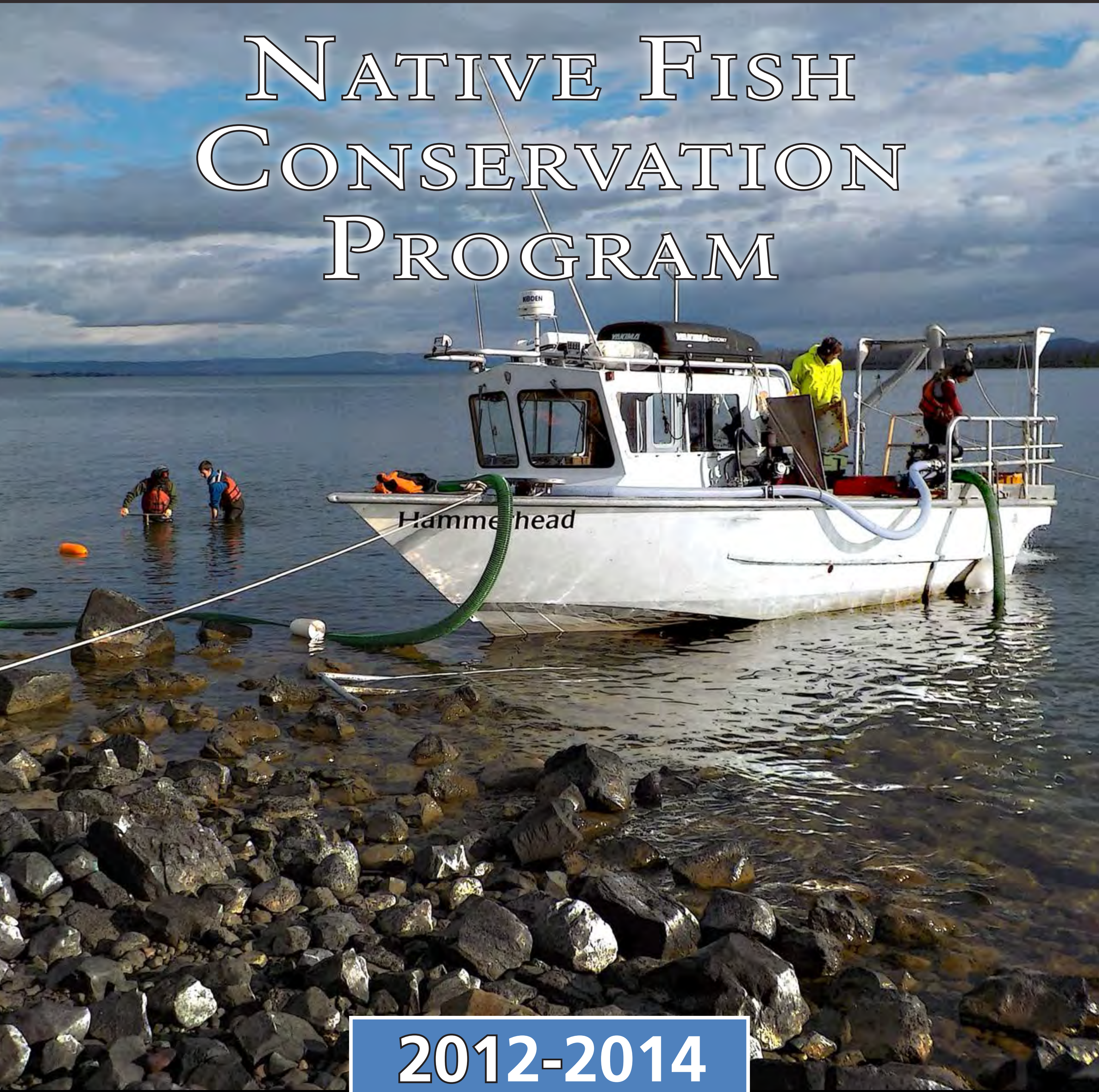
Yellowstone National Park
Native Fish Conservation Program 2012-2014
Wyoming, Montana, Idaho

Yellowstone Center for Resources
National Park Service
Department of the Interior

Native Fish Conservation Program



2012-2014

YELLOWSTONE FISHERIES & AQUATIC SCIENCES

Carrington Island in Yellowstone Lake is known as a significant lake trout spawning area because of the rock cobble substrate.

ON THE COVER: NPS Fisheries staff developing alternative methods to suppress lake trout fry and embryos in spawning areas around Snipe Point.

Native Fish Conservation Program

YELLOWSTONE FISHERIES & AQUATIC SCIENCES 2012-2014

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Yellowstone Center for Resources
Yellowstone National Park, Wyoming

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Lake trout captured by large, live entrapment nets are sorted into bins for removal. Cutthroat trout are returned to Yellowstone Lake. - Photo ©Scott Heppel

NPS *Patriot*, used for gillnetting operations in Yellowstone Lake.

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 Yellowstone cutthroat trout. In the early 2000s, the impacts of an expanding lake trout population and an increasing prevalence in whirling disease coincided with drought, resulting in a precipitous decrease in cutthroat trout. Cascading effects throughout 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.

Coinciding with the decrease in cutthroat trout numbers in Yellowstone Lake were changes in another previous stronghold for this species, the Lamar River. Rainbow trout, which were introduced by park managers in the early 1900s, had historically remained in the Yellowstone River below the falls at Canyon and downstream of the Lamar River and Slough Creek cascades. In the early 2000s, however, anglers more frequently reported catches of rainbow trout upstream of these cascades. Rainbow trout are a close relative that can hybridize with cutthroat trout. As a result, their increasing distribution raised concerns about the security of Yellowstone cutthroat trout in the upper Lamar River system. Since 2002, 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 support natural food webs, contribute significantly to the local economy, provide unparalleled visitor experiences, and define much of the park's 20th century historical context. As a result, the National Park Service (NPS) is taking actions to reverse decreasing trends in native fish populations and associated losses of ecosystem function. A parkwide Native Fish Conservation Plan (Koel et al. 2010b) was completed in 2011; over time, its implementation should restore the ecological role of native species such as fluvial (i.e., river dwelling) Arctic grayling, westslope cutthroat trout, and Yellowstone cutthroat trout, while ensuring sustainable 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 NPS and its collaborators during 2012 through 2014. This and previous annual reports are available in electronic format at the Yellowstone National Park website (http://www.nps.gov/yell/planyourvisit/fishreports.htm).

Hickey Brothers Research, LLC, and NPS staff conduct contract lake trout suppression with a large live-entrapment net.

Efforts to restore cutthroat trout and the ecology of the Yellowstone Lake ecosystem focused on the suppression of nonnative lake trout via gillnetting. Crews from the NPS and Hickey Brothers Research, LLC, increased gillnet effort from 46,110 units in 2012 to 74,640 units in 2014. One unit of effort is defined as 100 meters of gillnet fishing for one night. Catch-per-unit-effort with gillnets decreased from 6.3 in 2012 to 4.8 in 2013 and 3.7 in 2014. Also, 10 large, live-entrapment nets were set in 2012 and 2013 for about 880 net-nights. The combined total suppression effort removed more than 300,000 lake trout in 2012 and 2013, and another 277,000 in 2014. About one-half of the 1.7 million lake trout killed since 1994 were captured in the past three years. The catch of lake trout has not increased linearly with increasing effort, suggesting the number of lake trout is decreasing. In turn, predation of cutthroat trout by lake trout should have been substantially reduced by this intense netting effort.

Progress toward cutthroat trout recovery and the achievement of desired conditions for Yellowstone Lake were assessed through monitoring efforts. A strong pulse of juvenile cutthroat trout was detected entering the system. The average catch of cutthroat trout per 100-meter net increased from 22 in 2012 to 26 in 2013 and 31 in 2014. These catches were among the highest since 1995 and substantial increases over the low catch of 13 cutthroat trout per 100-meter net in 2010. These catches suggest the cutthroat trout population is responding positively to improved conditions within the Yellowstone Lake system.

Efforts to preserve Yellowstone cutthroat trout outside of Yellowstone Lake ecosystem were focused in the northeastern region of Yellowstone National Park. A bedrock falls in Ice Box Canyon was modified in 2013 to prevent further invasion of upper Soda Butte Creek by nonnative rainbow trout. The design and engineering of barriers for Slough Creek and upper Lamar River were also completed. Efforts to remove nonnative brook trout and rainbow trout from Slough and Soda Butte creeks and the Lamar River continued using electrofishing and targeted angling. Small tributaries of the Yellowstone River, near its confluence with Lamar River, continue to harbor brook trout at high densities. Thus, the Elk, Yanceys, and Lost Creek stream complexes were treated with rotenone during 2012 through 2014 to remove existing nonnative fish. These tributaries will be restocked with native Yellowstone cutthroat trout.

Recovery efforts for westslope cutthroat trout focused on restoring this native species to East Fork Specimen Creek, Grayling Creek, and the Goose Lake chain of lakes. Approximately 3,550 westslope cutthroat trout eggs were collected from Geode Creek in 2012, reared at the Sun Ranch Hatchery, and then stocked in incubators in East Fork Specimen Creek where most eggs hatched fry into the stream. Also, an existing waterfall on lower Grayling Creek was modified during 2012 and 2013 to prevent upstream movement of nonnative fish. The Grayling Creek watershed was then treated with rotenone during 2013 and 2014. Restocking of the watershed with native fluvial Arctic grayling and westslope cutthroat trout will begin in 2015. In addition, nonnative rainbow trout were removed from the Goose Lake chain of lakes and connecting streams in 2011. Westslope cutthroat trout fry were then stocked in Goose Lake to create an easily-accessible, genetically-pure, brood source for future restoration efforts. Approximately 3,400 fry were stocked in 2013 and 1,900 in 2014.

NATIVE FISH CONSERVATION PLAN

To implement actions that will facilitate the recovery of native fish and restoration of natural ecosystem functions, a Native Fish Conservation Plan/Environmental Assessment was completed in 2011 (http://parkplanning.nps.gov/projectHome.cfm?projectID=30504).

Goals of the plan include the:

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

The plan describes benchmarks for nonnative lake trout suppression, as well as an adaptive management strategy for future actions on Yellowstone Lake, and in streams and lakes elsewhere across the park. In addition, the plan describes the development and implementation of robust monitoring and scientific review through collaboration with partners.

Adaptive management is an integral component of the Native Fish Conservation Program. The adaptive management approach includes statistically valid, long-term monitoring to evaluate the effectiveness of conservation actions. This approach was chosen because of the varied environments and stressors impacting native fish across the park and the uncertainty regarding possible responses by native fish to management actions. For example, initial science indicates that lake trout expansion in Yellowstone Lake could be curtailed by inflicting an annual total mortality of 60% (see Native Fish Conservation Plan, http://go.nps.gov/Yellowstone_Native_Fish_Conservation_Plan). However, it is uncertain how long this mortality level must be maintained to meet lake trout suppression goals. Also, the rate of cutthroat trout recovery in Yellowstone Lake after the population is released from lake trout impacts is uncertain. Therefore, an adaptive management approach to fish conservation that takes into consideration performance metrics, such as the abundance of spawning cutthroat trout in tributary streams and angler success, is necessary to progress towards desired conditions.

The park's surface waters are considered in two domains for the 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 (figure 1). A hierarchical series of desired conditions was developed for each of these domains (see Native Fish Conservation Plan, tables 5 and 6). Each desired condition represents a hypothesized outcome for native fish given the initial state of the system and applied conservation actions. Monitoring is being conducted to determine if performance metrics are met and conservation actions influence native fish as predicted.

Many of the young cutthroat trout returning to Yellowstone Lake are likely coming from this large, remote watershed in the southeastern region of the park.

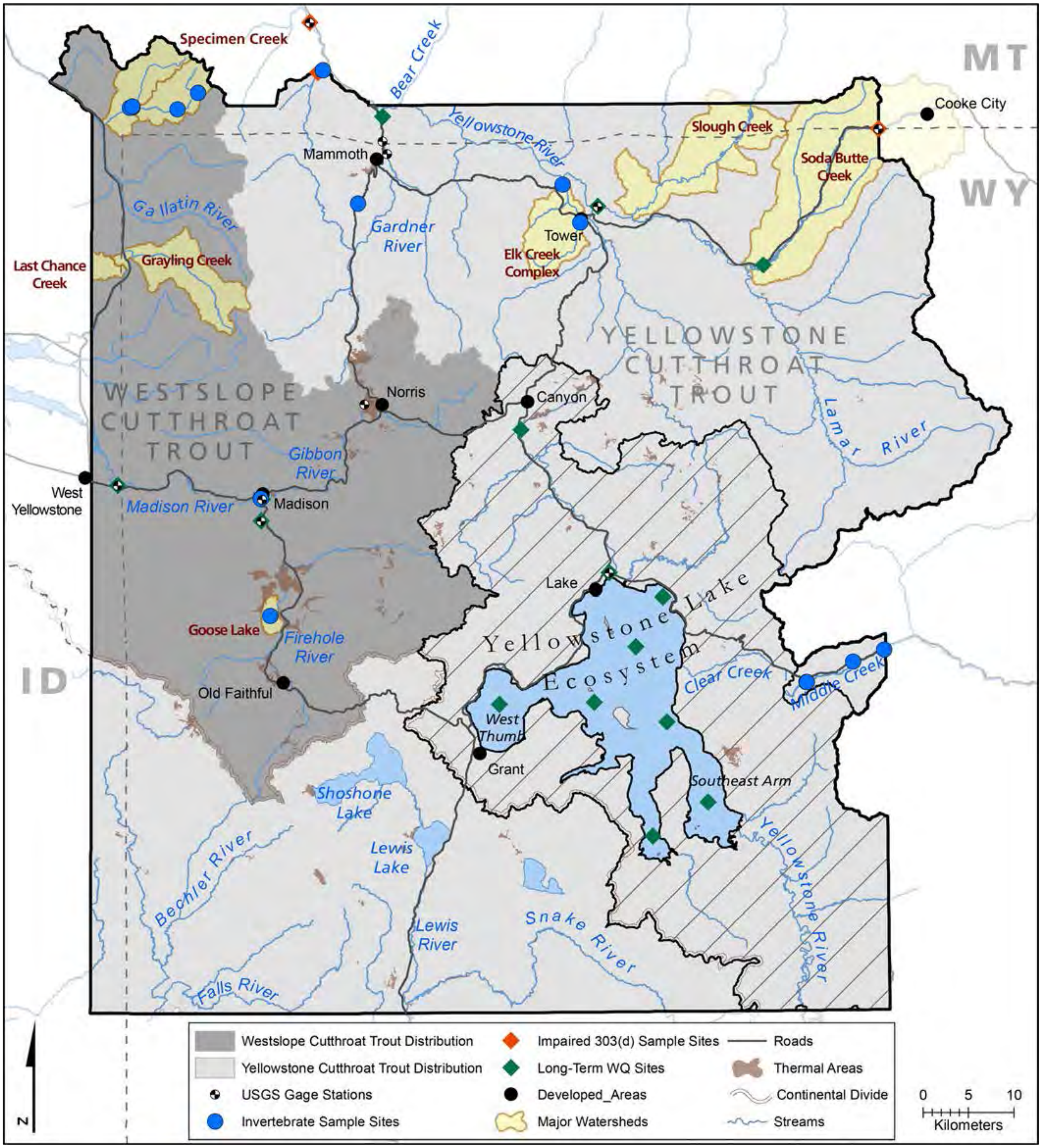


Figure 1. Major watersheds and surface waters of Yellowstone National Park, with sites established for long-term water quality (WQ) monitoring on streams and Yellowstone Lake. Areas sampled for aquatic invertebrates are also shown.

Suppression of lake trout eggs using an electroshocking grid.

Lake trout were intentionally stocked in Lewis and Shoshone lakes in 1890 by the U.S. Fish Commission and later introduced into Yellowstone Lake by an unknown source (Varley and Schullery 1995a, Varley and Schullery 1998, Munro et al. 2005). They are a serious threat to the native Yellowstone cutthroat trout population; as a result, the NPS has worked to suppress lake trout since the species was detected in Yellowstone Lake in 1994 (Koel et al. 2005). Although over 1.7 million lake trout have been netted from the lake, catches have generally increased each year.

Lake Trout Suppression Netting

In 2012 and 2013, Yellowstone Lake became sufficiently ice-free to begin netting in mid-May and continued through mid-October. In 2014, ice melted later than usual, so netting began at the end of May. Over the last three years, the total effort of suppression netting has been substantially increased. The NPS and contract fishing crews completed 46,112 units of gillnet effort in 2012, 62,090 units in 2013, and 74,641 in 2014. This represents a 178% increase over gillnet effort in 2011. One unit of effort is defined as 100 meters of gillnet fishing for one night. This increase was possible due to increased use of the contractor-owned fishing vessels (*Kokanee, Patriot, Northwester*), along with the NPS vessels (*Freedom, Hammerhead*).

Approximately 40% of the total gillnetting effort and 43% of the total lake trout gillnet catch occurred in the West Thumb region of Yellowstone Lake in 2012, an area which comprises less than 12% of the lake's surface area (figure 2). With increases in netting effort, nets were more widely dispersed throughout the lake, including into the southern arms of the lake. As a result, only 30% and 26% of the total gillnet effort occurred in West Thumb in 2013 and 2014 , respectively (figure 2). However, West Thumb netting still yielded a disproportionately higher catch compared to the rest of the lake: 43% and 35% of the catch in 2013 and 2014, respectively. In addition to gillnetting, the contracted netters also used 10 large live-entrapment nets in 2012 and 2013, resulting in 879 and 872 net nights of effort, respectively.

The combined total suppression effort removed 302,000 lake trout from Yellowstone Lake in 2012; 301,000 lake trout in 2013; and 277,000 lake trout in 2014 (figure 3). Catch-per-

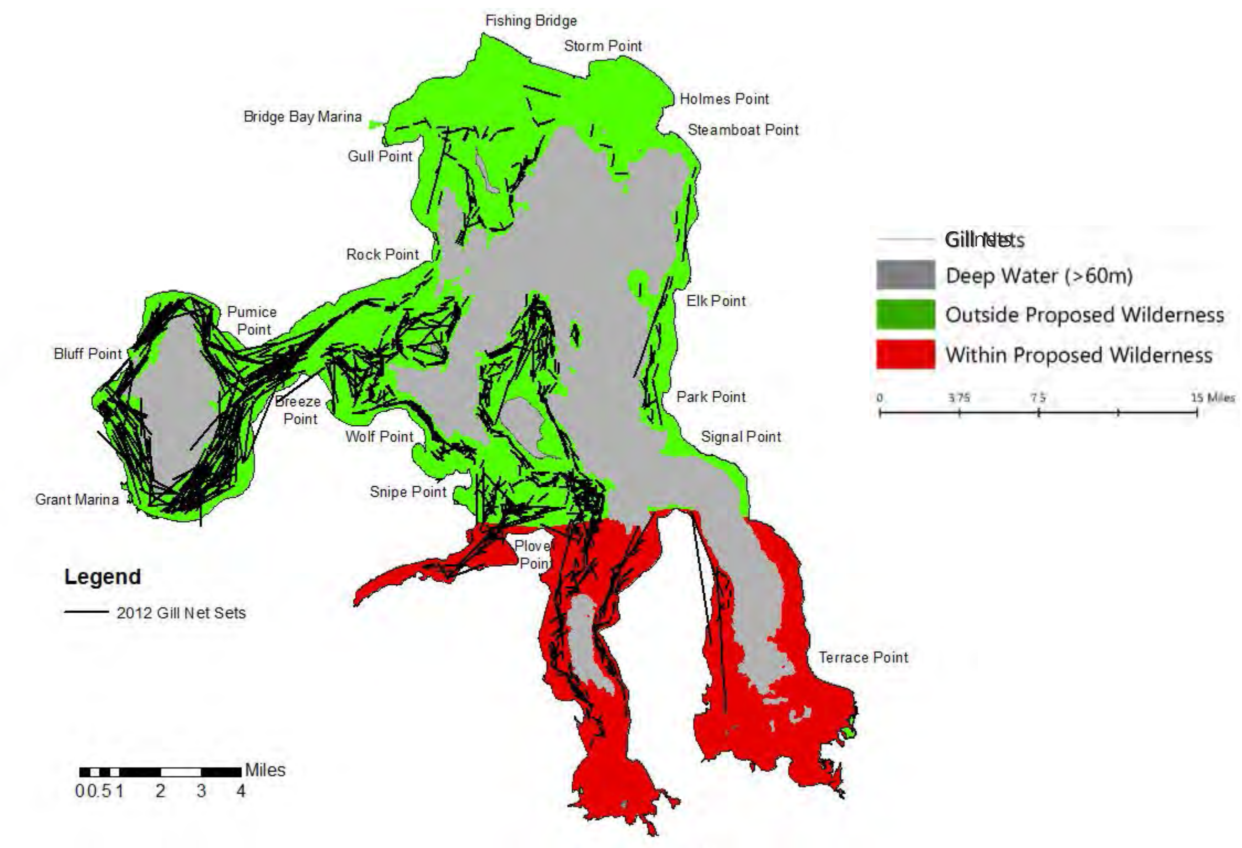


Figure 2. Area of Yellowstone Lake within (red) and outside (green) of proposed wilderness that is at water depths (< 60 m) suitable for gillnetting lake trout. Black lines indicate gillnet set locations, 2012-2014.

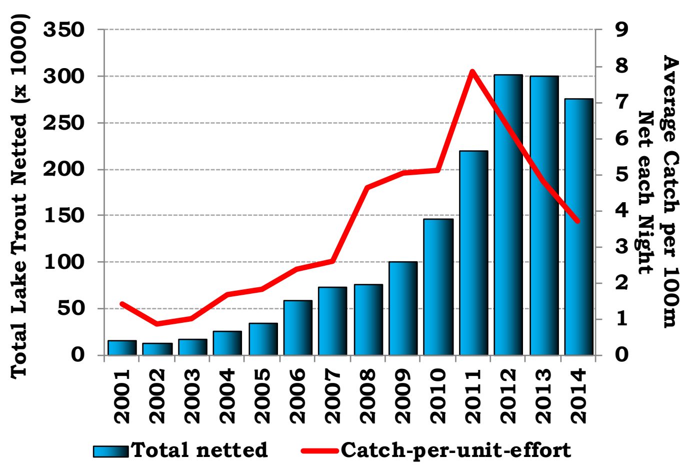


Figure 3. Number of lake trout removed from 2001 to 2014. The red line represents total catch-per-unit-effort (100 meter net/night for gillnets).

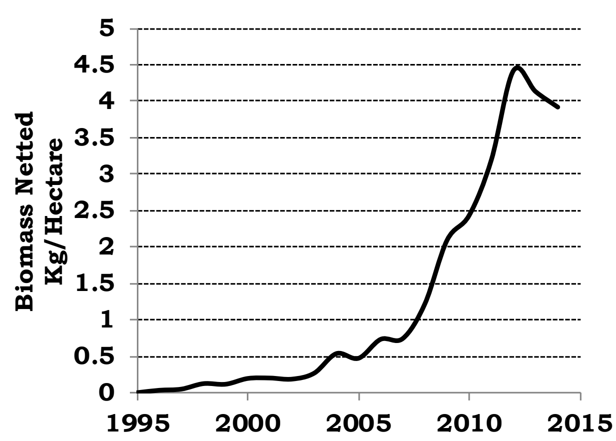


Figure 4. Total estimated lake trout biomass netted from Yellowstone Lake by all gear types, 1995-2014.

unit-effort for suppression gillnetting, which had been increasing each year since 2002, decreased from 8.2 in 2011 to 3.7 in 2014 (figure 3). Similarly, estimated total biomass of lake trout removed from the population had been increasing exponentially since the program's inception but decreased from 4.4 kilograms of lake trout per hectare in 2012 to 3.9 kilograms of lake trout per hectare in 2014 (table 1, figure 4). Recent estimates of more than 4 kilograms of lake trout per hectare removed from the lake are well above reported sustainable yields of less than 1.0 kilogram per hectare observed

Table 1. Estimated biomass (kilograms) of lake trout killed by small and large mesh gillnetting and live-entrapment netting on Yellowstone Lake, 2011-2014.

	Small Mesh Gillnetting		Large Mesh Gillnetting		Live-Entrapment Netting		Total	
	Kg	%	Kg	%	Kg	%	Kg	lbs
2011	61,700	57	29,800	27	17,400	16	109,000	240,300
2012	79,200	53	52,700	35	18,900	13	150,800	332,500
2013	71,400	51	60,300	43	9,300	7	140,900	310,600
2014	63,000	49	65,200	51	*	*	130,100	286,800

*Live-entrapment netting was not used in 2014.

in other large northern lakes (Martin and Oliver 1980). Thus, numbers of lake trout should be decreasing in Yellowstone Lake.

Lake Trout Gillnetting

The majority of gillnetting during the past three years focused on smaller fish residing in deeper water (20-60 meters) where cutthroat trout by-catch was low. Small-mesh gillnets with box sizes of 25 to 38 millimeters caught 245,230 lake trout (79,200 kilograms) in 2012; 247,120 lake trout (71,400 kilograms) in 2013; and 217,620 lake trout (63,000 kilograms) in 2014. Catches by small-mesh gillnets represented approximately 50% of the total biomass removed each year (table 1).

To increase the removal of larger lake trout, which have high reproductive potential and are more likely to prey on Yellowstone cutthroat trout, the use of large-mesh gillnets with mesh sizes of 44 to 64 millimeters was increased over the past three seasons. These nets were typically set at depths of less than 30 meters. Large-mesh gillnets caught 43,580 lake trout (52,700 kilograms) in 2012; 48,810 lake trout (60,300 kilograms) in 2013; and 58,830 lake trout (65,200 kilograms) in 2014. Catches by large-mesh gillnets represented 35% of the biomass removed in 2012, 43% in 2013, and 51% in 2014 (table 1). The highest numbers of adult lake trout removed by large-mesh gillnets occurred near Carrington Island, in the Breeze Channel, and near the West Thumb Geyser Basin (figure 2). Areas near the mouth of Flat Mountain Arm and south/southeast of Frank Island also yielded many mature fish.

Lake Trout Live-Entrapment Netting

During 2012 and 2013, contract netters used 10 large trap nets to remove lake trout from Yellowstone Lake. Trap nets capture and hold fish alive, thereby providing a means to target lake trout in shallow, near-shore areas where both lake trout and cutthroat trout are found. Trap nets consist of a mesh lead (or guide) line up to 275 meters long and funnel-shaped tunnels which direct fish into a 'box' constructed of heavy mesh. The boxes are 12 meters by 6 meters and up to 9 meters tall, enabling the capture of many large lake trout. Trap nets were lifted and checked 1-2 times per week. Any captured cutthroat trout were sorted from lake trout and released. Although the primary use of trap nets was to remove lake trout, they also permitted live capture of lake trout for research use (e.g., sonic telemetry and population size estimation via mark-recapture).

In 2012, trap nets were used from June 19 to September 27 for a total of 879 net nights. Total catch using trap nets was 12,711 lake trout (18,900 kilograms), and yield was 13% of total lake trout biomass (table 1). The top three lake trout-yielding trap nets were located in West Thumb. The average number caught each night by a trap net in the West Thumb was 24 lake trout; whereas, trap nets located elsewhere caught an average of 9 lake trout per night. Average biomass removed by trap nets was 32 kilograms of lake trout per net-night in the West Thumb area and 15 kilograms per net-night in other areas.

Lake trout egg nets set near Carrington Island in Yellowstone Lake. - NPS Photo

In 2013, trap nets were used from May 26 to August 28 for a total of 880 net nights. Total catch using trap nets was 6,648 lake trout (9,300 kilograms), and yield was 7% of the total lake trout biomass removed from the lake (table 1). Only one of the top lake trout-yielding trap nets in 2013 was located in the West Thumb area because catches were distributed more evenly throughout the lake than in previous years. Average biomass removed by trap nets was 12 kilograms of lake trout per net-night in the West Thumb area and 10 kilograms per net-night in other areas. This reduction is partially due to removal of the trap nets prior to lake trout spawning, in order to focus more on gillnetting during the fall spawning period.

Lake Trout Suppression Alternative Methods

Embryo Suppression on Spawning Areas – To reduce costs and ensure program viability into the foreseeable future, there is a critical need to develop new, more efficient ways of lake trout suppression. Experts agree that methods which target lake trout embryos and/or larvae on spawning sites hold the greatest promise. Carrington Island, a tiny island located in the West Thumb of Yellowstone Lake, was first documented as a major lake trout spawning area in the late-1990s (Ruzycki et al. 2003, Ruzycki 2004).

To determine the spatial extent of spawning substrate (rock/cobble) around the island, NPS crews used high-resolution Global Positioning Systems and a hand-held depth finder to map the outer and inner extent of substrate. Total area of spawning habitat around the crescent-shaped island was 0.5 hectare. Water depths at the outer-most margin of the substrate were relatively shallow at 0.4 to 2.6 meters.

Electroshocking to Suppress Lake Trout Embryos – The NPS has been working with the Montana Cooperative Fishery Research Unit (U.S. Geological Survey) to develop electroshocking methods to kill lake trout embryos. The project supplemented an ongoing Montana State University project to develop an electrode array for the same purpose in Swan Lake, Montana. The prototype array was used on Swan Lake in 2013, and nearly 100% of lake trout embryos were killed to a depth of 20 centimeters in the substrate (Brown et al. 2014).

A similar electroshocking array was used in Yellowstone Lake during 2014. The array is mobile, and several known spawning reefs (Carrington Island, Snipe Point, and Olson Reef) were shocked during five days in early October. No quantifiable method was incorporated to determine how many eggs were destroyed, though many dead eggs were observed after electroshocking. A graduate student from Montana State University is developing a plan to assess the effectiveness of future electroshocking events.

Fisheries crews removing lake trout from gillnets aboard the NPS Freedom.

Suction-Dredging to Suppress Lake Trout Embryos – Following the lake trout spawning period in late September 2012, embryos were found in abundance within the substrate in shallow water around Carrington Island. Biologists used high-pressure water pumps to disrupt the rock/cobble substrate and remove lake trout embryos from the shallow spawning area around the island. At least several thousand embryos were likely disrupted and blown outward into soft sand sediments where they were unlikely to survive.

In addition, a suction dredge was used on spawning grounds during four days in late October 2014. The dredge removed approximately 5,075 viable eggs: 4,000 eggs from Carrington Island, 75 eggs from Snipe Point, and 1,000 eggs at Olson Reef. Many more eggs were suctioned, but most were already dead since the electroshocking array was first used at these sites. The suction dredge was able to remove lake trout eggs from substrate in both shallow and deep water (17 meters).

Applied Research to Improve Suppression Efficiency

Sonic Tracking to Locate Spawning Areas – In 2011, the NPS and U.S. Geological Survey initiated a telemetry study with support from Trout Unlimited, the National Parks Conservation Association, and the Greater Yellowstone Coalition. The objectives of this research are to locate lake trout spawning areas and identify movement corridors of lake trout within Yellowstone Lake. Transmitters were implanted in 159 lake trout, and 40 stationary acoustic receivers were deployed in Yellowstone Lake. Receivers were distributed lake-wide, with higher concentrations in areas suspected to be frequently used by lake trout. At key passage points, receivers were distributed to form an acoustic curtain so at least one receiver would record the passage of tagged fish moving through the area. Over 90% of tagged lake trout were detected moving through Breeze Channel into West Thumb during spawning migrations. Over 50% of tagged lake trout were detected at least once near the Carrington Island spawning site.

Since 2011, additional receivers and transmitters have been incorporated in the study each year. During spawning season, fine-scale positioning arrays of receivers have been deployed at suspected and known spawning areas to track tagged fish in 3-dimensional space through time. In 2012, an array was deployed at Carrington Island. In 2013, three arrays were deployed near West Thumb Geyser Basin, along the southeast section of West Thumb, and near the mouth of Flat Mountain Arm to Plover Point. In 2014, the Flat Mountain Arm/Plover Point array was redeployed and expanded. More details are available at: http://www.nrmsc.usgs.gov/yellowstone_lake.

Lake Trout Population Size Estimate

In 2013, the NPS and Montana State University initiated a mark-recapture study to estimate the population size of lake trout in Yellowstone Lake. During June and July, 2,398 lake trout were captured in live-entrapment nets, measured, marked with two uniquely-numbered plastic tags, and released. Trap nets used to capture these lake trout were located throughout West Thumb and the main portions of Yellowstone Lake (figure 6). Many of these marked lake trout were recaptured in gillnets and trap nets during the remainder of the netting season. Anglers were also encouraged to return tags from marked fish they caught. Recaptured lake trout were killed; location, method of capture, total length, sex, and maturity were recorded.

A total of 1,334 lake trout were recaptured in 2013, which was more than half (56%) of the total marked and released. Recapture of tagged fish occurred by gillnetting (922; 69%), trap netting (357; 27%), and angling (55; 4%). The distribution of recaptured lake trout indicated they moved considerable distances throughout the lake. For example, lake trout marked near the mouth of Solution Creek along the southern shore of West Thumb were recaptured throughout West Thumb, in Breeze Channel, along the lake's east shore, and as far away as the southern end of the Southeast Arm (figure 6). Modeling efforts estimated lake trout abundance for four different length classes. Estimates of abundance and accompanying standard errors (in parentheses) were as follows: 303,484 (± 22,350) lake trout in the 210-451 millimeter length class; 41,288 (± 4,456) in the 451-541 millimeter class; 17,278 (± 4,456) in the 541-610 millimeter class; and 5,601 (± 812) in the greater than 610 millimeter class (Rotella 2014). Estimated exploitation rates, which are the proportions of fish removed from the population, along with accompanying 95% confidence intervals were as follows: 0.72 (0.63-0.84) for lake trout in the 210-451 millimeter class; 0.56 (0.46-0.71) for the 451-541 millimeter class; 0.48 (0.38-0.66) for the 541-610 millimeter class, and 0.45 (0.35-0.63) for the greater than 610 millimeter class (Rotella 2014).

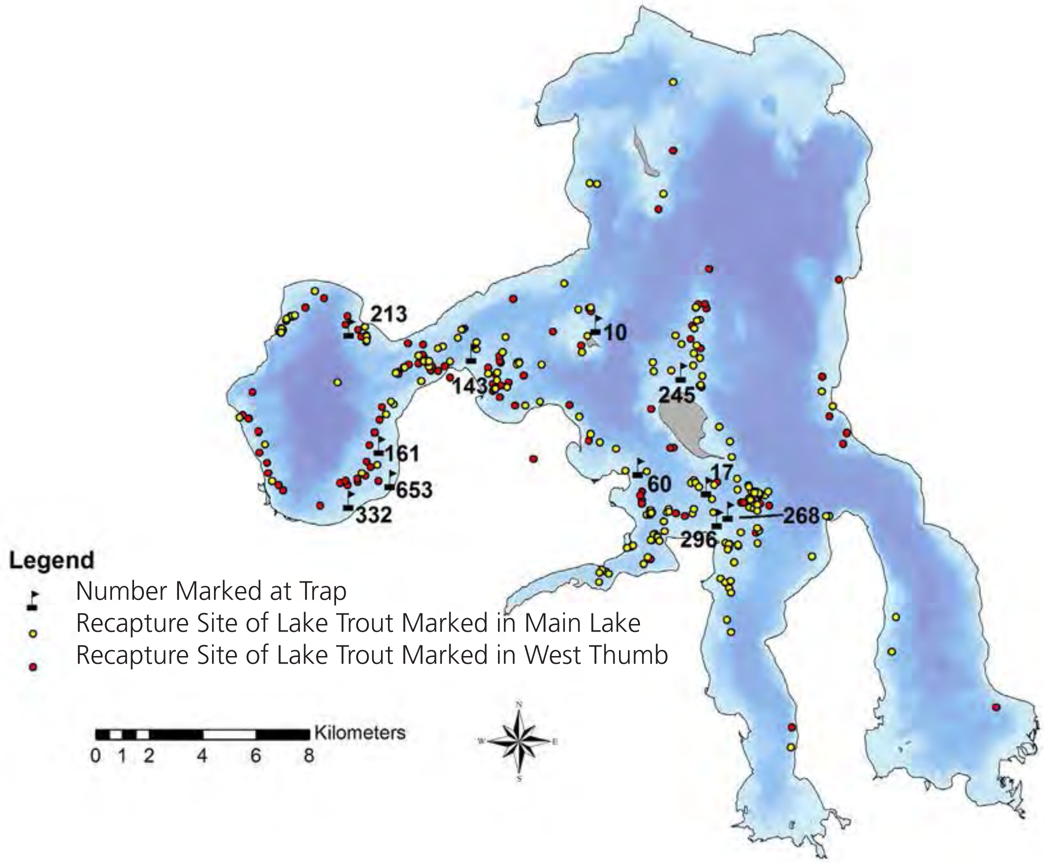


Figure 5. Number of lake trout marked and released at each trap net with recapture locations in Yellowstone Lake.

Lake Trout Egg Density and Survival

Little is known about the early survival of lake trout in Yellowstone Lake from spawning to age 2. As a result, current population modeling relies on estimates derived from research conducted mainly in the Great Lakes. However, early survival rates in Yellowstone Lake could potentially be much higher than those observed in the Great Lakes due to a lack of natural predators and other factors.

In 2013, the NPS collaborated with the U.S. Geological Survey, U.S. Fish and Wildlife Service, and the University of Vermont to obtain an assessment of lake trout embryo deposition at Carrington Island. A total of 108 "egg bags" were deployed by scuba divers in suitable spawning substrate along seven transects to the south, northwest, and north sides of the island. Fine-mesh bags were placed so that any eggs spawned over this substrate would be collected within the bag. Following placement, a photo was taken of each bag to estimate substrate size and location. About one-half of the egg bags were removed on October 15 to assess the abundance and distribution of eggs in the area.

Egg densities were higher northwest and south of the island, but varied widely among collection bags (1 to 282 eggs). No eggs were found in about one-half of the bags (53%). The pattern of egg deposition and density matched predictions based on work in the Great Lakes—most of the bags containing eggs, and all bags with high egg densities, were located at the edge of a short drop-off in the substrate. Developing embryos (alive and dead) and unfertilized eggs were preserved and will be analyzed to determine the approximate date of deposition. Remaining bags were retrieved during spring

2014 to determine overwinter survival rates and if spawning continued past the date the first set of bags were removed.

In 2014, a remotely operated underwater vehicle was used to verify successful spawning at Carrington Island and Olson's Reef, located between Eagle Bay and Flat Mountain Arm. Also, larval fish traps deployed at Carrington Island from early through mid-June revealed the presence of lake trout fry. These fry may be vulnerable to suppression with electrical equipment during that period.

Lake Trout Maturation Cycle and Reproductive Potential in Yellowstone Lake

In 2014, samples of gonads and body weights collected from lake trout killed in suppression nets were used to evaluate maturation from June through October. Reproductive tissue samples were stored for later histological analysis in the laboratory. These data will be used to determine frequency and pattern of lake trout spawning in Yellowstone Lake. In addition, a precise estimate of fecundity (i.e., productivity) is being developed for egg masses removed from female lake trout. The results will be compared to previous estimates collected when the lake trout population was rapidly expanding.

Spawning lake trout in Shoshone Lake. - Photo ©Jay Fleming

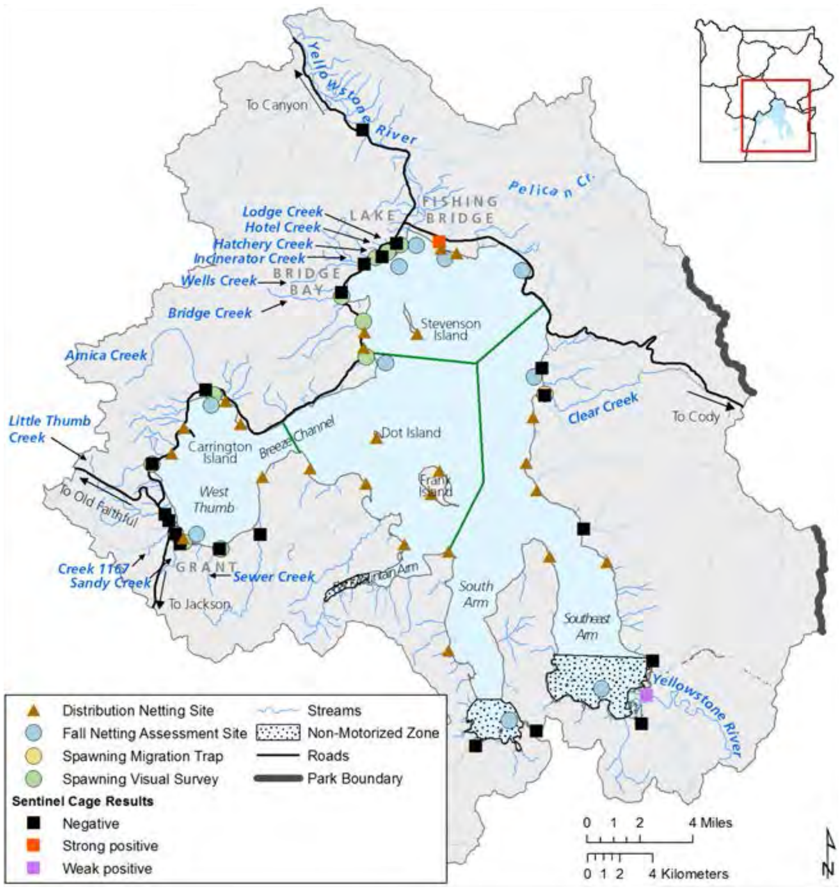


Figure 6. Sampling sites on Yellowstone Lake and associated creeks.

Progress toward cutthroat trout recovery and desired conditions for Yellowstone Lake was assessed annually through: 1) lake-wide population assessments of cutthroat trout and lake trout conducted via distribution gillnetting at three depth strata in August; 2) cutthroat trout spawning assessments using weirs/traps or by making visual counts on tributary streams from May through July; and 3) cutthroat trout catch success reported by lake anglers during the fishing season.

Lake-Wide Cutthroat Trout Population Assessment

Each fall, NPS biologists conduct distribution netting of cutthroat trout and lake trout in Yellowstone Lake to estimate age and size class structure, distribution, recruitment, and mortality from the lake trout suppression program. Twenty-four sites are sampled within the motorized portions of the lake, including West Thumb, the main basin surrounding Dot and Frank islands, the northern shore and area surrounding Stevenson Island, and the east shore and two southern arms (figure 6). At each sampling site, large-mesh and small-mesh

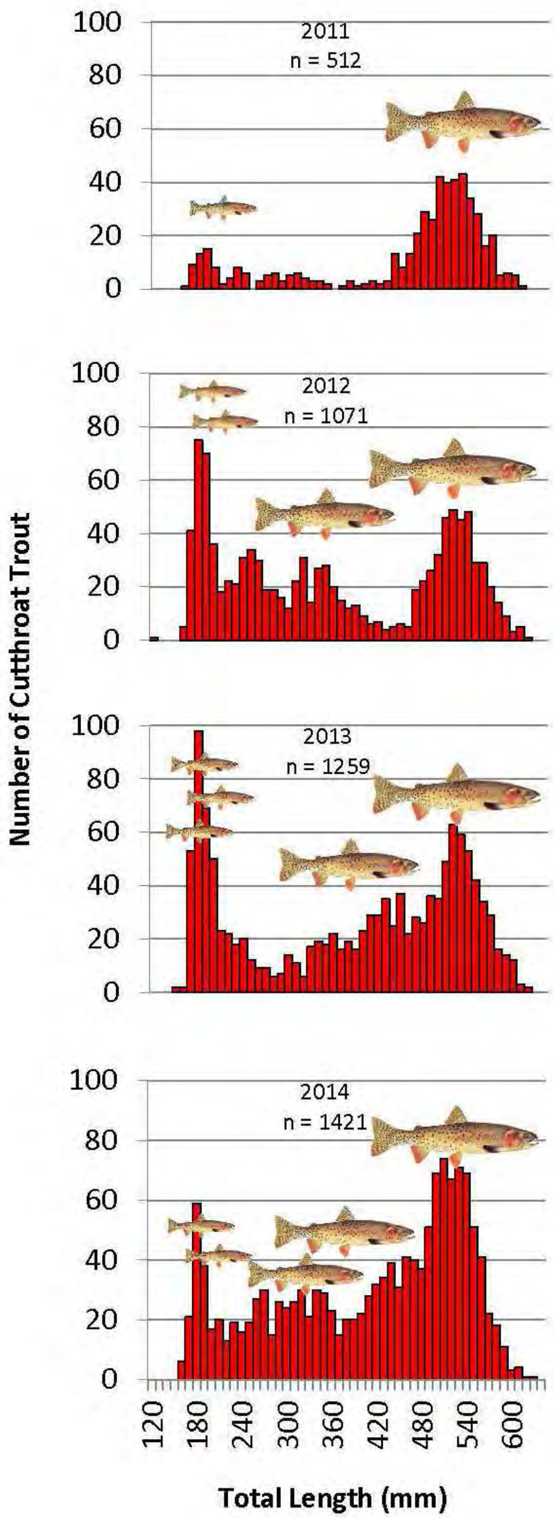


Figure 7. Length-frequency distribution of cutthroat trout collected from distribution netting on Yellowstone Lake with total number of trout (n), 2011-2014.

nets are set in shallow water, at mid-depth, and more than 40 meters deep. Mesh sizes on the large-mesh nets range from 57 to 89 millimeters, while sizes on small-mesh nets range from 19 to 51 millimeters.

The distribution nets caught 1,071 cutthroat trout in 2012; 1,259 cutthroat trout in 2013; and 1,421 cutthroat trout in 2014 (figure 7). These catches are more than double those in 2011. The increase in catch each year was primarily due to an influx of young, juvenile cutthroat trout within the system; however, increased catches of large, older-age fish also occurred. Cutthroat trout had a mean total length of 358 millimeters in 2012, 382 millimeters in 2013, and 405 millimeters in 2014 (figure 7). These mean lengths were much lower than those observed in earlier years. In 2014, most (53%) cutthroat trout were large adults between 430 and 620 millimeters in total length, while juveniles and subadults (29%) were less than 325 millimeters in total length.

Using the two shallow nets from each of the distribution sites, mean number of cutthroat trout caught per 100 meters of net per night was calculated (with 95% confidence intervals in parentheses). Catch per unit effort increased from an average of 11.8 (8.7-15.0) in 2010 to 28.4 (23.7-33.0) in 2014 (figure 8). The 2014 catch exceeds the secondary desired condition for the program's adaptive management strategy of 26 cutthroat trout per net (figure 9a).

The large recruitment of young cutthroat trout detected through distribution netting during 2012 through 2014 is an indication the cutthroat trout population is beginning to recover. Factors contributing to the increased number of young fish may include the greatly increased effort to suppress lake trout, as well as improved winter snow conditions and stream runoff in recent years.

Cutthroat Trout Tributary Spawning Assessment

For over 50 years, spawning cutthroat trout were counted as they ascended Clear Creek, a large tributary on Yellowstone Lake's eastern shore. In 2008, spring flood waters damaged the weir, rendering it inoperable. Since that time, efforts have been made to restore the ability to count spawning cutthroat trout at the site. In 2012, the NPS, with help from the Montana Conservation Corps, completely renovated the weir site, including removing badly damaged components of the old

Clear Creek Cutthroat Counting Station, reconstructed in 2012. Spawning cutthroat trout are counted in Clear Creek, a large remote tributary on Yellowstone Lake, using an acoustic monitoring system. -NPS photo

weir, reengineering and reconstructing the bulkhead on the southern stream bank, constructing a new shed and bridge, and rehabilitating stream bank erosion caused by the configuration of the old weir. The project did not include reconstructing the weir itself because the NPS installed a sonar (acoustic) fish counting system (Sound Metrics Corporation, model ARIS 3000) in 2013. During 2013 and 2014, fisheries staff learned to use system operating software, identified locations where the sonar could effectively capture fish images, and evaluated the solar energy supply.

Since 1988, the abundance of spawning cutthroat trout has also been visually estimated by people walking along 9 to 11 tributaries on the west side of Yellowstone Lake (Reinhart and Mattson 1990, Reinhart et al. 1995; figure 6). These surveys indicated a significant decrease in spawning-age cutthroat trout in Yellowstone Lake (figure 9b). In the late 1980s, more than 70 cutthroat trout were typically observed during a single visit to one of the streams, compared to only 1 or 2 cutthroat trout in recent years. One exception is Little Thumb Creek, a tributary in the West Thumb near Grant, where more than 70 cutthroat trout were seen during one week in 2012, more than 50 were seen in 2013, and more than 120 were seen in 2014. The desired conditions for Yellowstone Lake are an average of at least 40 to 60 spawning cutthroat trout observed per stream visit across all 11 tributaries (figure 9b).

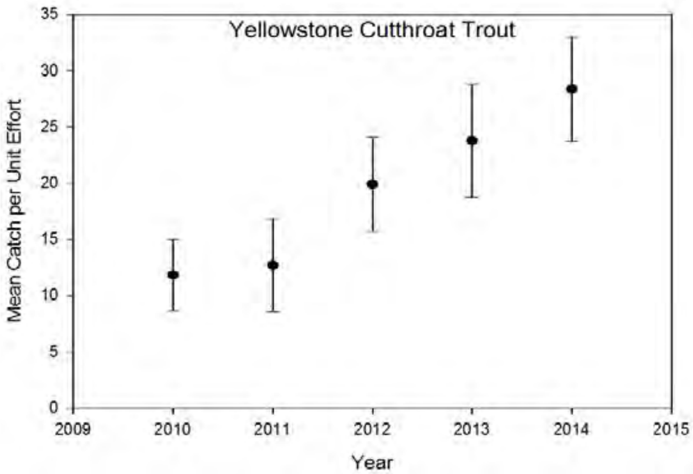


Figure 8. Mean number of cutthroat trout caught per 100 m net per night in distribution netting on Yellowstone Lake, 2010-2014. Bars delineate 95% confidence intervals.

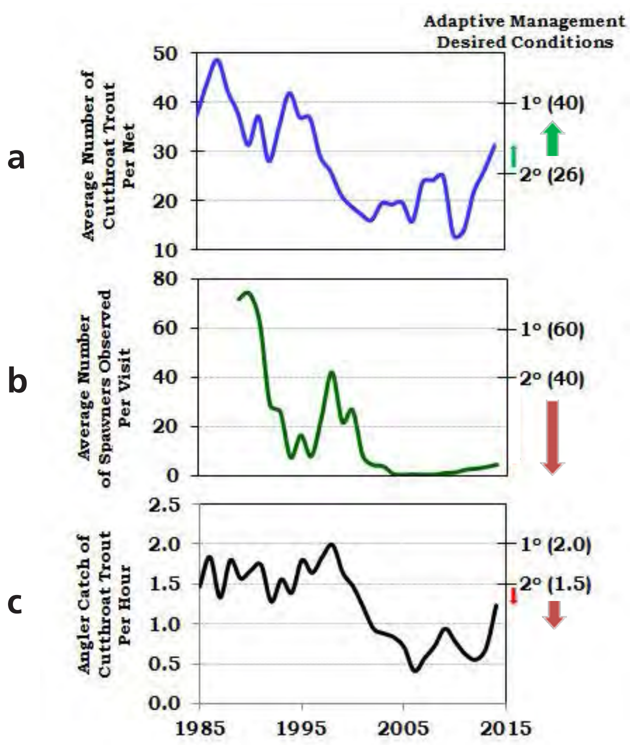


Figure 9. Metrics monitored to assess the effects of conservation actions on Yellowstone Lake include the average number of cutthroat trout that are (9a) caught per net during the fall netting assessment, (9b) observed during visual surveys of spawning streams, and (9c) caught per hour by lake anglers, 1985-2013. Primary and secondary desired conditions are from the Native Fish Conservation Plan.

Cutthroat Trout Angler Success

Since 1979, park visitors who purchase a fishing permit have been given a survey card on which to report waters fished, time spent fishing, and species and sizes of fish caught. About 5% of these anglers (approximately 2,000 per year on average) have completed and returned the cards to the park's fisheries program. Yellowstone Lake receives over 20% of the parkwide angling effort. In Yellowstone Lake, cutthroat trout catch rates were as high as 2 fish per hour in the 1990s, but decreased substantially in the early 2000s to only 0.6 fish per hour in 2012 (figure 9c). However, more recent angling reports from Yellowstone Lake are encouraging. In 2014, anglers reported catching 1.2 cutthroat trout per hour. This catch rate is still below the desired condition of 1.5 to 2 cutthroat trout per hour, but is higher than the previous 12 years (figure 9c). The average size of cutthroat trout being caught decreased to 438 millimeters (17 inches), due to an increase of smaller fish being caught rather than a decrease in larger fish.

Lake-Wide Lake Trout Population Assessment

A total of 394 lake trout were caught by distribution nets in 2012; 347 were caught in 2013; and 575 were caught in 2014 (figure 10). The mean total length for lake trout was similar among years (309-330 millimeters), but the range in sizes decreased with fish less than 200 millimeters and greater than 500 millimeters being caught less frequently each year. Most captured lake trout were immature fish less than 425 millimeters in total length.

High cutthroat trout consumption by lake trout is prevalent in the arms of Yellowstone Lake.

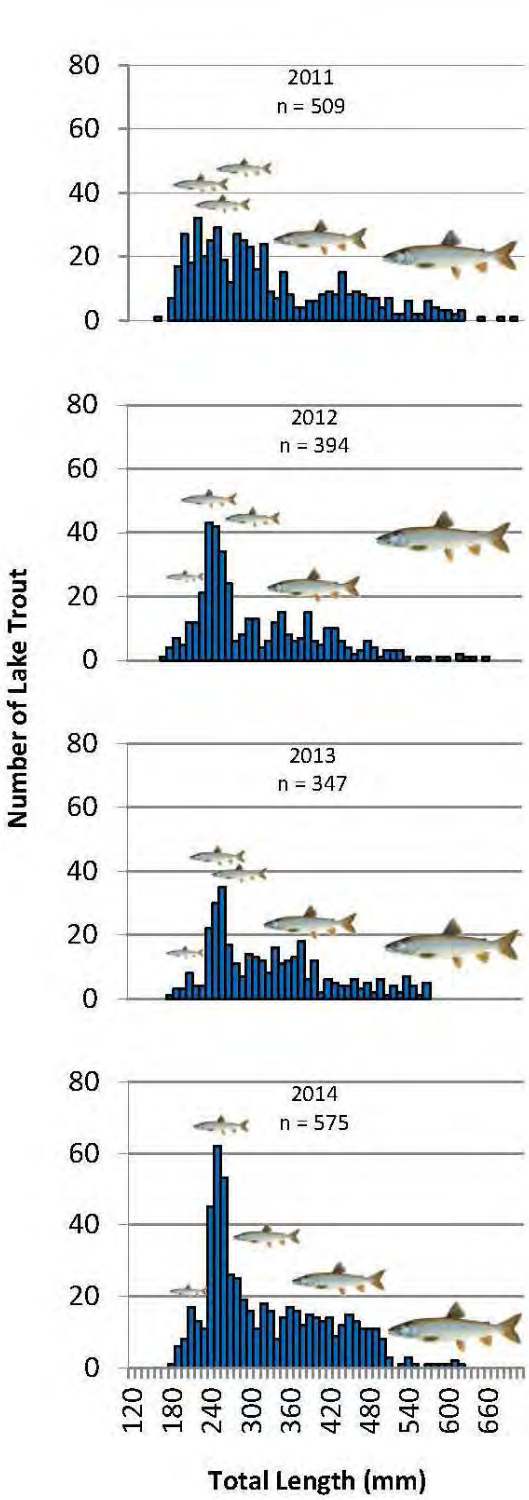


Figure 10. Length-frequency distribution of lake trout collected from distribution netting on Yellowstone Lake with total number of trout (n), 2011-2014.

The mean number of lake trout captured per 100 meters of net varied from 2.9 (95% confidence intervals = 2.1-3.7) in 2013 to 4.9 (3.4-6.3) in 2014 (figure 11), but was not significantly different among years. The highest catch per unit effort (6.3) occurred in West Thumb during 2012, along the east shore and in the southern arms during 2013 (3.6), and in the main basin during 2014 (6.6) (figure 12). Catch per unit effort for lake trout was lowest along the north shore.

Population Modeling and Lake Trout Mortality

The Montana Cooperative Fishery Research Unit has led efforts to analyze lake trout catch and monitoring data collected from Yellowstone Lake. Analyses include the total annual mortality for lake trout (ages 3 and greater) for each year during 1997-2014 (Syslo et al. 2011). Results indicate that mortality inflicted on lake trout due to suppression netting and other causes has increased from 0.24 (0.17-0.21) in 1997 to 0.53 (0.47-0.58) in 2013 (figure 13). This number slightly decreased in 2014 to 0.48 (0.36-0.57). Statistical modeling methods have also been used to reconstruct the abundances of lake trout each year. Results suggest that lake trout abundance (Syslo et al. 2011) increased from 129,382 (range = 111,593 to 147,171) in 1998 to 809,858 (676,672 to 942,996)

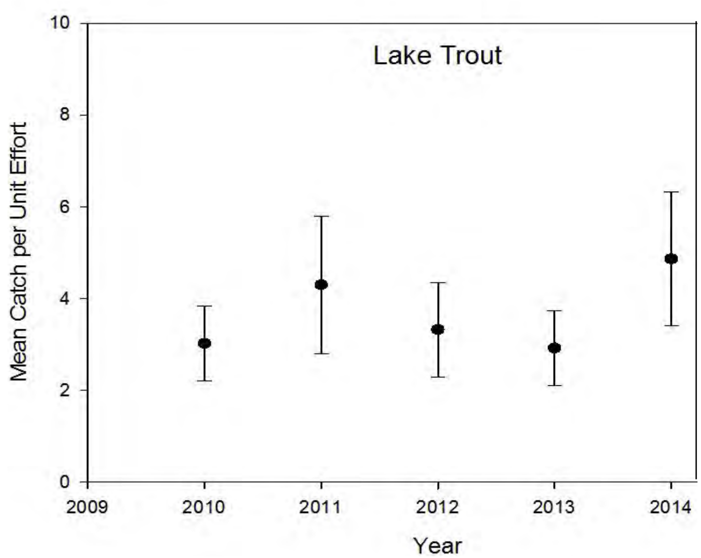


Figure 11. Mean number of lake trout caught per 100 m net per night in distribution netting within four Yellowstone Lake regions, 2010-2014. Bars delineate 95% confidence intervals.

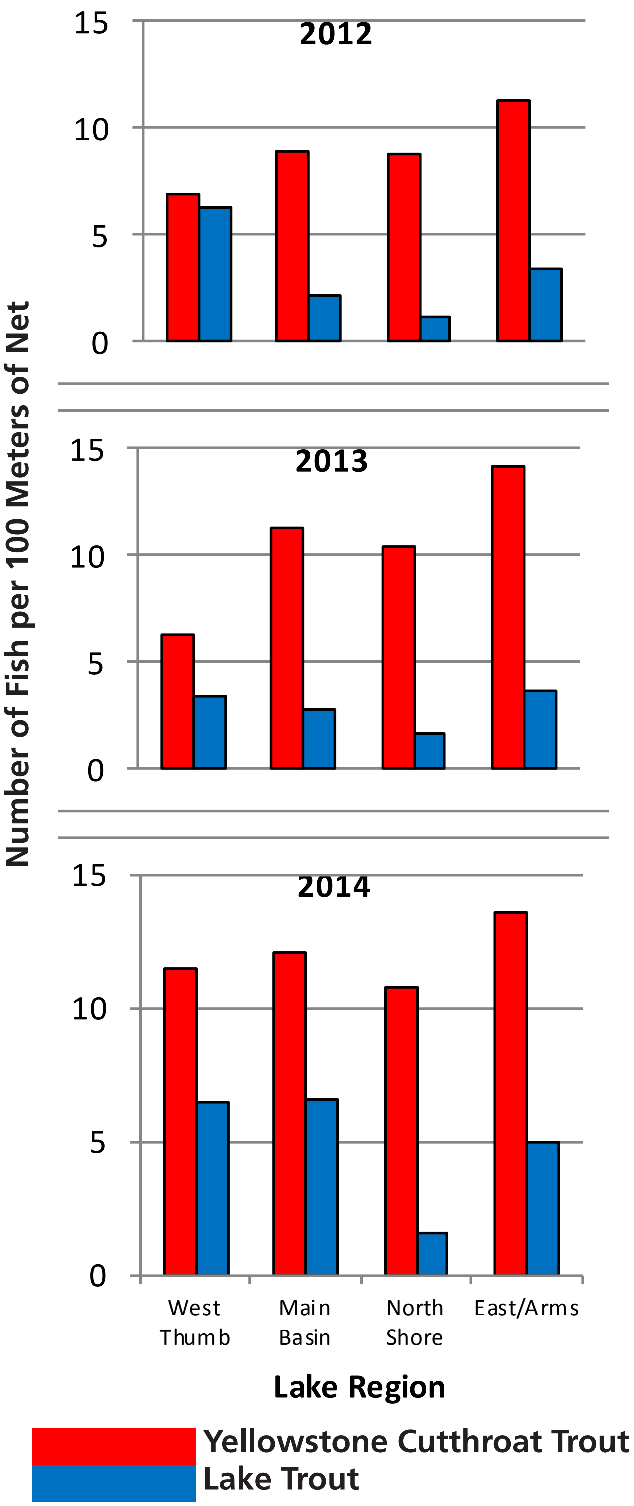


Figure 12. Mean number of cutthroat trout and lake trout caught per 100 m net per night in distribution netting within four Yellowstone Lake regions, 2012-2014.

in 2012, but then decreased to 485,468 (359,020 to 611,916) in 2014.

Whirling Disease Status Assessment

The exotic parasite *Myxobolus cerebralis*, which causes whirling disease, was first detected in Yellowstone cutthroat trout from Yellowstone Lake in 1998. Monitoring and research were conducted from 1999 through 2005 on 13 tributaries to determine its effects on cutthroat trout and whether actions could be taken to mitigate for them (Murcia et al. 2011, Murcia et al. 2015, Alexander et al. 2011). Parasite prevalence and severity of infection were high in exposed sentinel fry in Pelican Creek, and in the Yellowstone River downstream of the lake outlet. The spawning cutthroat trout population of Pelican Creek, which once numbered more than 30,000, was essentially eliminated. The prevalence of *Myxobolus cerebralis* in juvenile and adult cutthroat trout from Yellowstone

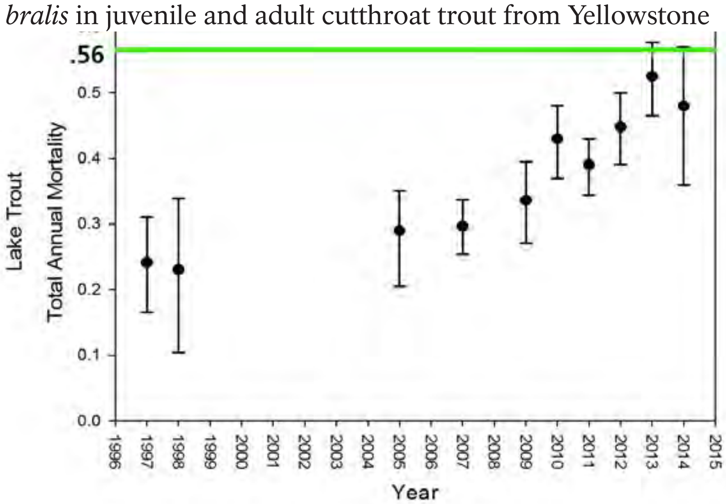


Figure 13. Lake trout annual mortality estimated using catch curves (data from distribution netting) from 1997 to 2014 in Yellowstone Lake. Horizontal line delineates the target of 0.56 stated in the Native Fish Conservation Plan.

Lake varied annually between zero and 20%. Prevalence was generally highest in the lake's northern region, near infected tributaries.

In 2012, research was initiated to determine if *Myxobolus cerebralis* had dispersed further across the ecosystem and whether it had the potential to limit cutthroat trout recovery in and near Yellowstone Lake. Cutthroat trout fry were placed in sentinel cages deployed in 22 downstream reaches of spawning tributaries for 12-day periods to assess whirling disease risk (figure 6). Ten fry from each location were assayed for the presence of *Myxobolus cerebralis*. In addition, some of the cutthroat trout caught at each of the 24 distribution netting sites were assayed for the presence of the parasite. Findings indicate that whirling disease risk remains high in Pelican Creek (figure 6). In addition, one fry tested weakly positive for *Myxobolus cerebralis* in the Yellowstone River upstream of Yellowstone Lake. All other streams tested negative. Within Yellowstone Lake, 14 of 139 (10%) cutthroat trout were infected. Overall, it does not appear whirling disease has spread widely throughout spawning tributaries to Yellowstone Lake, and the prevalence of infection in juveniles and adults within the lake remains low.

Science Panel Reviews of the Yellowstone Lake Program

The first scientific review panel evaluation of the Yellowstone Lake program occurred in 1995; soon after lake trout were discovered in the lake (Varley and Schullery 1995b). In 2008, the NPS again convened a panel of experts to evaluate the program and to make recommendations for improvement (Gresswell 2009). Science panel reviews have occurred annually since 2011 to inform the program's adaptive management strategy.

From 2012 to 2014, information reviewed by the scientific panel included suppression activities, updated population modeling, results from monitoring lake trout and cutthroat trout, proposed actions for the forthcoming field seasons, results of lake trout sonic telemetry studies, and summaries of alternative suppression techniques. In 2014, the panel noted substantial progress had been made and concluded the lake trout population should begin to collapse if effort was maintained at the 2013-level for at least five years. The panel also recommended that effort be continued for a minimum of 10 years or until suppression goals outlined in the Native Fish Conservation Plan are met (Gresswell et al. 2013a, Gresswell et al. 2013b).


Yellowstone Cutthroat fry. - Photo ©Jay Fleming

Electroshocking Flint Cascade, the upper extent of the cutthroat trout-rainbow trout hybridization in the Lamar River system. - NPS photo

Over the past decade, Yellowstone National Park has taken actions to restore and preserve native fish in several streams and lakes. These actions include suppression or complete removal of harmful nonnative species. Since 2006, four streams comprising 51.1 linear miles and four lakes comprising 49 surface acres of habitat have been restored for native fish. In addition, 14.8 and 15.2 linear stream miles of upper Soda Butte Creek and upper Slough Creek, respectively, have been electrofished annually to suppress nonnative and hybrid trout. These efforts are resulting in an increase in habitat occupied by native fish in Yellowstone National Park.

Westslope Cutthroat Trout Restoration on East Fork Specimen Creek

The East Fork Specimen Creek project began in 2006. Initially, it included the removal of nonnative fish from High Lake and all but the lowest portion of East Fork Specimen Creek, as well as the construction of a log fish barrier with a life expectancy of 10 years. During 2007 through 2012, more than 15,000 westslope cutthroat trout eggs and nearly 3,000 juveniles and adults were reintroduced to East Fork Specimen Creek to reestablish a viable, naturally-reproducing population within the watershed (figure 14, table 2).

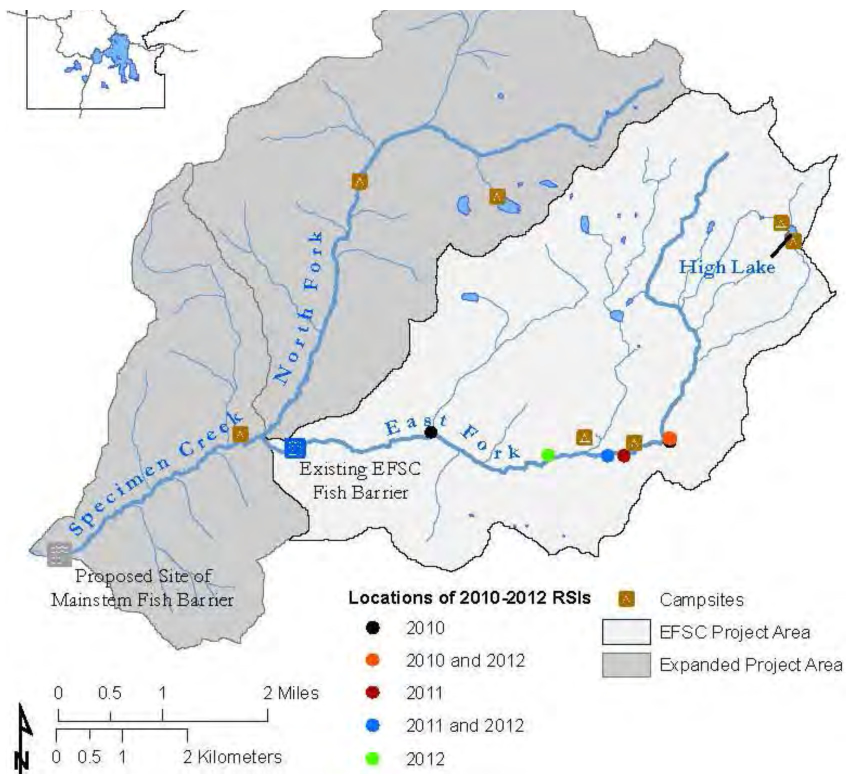


Figure 14. East Fork Specimen Creek westslope cutthroat trout restoration area in the Specimen Creek watershed, in northwestern Yellowstone National Park, with locations of remote site incubators (RSI) for reintroduction of westslope cutthroat trout embryos.

Table 2. Total number of westslope cutthroat trout reintroduced into the East Fork Specimen Creek watershed, 2007-2012.

	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	
	2012	3,550	
Total at Project Completion		**15,664**	**2,964**

The future of the project will include monitoring westslope cutthroat trout abundance and genetic integrity, as well as the condition and performance of the fish barrier. To ensure the persistence of westslope cutthroat trout, an engineered barrier will need to be constructed on the lower mainstem of Specimen Creek near Highway 191 (figure 14). If the barrier is completed, the project could be integrated into a larger westslope cutthroat trout restoration to all of Specimen Creek drainage including the North Fork. In fall 2011, an engineering and planning firm was retained to conduct detailed topographic mapping and design this fish barrier. A conceptual design and engineering plans have been created, which could lead to efforts to construct the barrier and complete the watershed-scale, westslope cutthroat trout recovery.

Native Fish Community Restoration on Grayling Creek

Fluvial (river-dwelling) Arctic grayling were once abundant in the Madison and Gallatin river drainages of Yellowstone National Park. However, the introduction of nonnative fish and the construction of Hebgen Reservoir on the Madison River just downstream of the park led to the species' decline and eventual extirpation from park waters. Fluvial Arctic grayling are currently the only native fish species extirpated from park waters. Westslope cutthroat trout, native to the same waters in Yellowstone as Arctic grayling, have fared little better over the last century. In fact, only one aboriginal population of westslope cutthroat trout remains in the park, located in Last Chance Creek, a tributary to Grayling Creek. In order to return Arctic grayling to Yellowstone National Park and ensure the persistence of westslope cutthroat trout, the park began surveying Grayling Creek in 2007 (Koel et al. 2008) and identified Grayling Creek as a critical project within the Native Fish Conservation Plan. (see "Through a Biologist's Eyes", page 34).

The first conservation action required on Grayling Creek was to isolate the restoration area by modifying an existing bedrock waterfall, located in a canyon near Highway 191 (figure 15). An engineering and planning firm completed a barrier design, and in fall 2012 the NPS partnered with technical blasters from the Gallatin National Forest to create the barrier. Additional finish work was conducted in 2013 and 2014 by contractors with Intermountain Restoration. The modification elevated the barrier to a height > 6 feet, and filled deep pools to create a large concrete "splash pad" at the barrier base. The falls are now a complete barrier to upstream fish movement by rainbow and brown trout located downstream in Hebgen Reservoir (figure 15).

The Grayling Creek restoration area includes 95 kilometers (59 miles) of connected stream habitat with a typical summer discharge of 40 cubic feet per second downstream near the fish barrier. Actions to remove nonnative fish from the Grayling Creek restoration area upstream of the barrier began in 2013, with assistance from the U.S. Forest Service, U.S. Fish and Wildlife Service, Montana Fish, Wildlife & Parks, and Turner Enterprises, Inc. More than two dozen fish biologists and technicians worked for several weeks to remove nonnative and hybrid trout from the restoration area using rotenone. A second rotenone treatment took place during 2014. The reintroduction of westslope cutthroat trout and fluvial Arctic grayling to the drainage began in 2015.

Westslope Cutthroat Trout Brood Development at Goose Lake

The restoration of native fish populations is contingent on having brood sources from which to reestablish native fish populations. A brood source should be accessible, secure from contamination, self-sustaining, genetically diverse, abundant, of traceable origin, and pose no risk to existing wild populations. The opportunity to create such a brood source for westslope cutthroat trout exists within the Goose Lake chain of lakes in the Firehole River drainage of Yellowstone National Park. These lakes are not connected to the

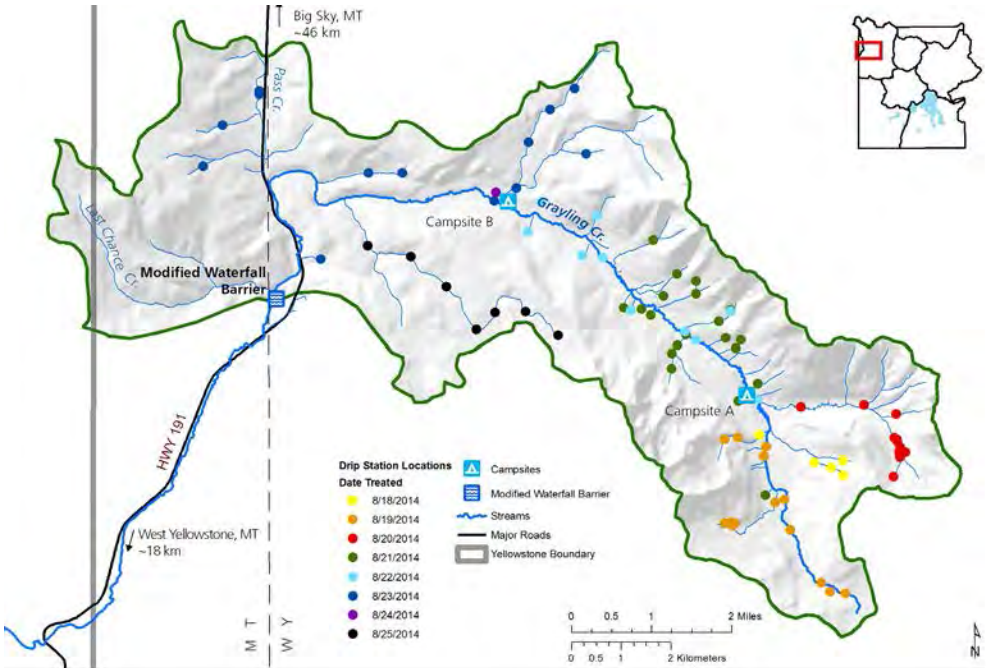


Figure 15. Locations of rotenone treatments and a modified waterfall barrier in the Grayling Creek drainage in 2014.

river (figure 1) and are easily accessible due to their proximity to the Fountain Flat Drive Service Road. These lakes were historically fishless, but were stocked with nonnative rainbow trout more than 100 years ago.

In 2011, Goose Lake, Gooseneck Lake, and a small, connected, unnamed lake were treated with rotenone to remove rainbow trout. In 2012, extensive monitoring including netting, snorkeling, and electrofishing confirmed that rainbow trout had been removed. During 2013 and 2014, more than 5,300 fry originating from multiple wild sources in the upper Missouri River drainage were stocked into Goose Lake. The future of the project will include monitoring abundance and genetic integrity, as well as stocking the upper two lakes of the complex.

Yellowstone Cutthroat Trout Conservation in Northern Yellowstone

Over the past decade, considerable efforts have been invested in understanding the status and trends of Yellowstone cutthroat trout across the northern reaches of the park. These efforts have identified several potential cutthroat trout conservation actions in small streams and lakes, as well as alarming trends and potential threats in three of the region's largest and most important cutthroat trout fisheries. Nonnative, hybridizing rainbow trout are abundant in the lower Lamar River, lower Slough Creek (downstream of the campground), and Yellowstone River between the Lower Falls at Canyon and Knowles Falls (figure 16).

Conservation of Yellowstone cutthroat trout of the Lamar River watershed is a top priority for the NPS. Multiple tools are being used to mitigate for rainbow trout in the Lamar River and its tributaries, including: 1) suppression via electrofishing by NPS crews, 2) creation of barriers to prevent further upstream movements and invasions by rainbow trout, 3) suppression via a catch-and-kill regulation for visiting anglers, and 4) suppression via removal by volunteer anglers.

Nonnative brook trout, which outcompete and displace cutthroat trout, exist in upper Soda Butte Creek. Each year, a week-long interagency electrofishing effort occurs to keep the population suppressed. Brook trout are not known to live anywhere else in the Lamar River drainage, but there are several populations in small tributaries of the Yellowstone River near its confluence with the Lamar River. These tributaries include the Elk-Yanceys-Lost Creek complex of streams; Tower Creek and its large tributary, Carnelian Creek; and the many creeks of the Blacktail Deer Plateau drainage (figure 16). Beginning with Elk-Yanceys-Lost Creek complex, the NPS is working to remove the threat of brook trout from these small tributaries with rotenone. Following treatment, the streams will be restocked with Yellowstone cutthroat trout from nearest-neighbor sources, such as Antelope Creek.

Elk-Yanceys-Lost Creek Complex – Given the close proximity of Elk, Yanceys, and Lost creeks to the confluence of the Lamar and Yellowstone rivers (figure 17), a project was initiated in 2012 to remove the threat of brook trout and restore Yellowstone cutthroat trout to the drainage. Historically, it is unclear if the Elk Creek drainage was home to cutthroat trout, but cutthroat trout were present in the stream when brook trout were introduced in 1942 (Varley and Schullery 1998). Since that time, brook trout have completely displaced all other fish species from the watershed.

The presence of a large, natural cascade on Elk Creek near the Yellowstone River that serves as a barrier to fish movements allowed the project to begin with nonnative fish removal (figure 17). In 2012, rotenone was applied to all of the fish-bearing portions of the drainage, leading to the removal of thousands of brook trout. However, post-treatment monitoring found some brook trout had survived the treatment due to complex, dense woody debris habitat and slow water travel times through some stream reaches. In 2013, all fish-bearing waters in the complex were retreated, but post-treatment

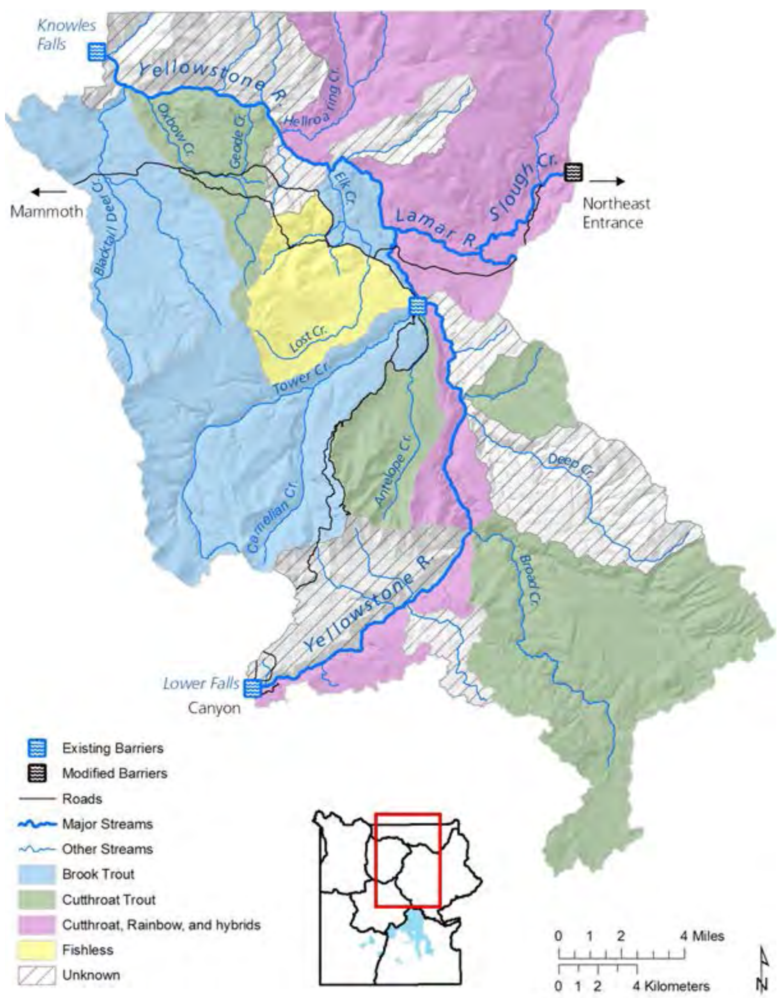


Figure 16. Fish species presence within tributary watersheds of the lower Lamar and Yellowstone river drainages. Brook trout are being actively removed in this area to prevent invasion by this harmful nonnative species.

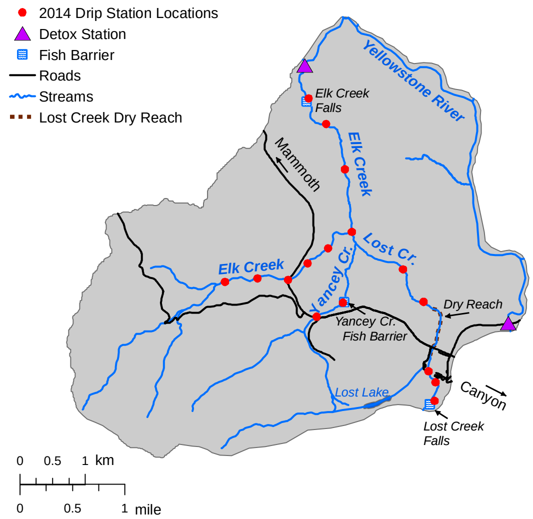


Figure 17. Location of Elk Creek removal of brook trout using rotenone in 2012-2014.

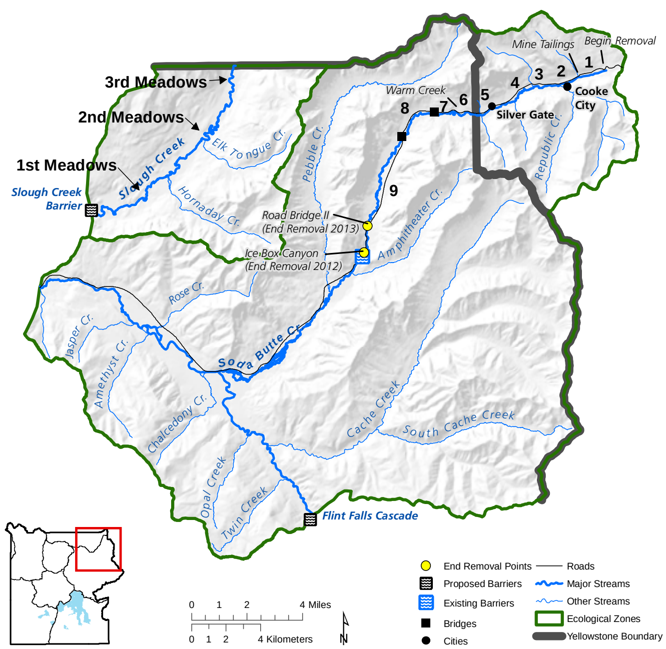


Figure 18. Middle Lamar River drainage including locations of electrofishing removals of rainbow trout and hybrid trout from Slough Creek (Meadows 1-3) and brook trout from Soda Butte Creek (reaches 1-9).

surveys revealed brook trout were still present in two locations. Therefore, a third treatment was conducted in 2014. The efficacy of this treatment will be evaluated in 2015 and lead to either a fourth treatment with rotenone or the reintroduction of Yellowstone cutthroat trout.

Soda Butte Creek – Interagency efforts to suppress brook trout in Soda Butte Creek have been ongoing for more than a decade. From 2012 to 2014, biologists from the NPS, U.S. Forest Service, Montana Fish, Wildlife & Parks, and Wyoming Game and Fish Department sampled upper Soda Butte Creek from Highway 212 downstream to Ice Box Canyon using boat-mounted electrofishing equipment (figure 18). Also, tributary streams were sampled using backpack electrofishing units. Electrofishing surveys resulted in 2,018 cutthroat trout in 2012, 2,531 in 2013, and 1,399 in 2014. Numbers of cutthroat trout sampled have varied over the years with effort expended, but in one stream section where effort has been constant, cutthroat trout numbers have shown a steady decrease from 759 in 2009 to 135 in 2014.

The number of brook trout removed from the mainstem of Soda Butte Creek has remained relatively consistent over the past several years with 108 brook trout captured in 2012, 111 in 2013, and 102 in 2014 (table 3). These catches are similar to the 5-year mean of 110 fish. However, in 2013, an additional 54 brook trout were captured from one unnamed tributary just inside the boundary of Yellowstone National Park. The presence of large numbers of young-of-year indicated brook trout are successfully spawning in this small creek. The lack of young-of-year brook trout in Soda Butte Creek upstream of this tributary is evidence this stream is a major source of brook trout.

Table 3. Total (and young-of-year) brook trout mechanically removed from Soda Butte Creek within the Gallatin National Forest, State of Montana, and in Yellowstone National Park, 2004–2014.

Site #	Removal Reach	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	Hwy 212 to McClaren Mine Tailings	19(1)	3(0)	0(0)	0(0)	0(0)	NS	NS	NS	0(0)	0(0)	1(0)
2	McClaren Mine Tailings to Woody Creek	15(0)	17(0)	3(0)	3(0)	2(0)	NS	NS	NS	NS	NS	0(0)
3	Woody Creek to Sheep Creek	8(2)	43(0)	16(0)	0(0)	1(0)	NS	NS	2(0)	0(0)	0(0)	1(0)
4	Sheep Creek to Silver Gate	251(79)	932(51)	142(6)	45(8)	5(0)	6(0)	NS	30(1)	5(0)	4(0)	2(0)
5	Silver Gate to Yellowstone Park Boundary	9(3)	80(9)	54(2)	48(19)	13(0)	30(2)	16(0)	22(2)	10(0)	2(0)	30(3)
6	Yellowstone Park Boundary to Warm Creek	7(0)	11(0)	0(0)	50(27)	23(2)	56(10)	43(2)	15(0)	29(9)	35(0)	8(0)
7	Warm Creek to Road Bridge	0(0)	1(0)	0(0)	0(0)	3(1)	51(12)	68(29)	35(6)	53(10)	54(23)	55(4)
8	Road Bridge I to Road Bridge II	NS	NS	NS	NS	0(0)	1(0)	7(0)	2(0)	11(2)	16(3)	3(0)
9	Road Bridge II to Ice Box Canyon	NS	NS	NS	NS	0(0)	0(0)	NS	0(0)	NS	NS	NS
T	Tributaries	0(0)	17(0)	15(0)	4(0)	1(0)	8(0)	NS	NS	0(0)	54(19)	2(0)
	Total	**309**	**1,104**	**230**	**150**	**48(3)**	**152(24)**	**134(31)**	**106(10)**	**108(21)**	**165(45)**	**102(7)**

In 2013, personnel from the NPS and Gallatin National Forest modified a natural falls in Ice Box Canyon to create a complete barrier to upstream fish migration (figure 18). Currently, the plan is to continue with the electrofishing removal of brook trout in the system, while exploring other alternatives. These removal efforts are preventing an increase in brook trout numbers, but not eliminating them from the creek. Also, removal efforts are not preventing brook trout from moving downstream into tributary streams above Ice Box Canyon. To date, no brook trout have been found in Soda Butte Creek downstream of Ice Box Canyon.

Slough Creek – Hybridization of cutthroat trout with nonnative rainbow trout poses a serious threat to the long-term persistence of cutthroat trout in Slough Creek. During 2012 and 2014, electrofishing surveys were conducted to assess trout abundance, collect tissue samples for genetic analysis, and remove nonnative rainbow trout and hybrid trout (figure 18). Overall, 36 rainbow trout and hybrids were removed from the system. The number of rainbow trout and hybrids appears to be increasing over the past decade; only 17 fish were removed in 2002 and 2003.

Results from electrofishing surveys in the first meadow of Slough Creek indicate the abundance of Yellowstone cutthroat trout has significantly decreased from 308 ± 49 in 2002 to 173 ± 32 in 2012. The mean length of cutthroat trout was 346 millimeters in 2002, 356 millimeters in 2012, and 254 millimeters in 2014. Almost all cutthroat trout sampled in 2012 were slightly hybridized with rainbow trout (99.9% cutthroat trout and 0.1% rainbow trout). Results of 11 fish specifically sampled because they visually appeared to be hybrid trout showed two were genetically pure cutthroat trout, one was a genetically pure rainbow trout, and eight were hybrids. The presence of a genetically pure rainbow trout is evidence nonnative fish are entering Slough Creek meadows from a downstream source.

In 2014, an engineering firm designed a barrier along Slough Creek to prevent upstream movements by rainbow trout; further site visits will be necessary in 2015 to finalize the design and cost estimates. When constructed, the barrier will prevent further immigration of rainbow and hybrid trout into the upper meadows of Slough Creek.

Upper Lamar River – The NPS has been collecting genetic samples since 2010 from fish in the Lamar River (figure 19) to determine if rainbow trout have hybridized with cutthroat trout upstream of Cache Creek. In 2012, NPS biologists investigated Flint Falls Cascade on the Lamar River, which had been reported as a potential fish barrier to movements upstream. Due to the lack of vertical drop, however, the cascade is almost certainly not a barrier to upstream fish movement. Thus, 40 kilometers of the Lamar River and over

644 kilometers of its tributaries remain highly susceptible to invasion by rainbow trout and other nonnative fish located downstream. The NPS has contracted an engineering survey and design of a fish barrier at Flint Falls Cascade, which may include alternatives to vertical and velocity barriers, such as electrical barriers, that could be used to deter nonnative fish movement.

In 2013, 215 tissue samples were collected from trout in nine sample locations between Calfee and Soda Butte creeks (figure 19). Genetic analysis of these samples revealed slight hybridization with rainbow trout (99.9% purity) as far upstream as Flint Falls Cascade, approximately 13 kilometers upstream of Soda Butte Creek (figure 19). However, all tissue samples collected 3 and 5 kilometers below the cascade were from genetically unaltered Yellowstone cutthroat trout, as were all samples collected upstream of the cascade.

In 2014, 145 tissue samples were collected from trout in six sample locations on Cache Creek, a tributary of Lamar River (figure 19). These samples are still being processed.

Joffe Lake – This artificial impoundment supplies drinking water to the headquarters area of Yellowstone National Park. Historically, the lake has supported a nonnative brook trout fishery for youth anglers. In 2013 and 2014, the lake was stocked with 4,000 Yellowstone cutthroat trout fingerlings. Plans are to continue infusing the system with native cutthroat trout, while suppressing the brook trout population via electrofishing during the fall spawning period.

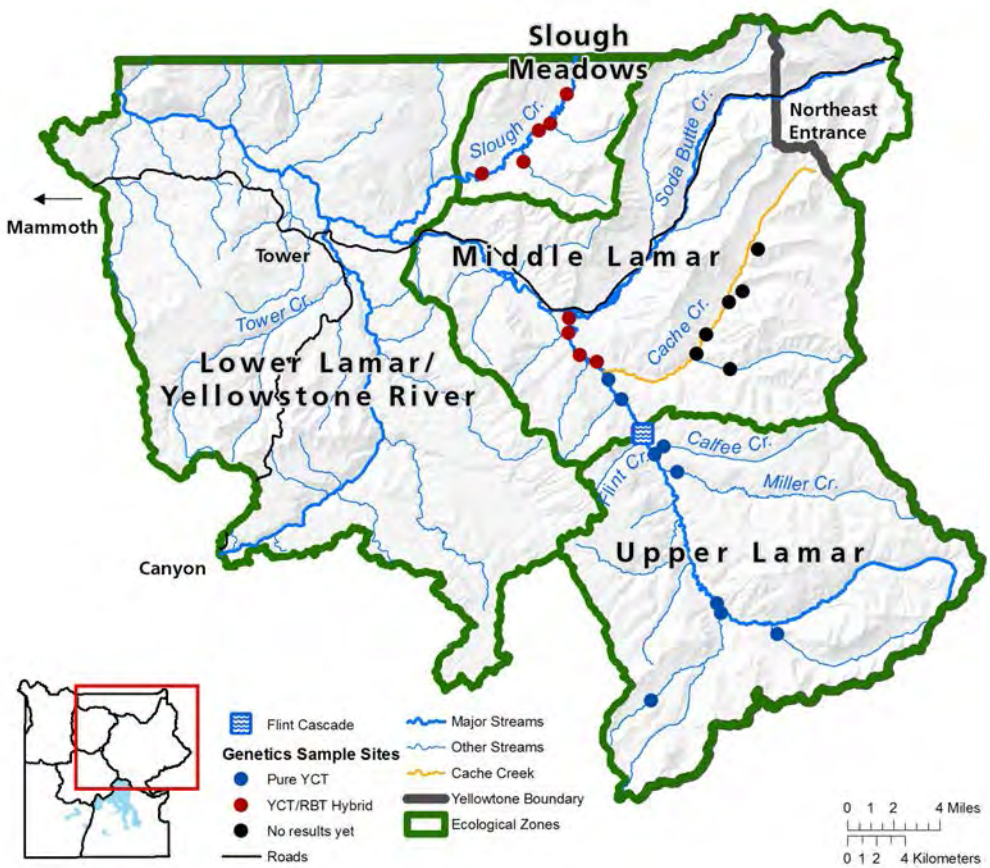
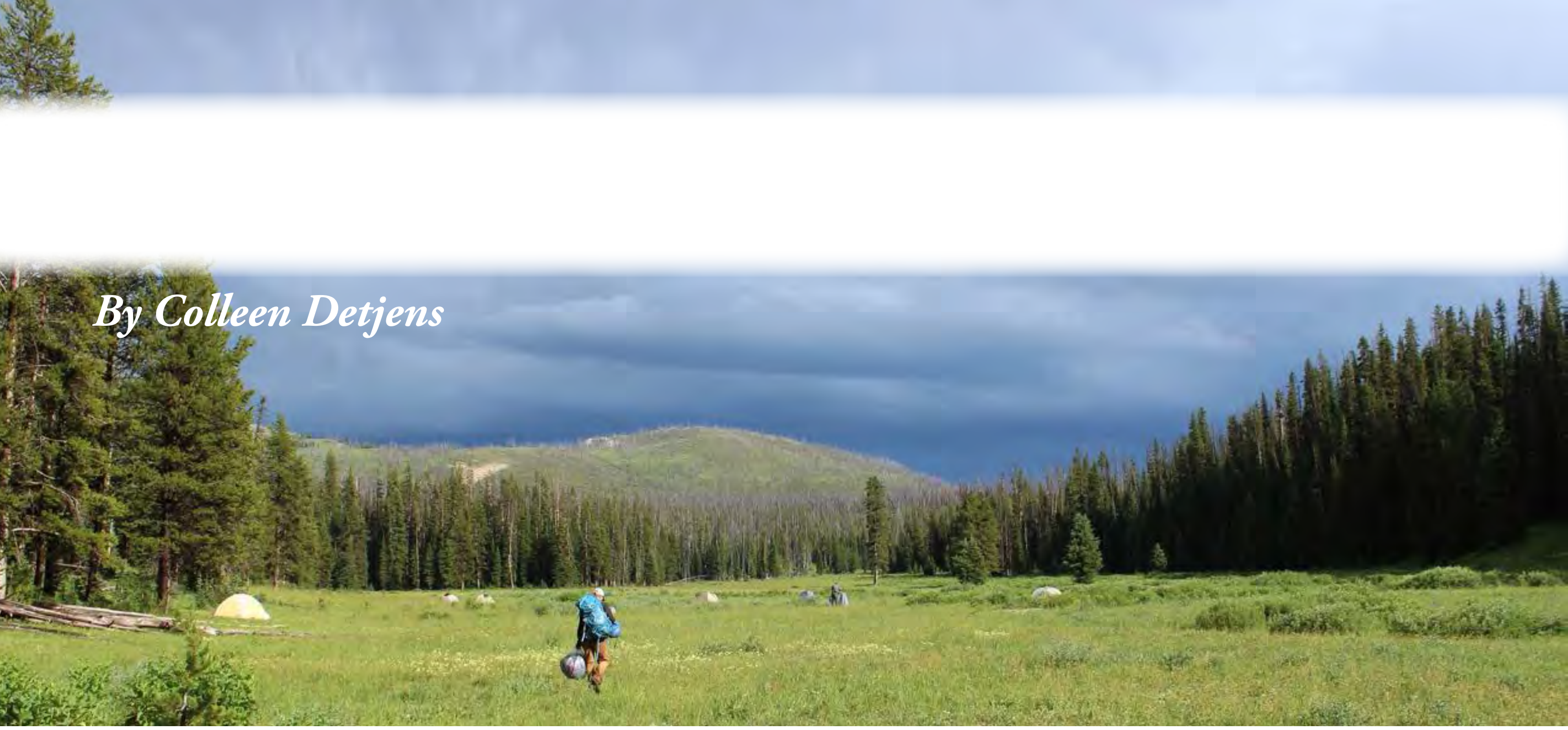


Figure 19. Lamar River watershed with genetic status of cutthroat trout collected at sites based on tissue sample collections collected from 2010 to 2014. The cutthroat trout of Cache Creek and the Lamar River and tributaries upstream of the Flint Creek Cascade remain genetically unaltered.

Caddis fly hatch near Lake Village. - Photo ©Doug Hilborn

By Colleen Detjens



By 1950, there were no truly fluvial (stream dwelling) populations of Arctic grayling left in Yellowstone National Park. Historically, fluvial grayling inhabited the Gallatin River, Grayling Creek, Madison River, and the lower portions of the Firehole and Gibbon rivers. The only remaining populations in the park exist in the form of lake dwelling grayling in several lakes outside of their native range. This fact led park biologists to seek out a suitable site in which to restore a viable, fluvial grayling population. Grayling Creek, on the west side of the park, was chosen for several reasons. In addition to previously being home to a population of fluvial grayling, it also contained westslope cutthroat trout, another species whose occupied range has dwindled over the years. Grayling have disappeared from their native range for several reasons, namely the introduction of nonnative brown and rainbow trout. Nonnative fish compete with native populations for habitat and food; rainbow trout also hybridize with the native cutthroat creating a less viable population. In addition, Grayling Creek is an extensive drainage with habitat that varies from small cascading tributaries to large meandering meadows and includes 18 miles (29 km) of main-stem stream. An existing waterfall at the downstream end provided an ideal location to create a complete barrier to upstream movement of nonnative fish, a key element to successfully restoring native fish populations.

The reintroduction of Arctic grayling into Grayling Creek has been a long process. In 2007, NPS biologists along with grayling biologists from Montana Fish, Wildlife & Parks (MFWP) conducted a site visit to confirm that Grayling Creek did indeed have enough suitable habitat to support a robust population of fluvial grayling. Reintroduction would also provide an opportunity to restore pure westslope cutthroat to the drainage. In the following years, NPS crews began to lay the groundwork needed to complete this large-scale project. Fish surveys were conducted to find the upper extents of fish occupation in the forks and the extensive numbers of tributaries to Grayling Creek. Genetic samples were collected to determine whether any pure westslope cutthroat remained; unfortunately, hybridization extended throughout the drainage. Spatial Analysis Program personnel were asked to map as much of the system as they could to determine where all of the tributaries and springs were located; a daunting task as it turns out because there are many small springs and tributaries on Grayling Creek and no trails. The Native Fish Conservation Plan and Environmental Assessment, which covers projects throughout the park, including Grayling Creek, was painstakingly written and reviewed. And, of course, funding and support had to be secured for all phases of the project from barrier construction through the treatment to the reintroduction of native species.

In 2011, engineers were brought to the Grayling Creek waterfall to determine the feasibility of modifying the existing feature into a complete barrier to upstream fish movement. Fish, especially rainbow and brown trout, are adept at taking advantage of small pockets and other irregularities to 'step' their way up a waterfall. They also make use of the deep pools that form at the base of waterfalls to gather enough velocity to jump over the falls. In October 2012, a U.S. Forest Service blasting crew began work to modify the falls. Their efforts created a sheer face of rock all the way across the stream. In 2013, work was continued by an independent contractor and a Montana Conservation Corp crew. Concrete was added to the top of the falls to make it over 6 feet (1.8m) tall, and a concrete splash pad was laid at the base to eliminate the formation of a deep pool.

While the barrier was being worked on by the contractors, the NPS crew was gearing up for the complex rotenone treatment that lay ahead. Planning started over the previous winter with sizable lists of the equipment and personnel needed. In addition to the extensive amount of equipment needed for rotenone treatments, enough gear was needed to support upwards of 30 people in the backcountry for two weeks. That meant bear spray, radios, toilet paper, stoves, pans, batteries, data sheets, an endless number of pencils, sunscreen, first aid kits, garbage bags, tape, extra laces for wading boots; the list goes on. Equally challenging was securing an advance commitment for support personnel from multiple other agencies. Crews from the U.S. Fish & Wildlife Service, MFWP, U.S. Forest Service, and Turner Enterprises, Inc., all came out to assist the already twelve-person strong NPS crew. The next step was getting everything into the backcountry; and since there are no trails, stock use was not an option. Instead, numerous helicopter flights were used. Equipment was flown to each of two base camp locations as well as to the barrier site.

Prior to the actual rotenone treatment, an NPS crew spent time in the backcountry collecting data on flow times and discharge rates on all the major tributaries and forks as well as the main stem of Grayling Creek. This information is vital to planning and executing a successful treatment, as it allows for adequate and precise application of rotenone. Although rotenone only affects gill breathing organisms, invertebrate and amphibian sampling is also conducted prior to and post treatment.

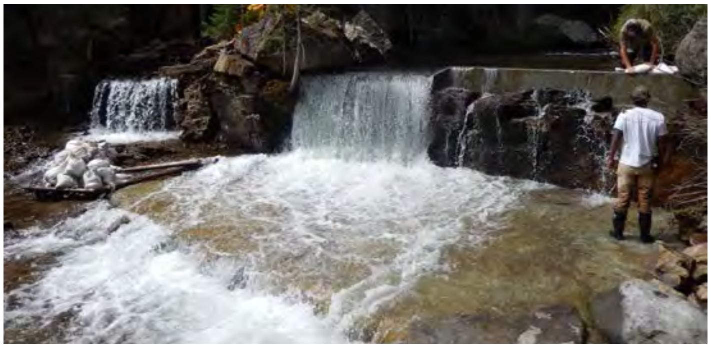
Once the majority of the pre-treatment work was done, the crews from other agencies joined the NPS crew to carry out the actual treatment. Coordinating the arrival of so many people hiking ten miles into the backcountry without a trail and through thick deadfall was a logistical feat. Gear had to be dropped off with helitack personnel to be flown in, trucks had to be shuttled, bear spray handed out, people checked in, and radios had to be borrowed, programmed, and distributed. Arriving with the additional crew were the two most important people in the group, the camp cooks. Given the number of people involved and the amount of work to be accomplished, camp cooks were a necessity. Thirty people cooking for themselves would have been chaotic, to say the least, and morale was certainly higher when a home cooked meal, complete with dessert, was waiting for everyone back at camp.

The actual treatment portion of the project was conducted over a period of eight to ten days in August 2013 and again in 2014. Due to the size of the project area, it was completed in sections. Each day of treatment required careful planning as to how much rotenone to apply, and where and how to divide the work amongst the available personnel. Rotenone was applied via backpack sprayers, a sand mixture, and drip stations, where the mixture of rotenone and water drips out at a controlled rate. The amounts used for each of these applications are carefully recorded. Among the many challenges presented by a project of this magnitude was successfully collecting data sheets from 30 people at the end of every day!

Braving high temperatures and relentless sun one year, constant cold and rain the next year, and all around grueling days in the field, the multi-agency effort was a success. In April 2015, NPS crews stocked the lower portion of Grayling Creek with over 800 adult westslope cutthroat. In the following month, remote site incubators were set up in the south fork and stocked with 110,000 grayling eggs. The progress of these eggs was carefully monitored on-site by NPS staff for two weeks. By the first week of June, thousands of grayling fry were seen throughout the meadow. Yet to come are more incubators in both the lower and upper portions of the creek where westslope cutthroat eggs will be stocked. Stocking efforts will continue over the next several years. With each returning grayling, the creek will be a little closer to having a viable fluvial population, something that hasn't existed within the park in many years.

Colleen Detjens is a native fish conservation biologist for the Yellowstone Native Fish Conservation program. A Chicago native, Colleen came to Yellowstone in 2011 and hasn't looked back since! Colleen works in cooperation with Montana State University's Institute on Ecosystems.

Intermountain Restoration modified an existing waterfall to form a barrier during 2013.



Final modifications to the existing waterfall during 2014 created a barrier that prevents upstream migration of fish.

Flow time data is collected by putting biodegradable, fluorescent green dye into the water and following it downstream.

Rotenone treatments were applied to Grayling Creek in 2013 and 2014.

The multi-agency crew heads to the North Fork of Grayling Creek with drip stations in hand.

NPS technician Nate Thomas and Fisheries biologist Mike Ruhl monitor a rotenone drip station.

Morning briefings were needed to keep everyone informed of the work ahead.

The meals provided by the camp cooks kept everyone in good spirits.

Equipment was moved in and out of the backcountry via helicopter.

Removing eggs from a female grayling from Axolotl Lake near Ennis, MT, in May 2015.

NPS technicians and interns carefully placed eggs into the incubator located in South Fork, Grayling Creek, May 2015.

Grayling fry successfully made their way from the incubators into Grayling Creek.

Artctic grayling *(Thymallus arcticus)*.- Photo ©Jay Fleming

Water Quality Monitoring

Eighteen long-term monitoring sites were sampled in 2012, while 17 sites were sampled in 2013 (figure 1, appendix a). In 2012 and 2013, ten or eleven stream sites were sampled in January and again during April through October, while seven sites on Yellowstone Lake were sampled during June through October. In addition, discharge was monitored weekly during May through September at two sites on Reese Creek. Core water quality parameters collected during each site visit included 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 three 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 (EPA), and other federal agencies, universities, and private citizens. The water quality sampling effort in Yellowstone during 2012 involved a total of 163 site visits, 291 activities, and 3,406 results. During 2013, effort included a total of 121 site visits, 276 activities, and 2,721 results. Results included field observations, multiprobe measurements, and laboratory analyses. Water quality testing was not conducted in 2014.

Core and Chemical Water Quality Parameters

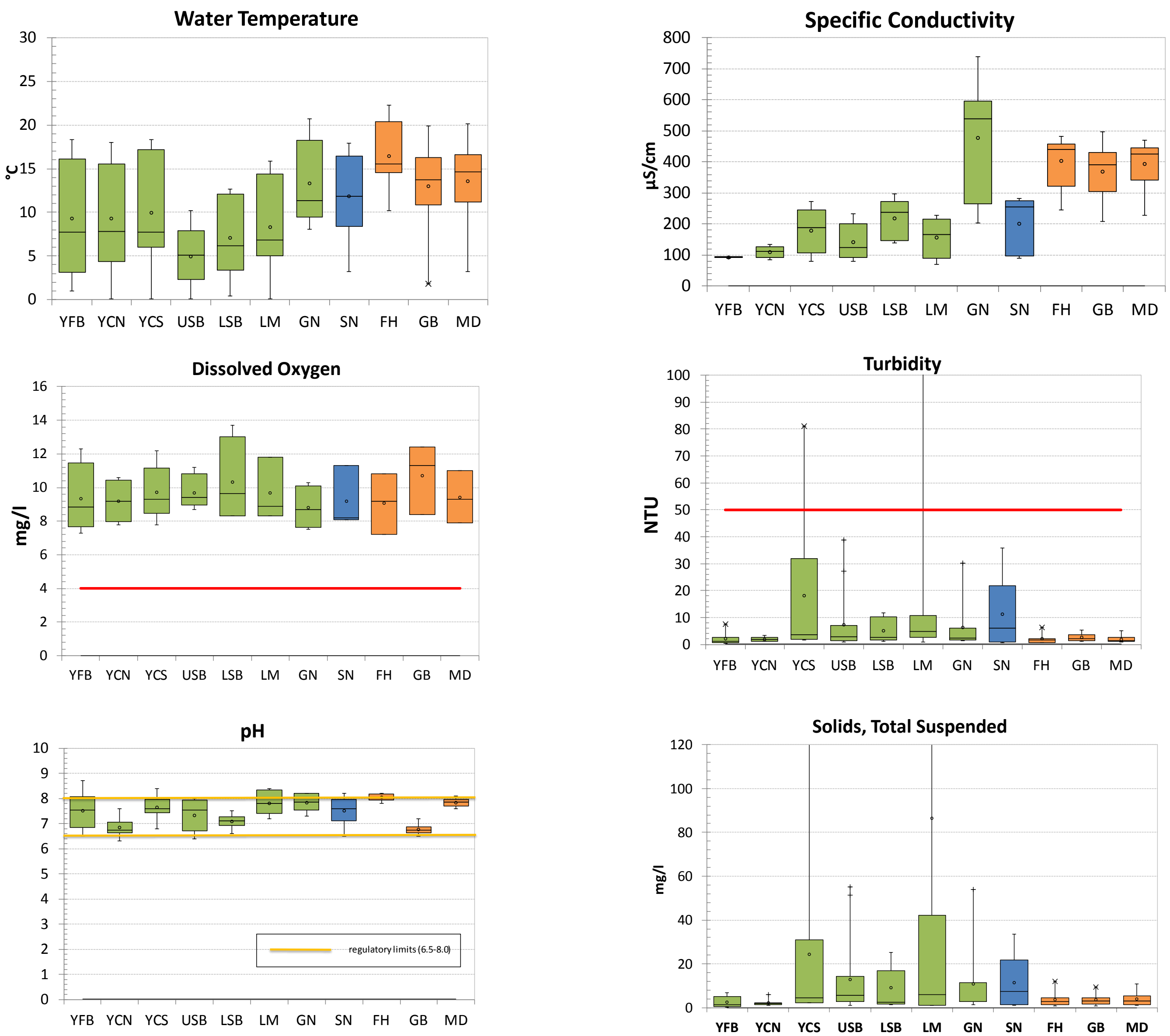
Physical and chemical characteristics of water quality in Yellowstone National Park are related to seasonal changes, elevation, precipitation events, and the presence of thermal features. During 2012 and 2013, spatial trends in core water quality parameters were similar to those observed during 2002-2011 (figures 20 and 21).

During 2006-2010, water samples for chemical analysis (ions and nutrients) were collected at 10 stream sites within the Yellowstone, Snake, and Madison river drainages. In 2011, chemical analysis occurred at only five sites: one in each of three major river drainages (Yellowstone, Snake, and Madison) near the park boundary, one on the Yellowstone River at the Yellowstone Lake outlet, and one on Lamar River near its confluence with the Yellowstone River (figure 1). In 2013, chemical analysis was further reduced to three sites. With the exception of pH at three sites, all monitored sites met or surpassed national and state water quality standards for core and chemical parameters (anions, cations, and nutrients) on all collection days. The Environmental Protection Agency freshwater aquatic life standards for pH are 6.5-9.0 standard units. The three sites which had pH value exceedances were as follows:

- The upper Soda Butte Creek site near the park boundary had a low pH value of 6.4 on May 22, June 5, and July 17, 2012. It also had a low pH value of 5.7 on April 15, 2013.
- The Yellowstone River near Canyon had low pH values on January 16 (5.5), April 17 (6.1), and May 16 (6.3), 2013.
- The Gibbon River had low pH values on January 17 (6.3) and May 15 (6.1), 2013.

There are several thermal features upstream of the Yellowstone River and Gibbon River sites that have acidic runoff and likely contributed to low pH values. Soda Butte Creek near the park boundary is located approximately 8 kilometers downstream of McLaren mine tailings. These tailings were deposited in the stream channel and surrounding floodplain and could have contributed to low pH values observed during the collections.

The calculation of relative concentrations of major anions and cations for each site revealed a pattern among the water quality sites and river drainages for both 2012 and 2013.



Yellowstone River Basin: YFB = at Fishing Bridge, YCN = at Canyon, YCS = at Corwin Springs, USB and ISB = upper and lower Soda Butte Creek, LM = Lamar River, GN = Gardner River

Snake River Basin: SN = Snake River

Madison River Basin: FH = Firehole River, GB = Gibbon River, MD = Madison River

O Mean

— Median

X Near Outliers

\+ Far Outliers

— Regulatory Limits

Figure 20. Box and whisker plots illustrating annual variation for selected parameters at each water quality location in 2012. 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.

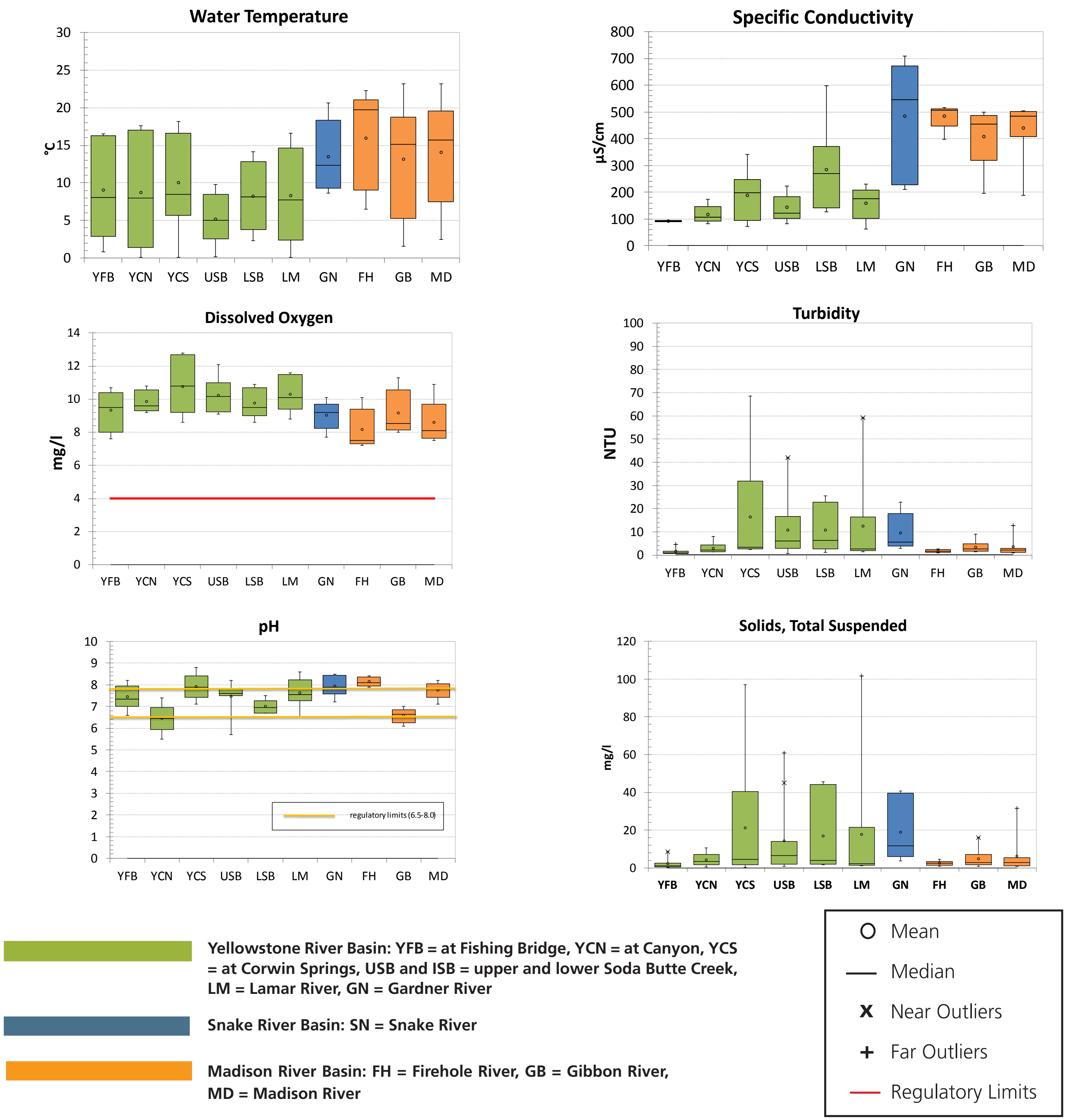


Figure 21 Box and whisker plots illustrating annual variation for selected parameters at each water quality location in 2013. Lower and upper portions of boxes represent the 25th and 75th percentile, respectively; lower and upper black horizontal bars represent 10th and 90th percentile, respectively. Outlying values are represented by "X"; means are indicated by an open circle.

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 site on the Snake River had relatively equal proportions of sulfate, sodium, chloride, and calcium compared to the other ions 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

Segments of Reese Creek, Soda Butte Creek, and the Yellowstone River were monitored because they are listed as 303(d) impaired by the State of Montana, which implies they only partially support aquatic life and coldwater fisheries (figure 1).

Reese Creek – The lowermost reach of Reese Creek (figure 1) is on Montana's 303(d) list because historical irrigation practices often dewater the stream during mid-summer and fall, making it unsuitable for sustaining trout. Because Reese Creek supports resident and migratory (spawning) cutthroat trout from the Yellowstone River, monitoring of discharge during summer is important to conserve these native fish populations and overall biological integrity. To ensure an adequate amount of water remains in lower Reese Creek, the NPS measures stream flows and estimates 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.

In 2012 and 2013, discharge was estimated during 15 site visits at the Reese Creek mainstem immediately above the uppermost diversion structure, and at the channel of the uppermost diversion ditch. 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 Reese Creek is to have a minimum flow of 1.306 cubic feet per second from April 15 to October 15. During 2012, early spring runoff resulted in high peak flows during June, followed by a dry summer with minimal flows through fall. Discharge on Reese Creek ranged from 3.14 to 0.43 cubic feet per second from early July to the end of September (figure 22). In-stream flow decreased below minimum flow requirements for the last eight samples collected during summer and fall. During 2013, stream flows remained relatively stable throughout spring, with discharges ranging from 5.05 to 2.55 cubic feet per second (figure 22). Beginning in mid-July, in-stream flow again fell below minimum flow requirements and remained below required levels until early September.

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. Partner agencies initiated a 3-year effort to relocate mine tailings away from the floodplain in 2011, an activity that posed a risk of heavy metal contamination of the creek. The NPS conducted intensive monitoring and sample collection from June through October, in both 2012 and 2013. Metal concentrations for arsenic, selenium, and zinc were below EPA standards for drinking water and aquatic life. However in 2012, high total copper concentrations (0.0182 milligrams per liter) exceeded acute and chronic aquatic standards during one sample event in May. Dissolved iron concentrations also exceeded drinking water (five sample events) and aquatic life standards (two sample events) between May and July (figure 23). In 2013, total and dissolved concentrations for arsenic, copper, selenium, and zinc were below standards for drinking water and aquatic life. Dissolved iron concentrations exceeded drinking water (six sample events) and aquatic life standards (two sample events) between January and October 2013 (figure 23).

Yellowstone River Upstream of Corwin Springs – This reach 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 in 1999-2001 (Miller et al. 2004). To determine the current level of arsenic in the river, the NPS sampled water in January and again from April through October in both 2012 and 2013. Drinking water standards for arsenic should not exceed 0.01 milligrams per liter. During 2012, total arsenic concentrations ranged from 0.0078 to 0.0348

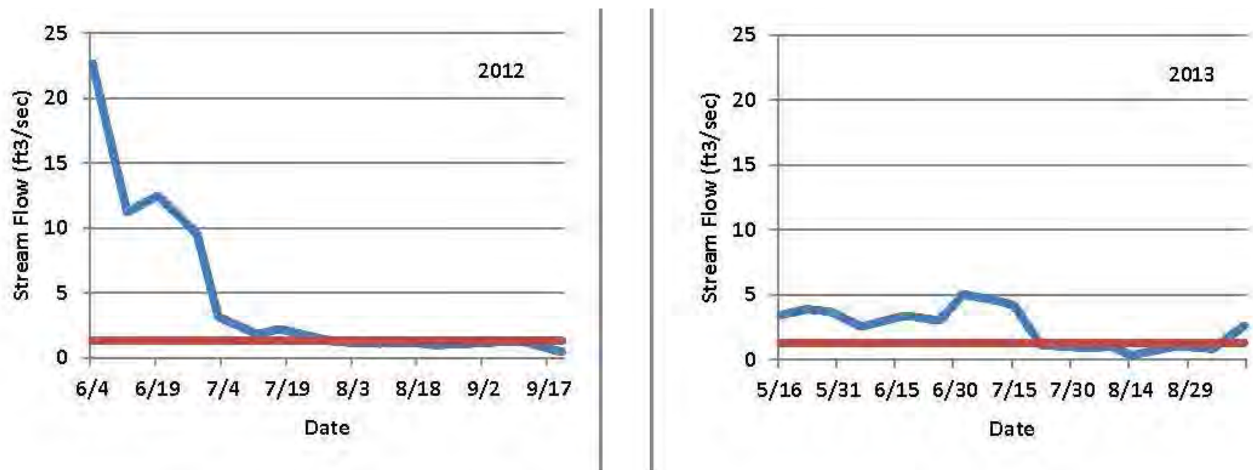


Figure 22. Reese Creek stream flow (blue) compared to a required minimum stream flow (red) for 2012-2013.

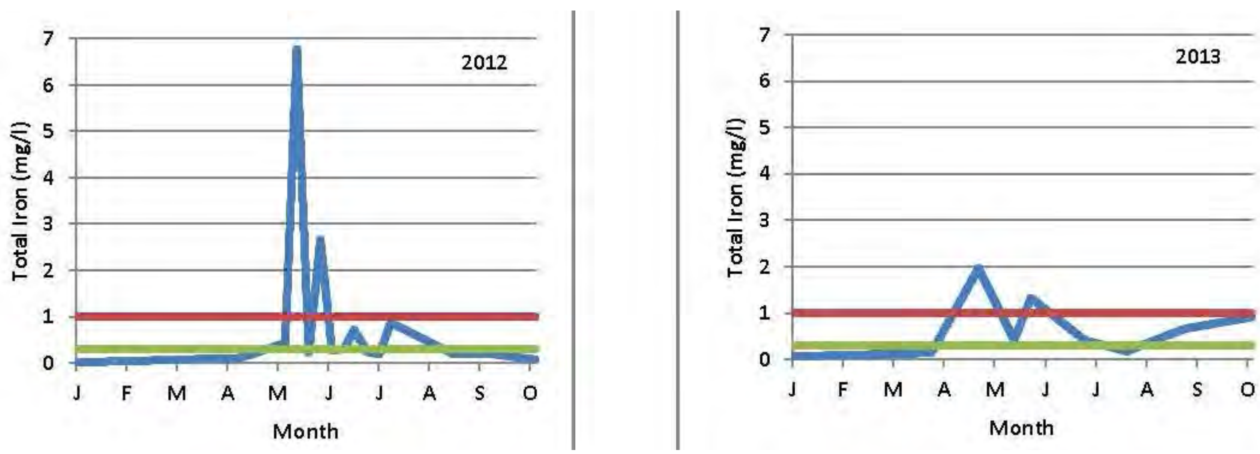


Figure 23. Soda Butte Creek total iron concentrations (blue) compared to EPA drinking water standards (green) and aquatic life criteria (red) for 2012-2013.

milligrams per liter and exceeded drinking water standards during six of eight site visits (figure 24). In 2013, total arsenic concentration ranged from 0.0056 to 0.508 milligrams per liter and exceeded drinking water standards during four of six site visits (figure 24).

Yellowstone Lake Limnology

Understanding 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 in 2012 and 2013 (figure 1). Surface water chemical characteristics were consistent throughout the lake except for the Southeast Arm. The upper Yellowstone River enters the southern tip of the Southeast Arm and delivers sediments from the upper portions 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 fish in Yellowstone Lake. From 2012 to 2014, 23 water temperature loggers were deployed in the West Thumb

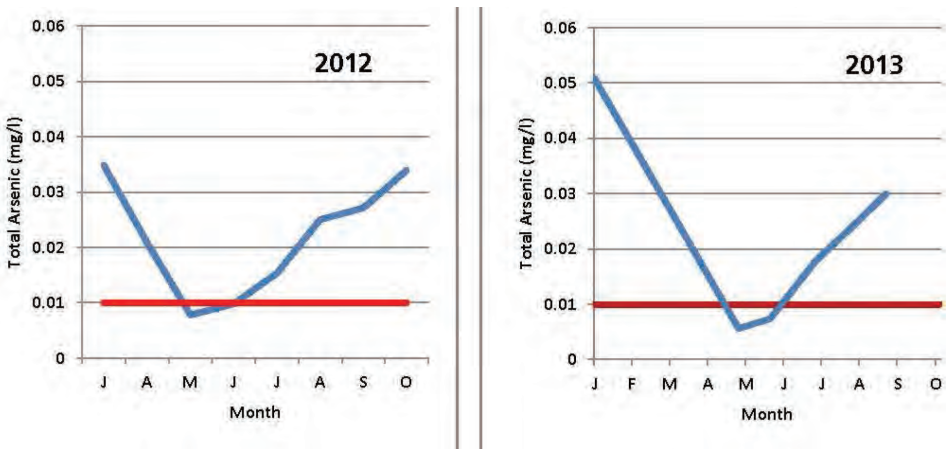


Figure 24. Yellowstone River at Corwin Springs total arsenic concentrations (blue) compared to drinking water standards (red) for 2012-2013.

portion of Yellowstone Lake to document change in water temperature throughout the summer. The depth of these loggers ranged from the surface (0 meters) to the lake bottom (90 meters), with most loggers being deployed at 1-meter intervals between 0 and 20 meters. Surface water temperatures began to warm in early to mid-July each year. The thermocline (area with greatest water temperature change) continued to increase in depth, with highest average surface temperatures (17-18ºC) occurring in August (figure 25). The maximum depth of the warmer surface water extended down 10-12 meters for all three years. In 2012 and 2014, surface water temperatures began to gradually cool in early September, with average temperatures falling below 12ºC by mid-September. By comparison, surface water temperatures in 2013 did not begin to cool until late September, which was followed by an abrupt cooling of water temperatures in early October (figure 25).

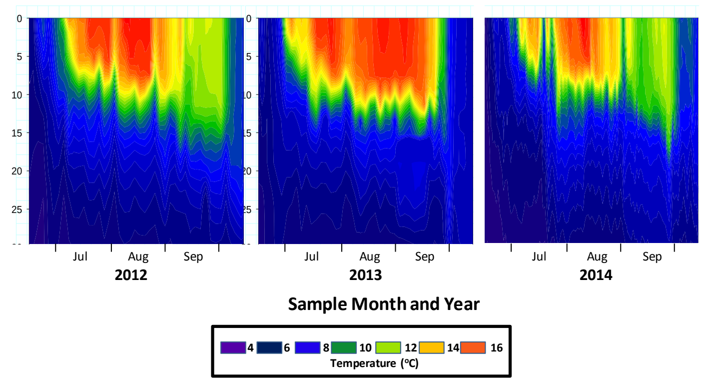


Figure 25. Yellowstone Lake isopleths showing seasonal and annual variation in water temperature throughout the water column, 2012-2014. Only upper 30 meters are shown (y-axis) for better resolution of surface water temperatures.

Health Assessments via Macroinvertebrate Surveys

Macroinvertebrates were sampled at 23 sites in three watersheds during 2012: four in the Shoshone, eight in the Yellowstone, and eleven in the Missouri (figure 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. Macroinvertebrate data will be used to monitor recovery of the tributary.

During 2013, macroinvertebrates were sampled at 11 locations (figure 1). Four sites were sampled within the Yellowstone River watershed and within the Elk Creek drainage. An additional seven sites were sampled within the Missouri River watershed and included one site in the Goose Lake area, two sites on Cougar Creek, and four sites on Grayling Creek.

In 2014, macroinvertebrates were sampled at 24 sites in three watersheds: four in the Shoshone, fifteen in the Yellowstone, and five in the Missouri (figure 1). As in 2012, the four sites in the Shoshone River watershed are being monitored on Middle Creek to evaluate past road construction activities in that portion of the park.

Sampling sites in the Yellowstone and Missouri River watersheds were within current or proposed native fish restoration areas. To assess rotenone's impact on stream invertebrate communities, aquatic invertebrate surveys were conducted before and after rotenone application was used to remove nonnative fish from Elk Creek within the Yellowstone River drainage during 2012-2014 and from Grayling Creek within the Madison River drainage during 2013-2014. All invertebrate samples were sent to an independent contractor for analyses (results pending).

Amphibians in Native Fish Restoration Areas

Wetlands were surveyed for presence of amphibians from 2012 to 2014 in the Elk-Yanceys-Lost Creek complex, as well as a small watershed that encompasses the Goose Lake chain of lakes.

Elk-Yanceys-Lost Creek Complex – Since amphibian sampling in the lower Elk Creek drainage began in 2006, 48 wetlands have been sampled. Twenty of these wetlands (42%) were occupied by amphibians, with one or more life stages (eggs, larvae, and/or adults) present. The three species known to breed in this drainage include: 1) boreal chorus frog (*Pseudacris maculata*), 2) blotched tiger salamander (*Ambystoma tigrinum melanostictum*), and 3) Columbia spotted frog (*Rana luteiventris*). During 2012, 20 sites were sampled that had previous observations of amphibians (figure 26). Breeding populations of blotched tiger salamanders and Columbia spotted frogs were observed at 10 sites (50%), and adults were found at two additional sites (10%). No amphibians were detected at the remaining eight sites (40%), which were dry or contained little water. None of the wetlands used for breeding sites were directly connected to Elk Creek or its tributaries; therefore, they were not treated with piscicides during native fish restoration activities in 2012-2014.

In 2013, fewer breeding populations of blotched tiger salamanders and Columbia spotted frogs were observed at the same 20 sites sampled in 2012. Breeding populations of blotched tiger salamanders were observed at seven of the sites (35%), and Columbia spotted frogs were observed at two sites (10%). Adults of these two species were found at two additional sites (10%). Boreal chorus frogs were found at two sites (10%). Ten sites (50%) were dry, and one site contained little surface water to maintain an environment adequate for amphibian larvae. In 2014, breeding populations of amphibians occurred at 14 of the 20 sites. Breeding populations of blotched tiger salamanders were found at 11 sites (55%), Columbia spotted frogs were found at four sites (20%), and boreal chorus frogs were found at two sites (10%). No amphibians were detected at the remaining six sites (30%).

Goose Lake Chain of Lakes – In 2011, the Goose Lake chain of lakes was treated with rotenone to remove nonnative rainbow trout. At the time of treatment, Goose and Gooseneck lakes contained larval blotched tiger salamanders. After treatment, 157 larval salamanders were found dead along the shoreline. In Yellowstone, larval salamanders may overwinter two or more years before transforming into adults (Koch and Peterson 1995). Juvenile Columbia spotted frogs were found in the small headwater lake and Gooseneck Lake. They all appeared healthy and not affected by the treatment. In July 2012, three lakes were sampled for the presence of amphibians. Larval blotched tiger salamanders were found only in Goose Lake, while Columbia spotted frog tadpoles were found in all three lakes. Previous survey years never revealed a breeding population of Columbia spotted frogs in Goose Lake. Because rainbow trout are known to prey on amphibians, removal of these fish from Goose Lake most likely contributed to the survival and increased abundance of Columbia spotted frogs.

In July 2013 and 2014, the three lakes were sampled again for the presence of amphibians. Larval blotched tiger salamanders were only found in Gooseneck Lake and the small headwater lake, while adult salamanders were only found in Gooseneck Lake (2013). In 2013, adult Columbia spotted frogs were found in Goose and Gooseneck lakes but were not observed in the small headwater lake. In 2014, adult Columbia spotted frogs were observed in all three lakes.

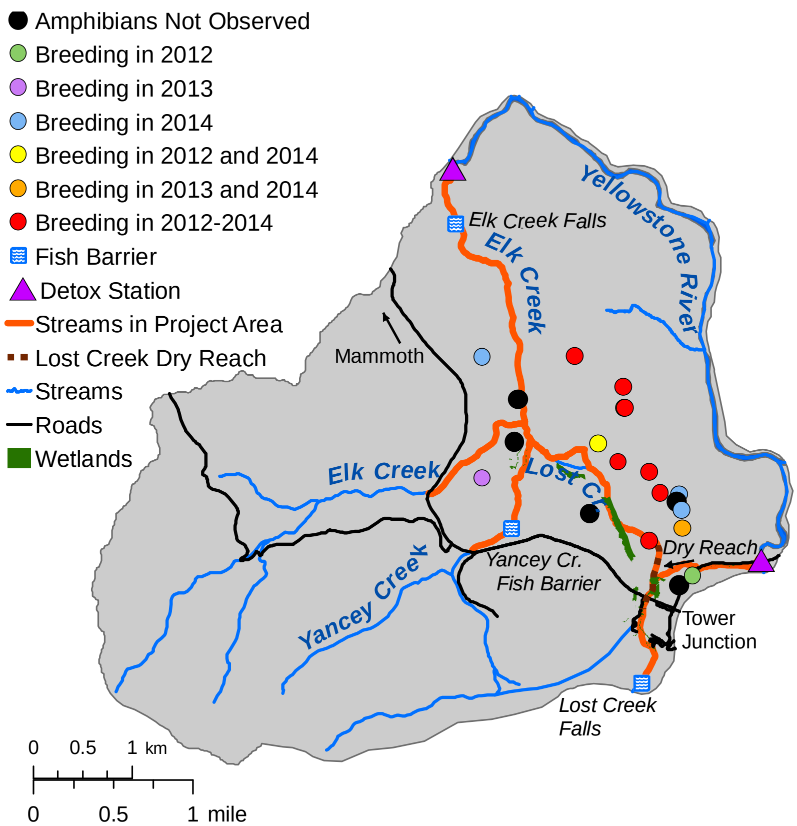


Figure 26. Amphibian monitoring sites in the Elk Creek drainage.

Salmon fly over the Yellowstone River. - NPS Photo

Yellowstone cutthroat trout ready for release. - Photo ©Mike Canetta

Volunteer Angler Report Card Trends

Angling remains a popular pastime for those visiting, living near, or working in Yellowstone National Park. There were 42,870 fishing permits issued in 2012 (3.4 million visitors total); 42,259 permits issued in 2013 (3.2 million visitors total); and 42,831 permits issued in 2014 (3.5 million visitors total). Fishing permits, which are required for fishing in park waters, were accompanied by a volunteer angler report card to provide anglers an opportunity to share their fishing success and opinions with park managers.

The general fishing season in Yellowstone National Park opens on Memorial Day weekend and lasts until early November. In 2014, an estimated 41,435 anglers spent an estimated 169,739 days fishing, caught 399,808 fish, and released 95% of captured fish. The estimated total number of days anglers spent fishing has decreased in recent years. There are similar numbers of anglers each year, but on average each angler is fishing fewer days in the park.

Native fish (cutthroat trout, Arctic grayling, and mountain whitefish) comprised 49% of all fish caught in 2012, 54% of the catch in 2013, and 62% of the catch in 2014. Cutthroat trout have remained the most sought after and caught species, representing 44% of all fish caught in 2012, 49% of the catch in 2013, and 59% of the catch in 2014 (figure 27). Rainbow trout were the second most frequently caught fish

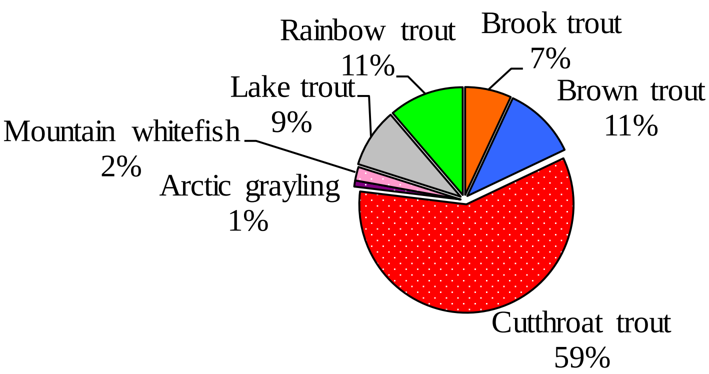


Figure 27. Native cutthroat trout remained the most sought after and caught fish species by anglers in 2013, comprising 59% of all fish caught in the park.

(11-18% of angler catch), followed by brown trout (11-12%), lake trout (8-11%), and brook trout (7-10%).

Anglers reported the lengths of 11,864 fish: 54% were longer than 305 millimeters (12 inches), and 39% were longer than 356 millimeters (14 inches). Lake trout had the greatest average length of 416 millimeters (16 inches) and were the most likely fish to be kept (35%). The release of native fish (cutthroat trout, Arctic grayling, and mountain whitefish) is

Raft eletroshocking along the Madison River. - NPS photo

required by park regulations, and 99.9% of them were reported released.

Anglers reported being satisfied with their overall experience (80%), the numbers of fish caught (65%), and the sizes of fish caught (70%). These satisfaction rates are all slightly higher than rates reported in previous recent years.

Fly Fishing Volunteer Program

Each year during 2012-2014, between 36 and 42 volunteers contributed between 1,443 and 1,785 hours to the park's fisheries program. Volunteer anglers focused on collecting samples for cutthroat trout genetics, including the distribution of pure and hybridized fish in Lamar River, Slough Creek, and Soda Butte Creek. Volunteers also collected samples to evaluate possible genetic factors influencing rainbow trout thermal tolerance in the Firehole River, as well as the concentration of mercury in fish in several lakes. As in past years, the volunteers indicated their experience was positive and they were happy to contribute to Yellowstone fisheries research.

Projects by Graduate Students

During reporting years 2012-2014, the following graduate students assisted the park Fisheries Program with research efforts.

Graduate student: Tonya Chamberlain
(Master of Science candidate)
Committee Chair: Dr. Amy Krist, Department of Zoology & Physiology, University of Wyoming
Title: An investigation of life history shifts in zooplankton in Yellowstone Lake following the introduction of lake trout
Status: Graduated 2013

Graduate student: Kole Stewart
(Master of Science candidate)
Committee Chair: Dr. Thomas McMahon, Department of Ecology, Montana State University
Title: Using otolith microchemistry to distinguish spawning locations of Yellowstone cutthroat trout and lake trout in Yellowstone Lake, Wyoming
Status: Field studies, analyses and writing ongoing

Graduate student: John Syslo
(Doctor of Philosophy)
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: Graduated 2015

Interagency Workgroups

Biologists from Yellowstone National Park 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 and conservation agreement for westslope cutthroat trout and Yellowstone cutthroat trout in Montana, and a memorandum of understanding concerning the recovery of fluvial Arctic grayling.

Yellowstone Lake Workgroup

The Yellowstone Lake Workgroup consists of Trout Unlimited National (Idaho, Montana, and Wyoming Councils), National Parks Conservation Association, Greater Yellowstone Coalition, Yellowstone Park Foundation, and Yellowstone National Park. The groups entered into a memorandum of understanding in 2012 to enhance the cooperative relationship among the participants and to ensure that the Greater Yellowstone Ecosystem is protected, maintained, and managed to achieve the goals established for the park. Among those goals is the conservation and protection of ecosystems that ensure native, coldwater fisheries will persist for the enjoyment of present and future generations. The cooperative activities of this workgroup are currently focused on lake trout sonic telemetry studies and the development of alternative lake trout suppression methods, such as the destruction of lake trout embryos on spawning areas.

Implanting acoustic telemetry tags in lake trout to identify breeding areas. - NPS photo

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- Yellowstone Park Foundation, through the Fisheries Fund Initiative, Fly Fishing Volunteer Program, and Native Fish Conservation Program;
- Recreational Fee Demonstration Program of the Federal Lands Recreation Enhancement Act;
- Natural Resource Preservation Program of the NPS;
- National Fish and Wildlife Foundation;
- Park Roads and Parkways Program of the Federal Highway Administration;
- Greater Yellowstone Network, Vital Signs Monitoring Program of the NPS;
- Greater Yellowstone Coordinating Committee; and
- Trout Unlimited, Greater Yellowstone Coalition, and the National Parks Conservation Association.

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The crew in the field at Grayling Creek. The group was comprised of staff from Yellowstone National Park, Montana Fish, Wildlife & Parks, the U.S. Forest Service, the U.S. Fish & Wildlife Service, Turner Enterprises, Inc., and the amazing camp cooks.

Fish crew - 2012. - NPS photo


Fish crew - 2013. - NPS photo

Fish crew - 2014. - NPS photo

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Wendy Hafer helps deliver supplies into camp with the park helicopter. - NPS photo

Appendix A. Water quality stations sampled in 2012-2013.

Yellowstone River Drainage	YELL_YS616.4M	Yellowstone River at Fishing Bridge
	YELL_YS600.5M	Yellowstone River at Canyon
	YELL_YS549.7M	Yellowstone River at Corwin Springs
	YELL_SB015.7M	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_YL001.OM-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
Snake River Drainage	YELL_SN999.9M**	Snake River at old Flagg Ranch

*stream sites that appear on Montana's 303(d) list

**stream sampled in 2012 only

Yellowstone cutthroat trout sampling. - NPS photo

Appendix B. Seasonal staff in 2012-2014.

Seasonal Staff 2012	Seasonal Staff 2013	Seasonal Staff 2014
Christopher Daly	Benjamin Brogie	Benjamin Brogie
Colleen Detjens	Brent Trim	Cristina Dressel
Earl Drescher	Carla Rothenbuecher	Josh Litvinoff
Jaclyn Schultz	Colleen Detjens	Alex Poole
Jay Fleming	Cynthia Nau	Nathan Roueche
Kole Stewart	Jacob Williams	Kristopher Shultz
Kyle Mosel	Kole Steward	Nathan Thomas
Michael Consolo	Michael Consolo	William Voigt
Nathan Thomas	Michael Polchlopek	Jacob Williams
Tiffany Hutton	Nathan Thomas	
William Holden	Stephen Huffman	
William Voigt	Theresa Campbell	
	William Voigt	

Appendix C. Student Conservation Association (SCA) Interns in 2012-2014.

SCA Staff 2012	SCA Staff 2013	SCA Staff 2014
Alyssa Riggs	Chay Leinweber	Taher Ali
Amanda Guenther	Chelsey Sherwood	Carl Ausprung
Carly Cavutt	Donald Blenkendorf	Trevor Beutel
Cynthia Nau	Eric Raslich	Shannon Boyle
Haley Carlson	Joshua Litvinoff	Lauren Frisbie
Heath Kessi	Kody Kasper	Hayley Glassic
Heather Paddock	Larissa Lee	Drew Mac Donald
Jacob Williams	Levi Garrett	Lauren McGarvey
Nathan McWilliams	Rick Inniello	Andriana Puchany
Regina Thill	Thomas Short	Rachel Voorhorst
	Zebidiah Buck	Justin Walley

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