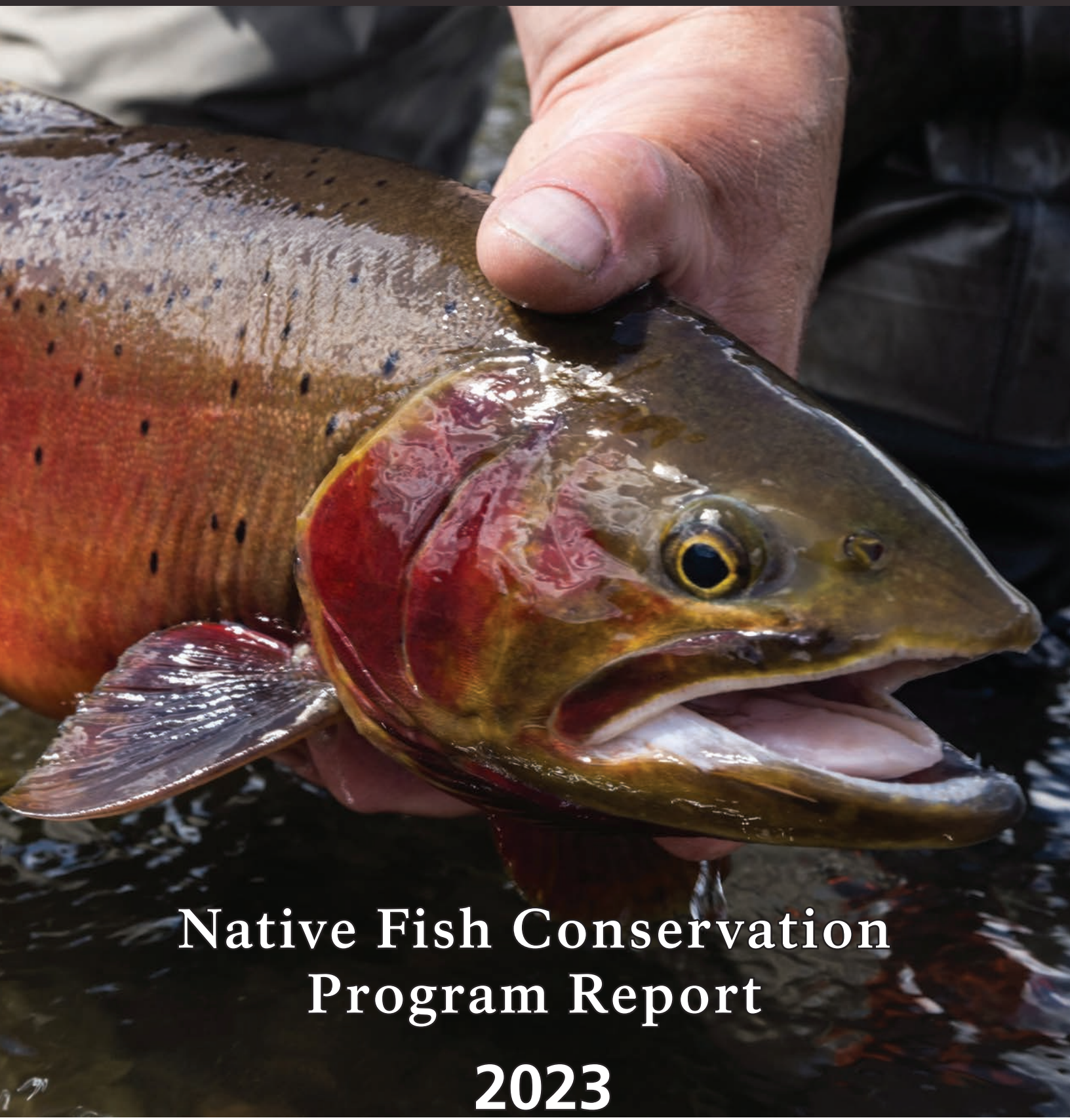
Yellowstone National Park
Native Fish Conservation Program 2023
Wyoming, Montana, Idaho

Yellowstone Center for Resources
National Park Service
Department of the Interior



Native Fish Conservation Program Report

2023

BACKGROUND

Yellowstone National Park supports some of the most pristine aquatic ecosystems in North America. The high plateau upon which Yellowstone lies includes the Continental Divide between drainages of the Pacific and Atlantic oceans. Streams flowing through the park join to become three of America's most important waterways: the Yellowstone, the Missouri and the Snake rivers (Figure 1). At the heart of the park lies Yellowstone Lake. At an altitude of 7,730 feet, surface area of 136 square miles, and depth up to 400 feet, the lake is the largest alpine body of water in North America.

About five percent of the park is covered by water, including more than 220 lakes and 2,650 miles of streams. These waters support 12 species or subspecies of native fish, including popular sport fish such as Arctic grayling, mountain whitefish, westslope cutthroat trout, and Yellowstone cutthroat trout.

Prior to establishment of Yellowstone in 1872, about 40% of park waters were barren of fish because natural waterfalls and watershed divides blocked access following glacial recession. Between 1889 and the mid-1950s more than 300 million fish were stocked by managers to park waters, including waters that supported native fish, leading to extensive establishment of non-native populations. The extent of adverse effects of non-natives were not initially recognized. However, in the decades following these introductions, non-native brook, brown, rainbow, and lake trout had significant detrimental effects on native fish through hybridization, predation, and displacement.

Yellowstone's native fish support natural food webs, contribute significantly to the local economy, and provide unparalleled visitor experiences. As a result, the National Park Service (NPS) has undertaken actions to reverse decreasing trends in native fish populations and associated losses of ecosystem function. A Native Fish Conservation Plan (https://parkplanning.nps.gov/projectHome.cfm?projectID=30504), completed in December 2010, continues to be implemented with the goal of restoring the ecological roles of native species 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 2023. This and previous annual reports are available in electronic format at the Yellowstone National Park website (http://www.nps.gov/yell/planyourvisit/fishreports.htm).

ACTIONS TO RESTORE YELLOWSTONE LAKE

Nonnative predatory lake trout were intentionally stocked by the U.S. Fish Commission in 1890 to historically-fishless Lewis and Shoshone lakes in the upper Snake River drainage of Yellowstone National Park. During the century that followed, lake trout became established in Yellowstone Lake and were

Large live entrapment net lifted by contract crews aboard the Northwester used to capture Yellowstone cutthroat trout and lake trout for population dynamics and movement studies, respectively. (NPS Photo: P. Bigelow)

Front cover photo: Yellowstone cutthroat trout spawning in the headwaters of the Yellowstone River in the Bridger-Teton Wilderness, Wyoming during June 2023. (Photo: C. Guy)

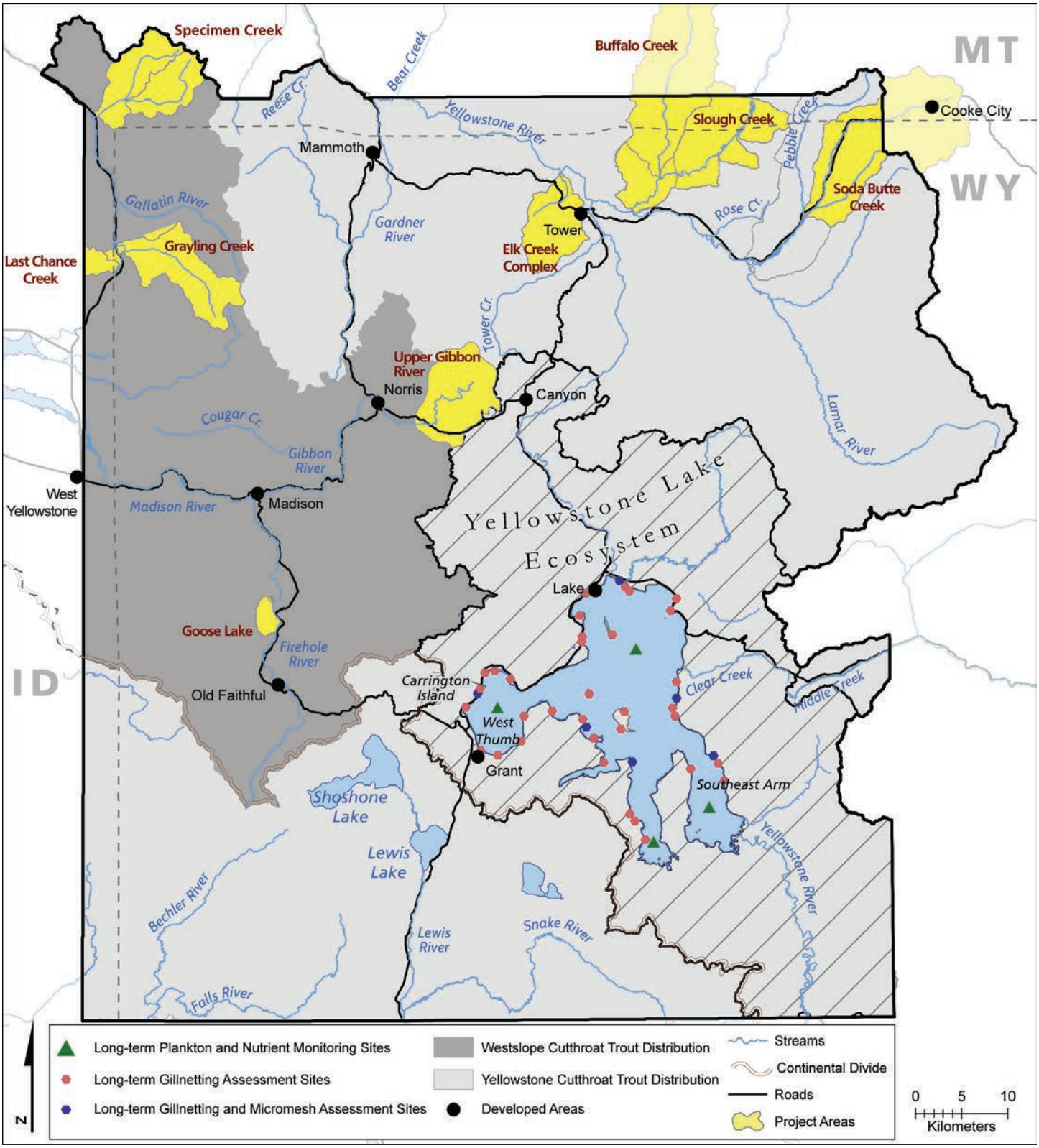


Figure 1. Yellowstone National Park with watersheds supporting native Arctic grayling and westslope cutthroat trout (dark gray, Gallatin and Madison watersheds) and Yellowstone cutthroat trout (light gray, Snake and Yellowstone). Native fish conservation project areas outside of Yellowstone Lake are highlighted in yellow.

first detected there in 1994. Because lake trout pose serious threats to the native cutthroat trout population and the natural ecology of Yellowstone Lake, the population has been suppressed by gillnetting since 1995. Over the past 28 years more than 4.5 million lake trout have been gillnetted resulting in cutthroat trout recovery. Suppression actions to complement gillnetting have also been developed and implemented. These actions include tagging and telemetry of adults to locate movement corridors and congregations of fish, and experimental treatments of spawning sites with organic material to kill embryos and fry during autumn.

Lake Trout Suppression Netting

Yellowstone Lake became ice free to begin gillnetting on May 22, 2023 and gillnetting continued until mid-October. Six specialized boats were used for gillnetting including the contractor-owned boats Kokanee, Patriot, Northwester, and Stuth Bros. and the NPS boats Cutthroat and Freedom (Figure 2). Experienced gillnetting crews processed 82,770 units of gillnet effort in 2023, a 12% reduction from the recent 5-year (2018-2022) average of 94,400 units. Each day during the 2023 gillnetting season, approximately 40 miles of gillnet were fishing for lake trout. Cumulative length of gillnets, totaling more than 5,000 miles, approximately one-fifth the circumference of the earth, were set and lifted from the lake in 2023. Gill nets were distributed across most of the lake during 2023, fishing areas less than 200 feet deep, the depths that have proven to be most productive (Figure 2). Proportionally, effort continued to be focused on the West Thumb, Breeze Channel, and Main Basin regions near Frank Island where catches remain the highest. Although all size classes of lake trout were targeted, slightly more effort continued to be focused on removal of large, adult lake trout. The suppression effort removed 236,853 lake trout in 2023 with an overall (all mesh sizes) catch-per-unit-effort (CPUE; catch per 100 meters of gillnet per night) of 2.6. Of these, 173,853 lake trout were caught in smaller meshes

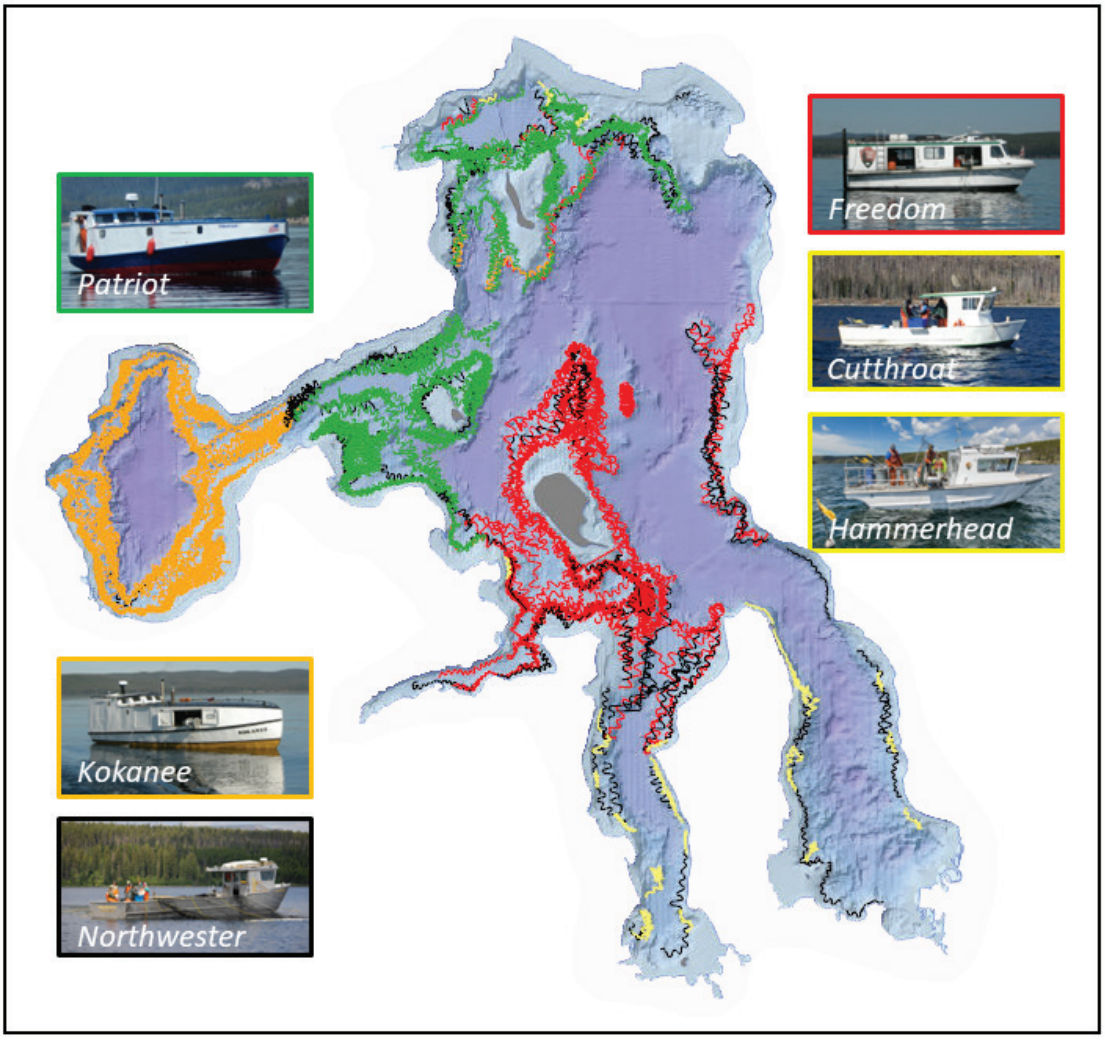


Figure 2. Locations of gillnets set to capture lake trout May – October 2023. Colors represent sets by specific boats throughout the season.

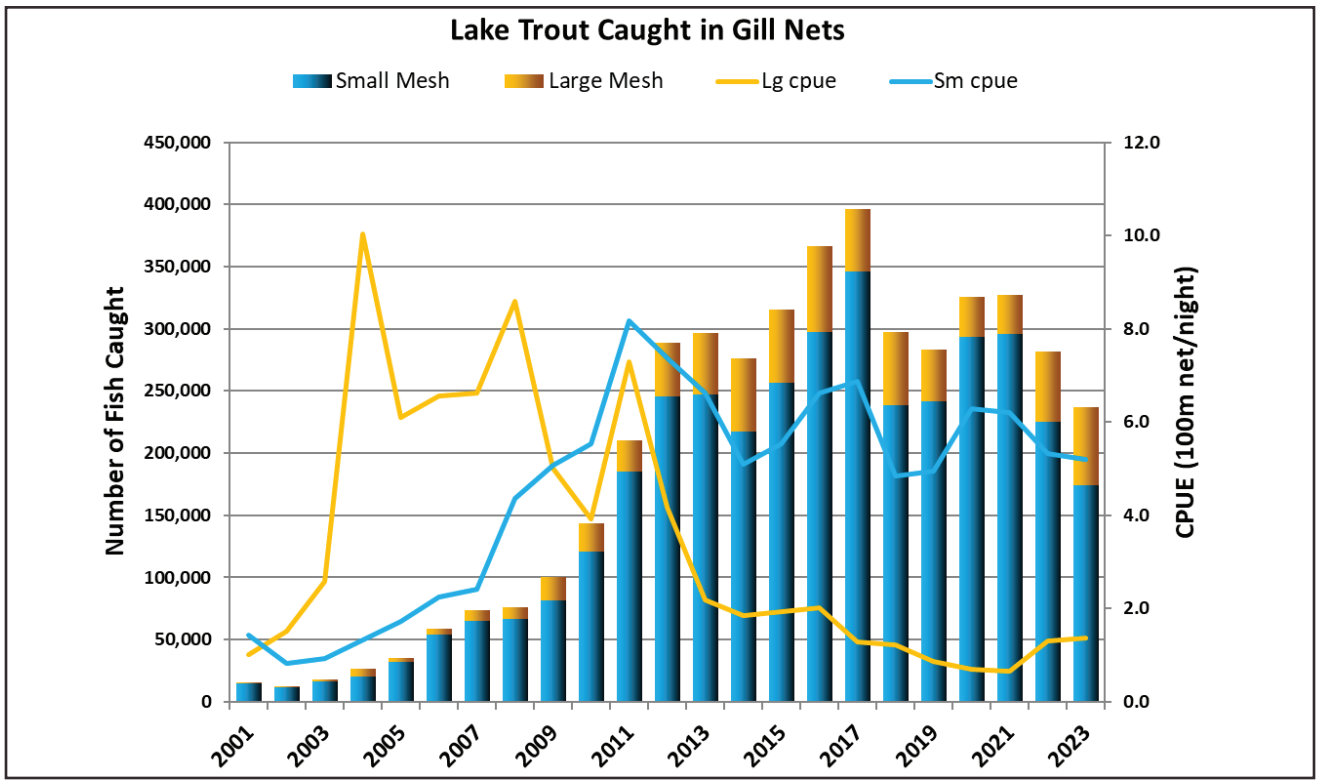


Figure 3. Number of lake trout gillnetted (bars) and catch-per-unit of effort (lines) during 2001-2023. Blue represents the smaller mesh sizes (1 to 1.5-inch bar) which tend to catch juveniles, and gold represents the larger mesh sizes (1.75 to 2.5-inch) which tend to catch adults.

with a catch rate of 4.7, and 63,000 lake trout were caught in the larger meshes with a catch rate of 1.2 (Figure 3). Overall catch decreased 16% from 2022 but catch and catch rate in the larger meshes were the highest we've experienced since 2016 due to two strong year (2017 and 2018) classes growing into those size ranges. Effort will continue focusing on these fish, hopefully curbing their abundance before most reach reproductive ages in the next two years.

Use of large live entrapment nets occurred again in 2023. Nine nets, 20 to 30 ft tall with length up to 1,200 ft, were deployed throughout the lake (Figure 2). Locations were chosen based on optimizing Yellowstone cutthroat and lake trout catch in all major lake basins and suitable bathymetry for net deployment. These nets are designed to target lake trout in the same length range as our large-mesh gill nets and are a timely addition to suppression efforts as numbers of those fish in the population increase. Their ability to live-capture fish in relatively shallow water, where gill nets would not be suitable due to high by-catch, allows capture of both lake and Yellowstone cutthroat trout in those areas. These captures can be released unharmed for research purposes and have provided both lake trout for continued acoustic telemetry studies and Yellowstone cutthroat trout for a mark-recapture study. In 2023, 4,352 lake trout were captured and either tagged and released or removed from the population. Another 7,400 Yellowstone cutthroat trout were captured, with 5,400 tagged and released for the mark-recapture population estimate (see *Yellowstone Cutthroat Trout Population Dynamics, page 10*).

Lake Trout Population Modeling

Total abundance of age-2 and older lake trout were estimated using a statistical catch-at-age model by research collaborators at Michigan State University. Using catch data through 2022, the current estimates were developed in spring 2023. Estimated total abundance of lake trout at the beginning of 2022 was 651,103 (95% CI: 509,239 – 792,960) fish, which was an approximate 9% decrease from the abundance at the beginning of the previous year 2021. Approximately 57% of the 2022 lake trout abundance at the beginning of the year were age-2 (i.e., newly recruiting fish). Abundance of age-3 to age-5 lake trout increased in 2022 due to higher recruitment over the last couple of years, however, the abundance of age-6 and older lake trout continued to decrease (Figure 4). By the end of 2022, total abundance had been reduced to approximately 283,000 fish due to suppression gillnetting and death from natural causes.

The sustained gillnetting efforts have caused an 92% decline in estimated abundance of older (age-6+) lake trout, from a high of about 53,300 in 2012 to a low of only 4,000 in

2022 (Figure 4). As a result, the larger, older lake trout have become more difficult to catch by gillnetters. However, the lake trout population is demonstrating resilience, necessitating continued high levels of gillnetting suppression for at least several more years to ensure the newly recruiting lake trout do not reach maturity and the long-term population decline will continue.

YELLOWSTONE LAKE MONITORING

Gillnetting Assessment of Cutthroat and Lake Trout

Since 2011, cutthroat trout and lake trout in Yellowstone Lake have been monitored annually during August by standardized lake-wide gillnetting at 24 sites located around the lake (Figure 1) to assess the relative abundance and size structure of both species. The assessment gillnets have a range of mesh sizes to capture fish in multiple size classes within three depth strata (shallow, mid-water, and deep). The average lake trout CPUE (all mesh sizes in all three depth strata) during assessment gillnetting in 2023 was 1.83 (1.41 – 2.25; 95% CI) fish/100-m net nights, which continued a long-term decline and was the lowest lake trout CPUE observed between 2011 and 2023 (Figure 5). The highest CPUE was 4.93 (3.46 – 6.41) in 2014. These assessment netting results are an additional promising indication that the suppression gillnetting is reducing the density of this invasive population. Lake trout size structure shifted from being dominated by fish around 250 mm long in 2019 and 2020 to most of the fish ranging in length from 300-400 mm during 2021 to 2023 (Figure 6).

The average number of cutthroat trout caught in 100 meters of net per night (CPUE; small mesh in shallow strata) in 2023 was 27.73 (20.21 – 35.25; 95% CI), continuing a trend of recovery since 2011 when cutthroat trout CPUE was at its lowest (Figure 7). Between 2011 and 2023, the CPUE ranged from 14.64 (8.66 – 20.64; 95% CI) to 44.30 (36.04 – 52.56). Cutthroat trout size structure has stayed relatively constant in recent years with most of the catch greater than 400 mm length (Figure 6).

Prior to 2011, cutthroat trout in Yellowstone Lake were historically monitored each September by standardized lake-wide gillnetting using a range of mesh sizes set only in shallow water at 11 sites located around the lake. The contemporary (described above) and historical data series were combined (1980 – 2023) using a General Additive Model (Figure 7). During the late-1990s and 2000s, when the lake trout population was expanding, cutthroat trout abundance was low. During 2012 – 2023, a period of intensive lake trout suppression and population decline, cutthroat trout CPUE substantially improved to near pre-lake trout levels, surpassing secondary conservation benchmarks (desired conditions) for the assessment gillnetting described in the 2010 Native Fish Conservation Plan. Although making significant improvement, the lake's Yellowstone cutthroat trout population will need

Hickey Brothers Research, LLC contract gillnetting crew aboard the Kokanee with a catch of large lake trout from Yellowstone Lake. (NPS Photo: P. Bigelow)

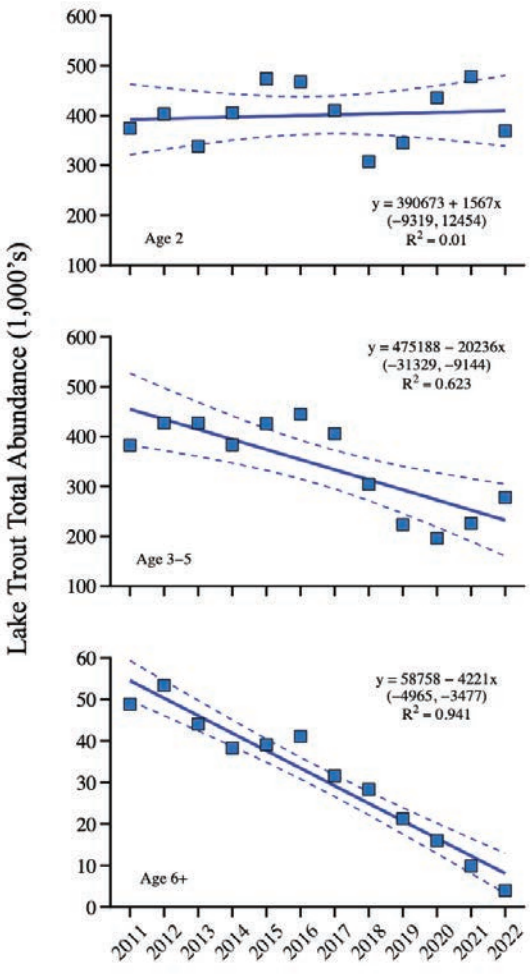


Figure 4. Abundances of age-2, age-3 to age-5, and age-6+ lake trout at the start of the year from 2011 through 2022 estimated using a statistical catch-at-age (SCAA) model. Blue lines represent simple linear regression models with 95% confidence intervals (dashed lines). There has been no decline in age-2 abundance. Although abundance of age 3-5 lake trout have declined significantly since 2011, recent high levels of recruitment have led to an increase in abundance of those fish over the last two years. Age 6+ abundance has continued to decline significantly.

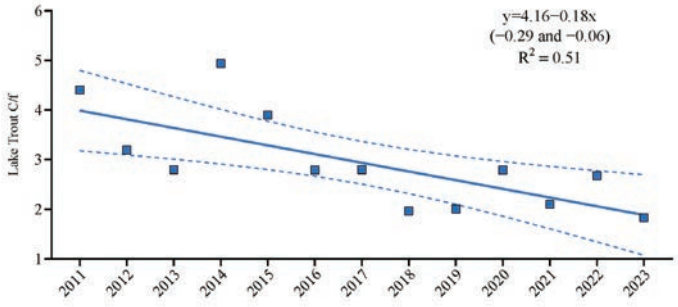


Figure 5. The catch-per-unit-effort (C/f) of lake trout caught in 100 meters of gillnet per night during annual standardized gillnet assessment surveys in Yellowstone Lake has declined, 2011–2023. The blue line represents a simple linear regression model with 95% confidence intervals (dashed lines).

to continue this positive trend in order to reach the plans overarching primary goal of being restored to levels similar to that which occurred during early stages of the lake trout invasion.

Micromesh Gillnetting of Juvenile Cutthroat Trout and Lake Trout

We expanded our annual assessment netting in 2023 by incorporating micro-mesh gillnets with extremely fine twine and small mesh sizes at six sites around Yellowstone Lake in mid-August (Figure 8). Mesh sizes included 6 mm, 12 mm, and 19 mm bar-measure. The primary objective was to assess the efficacy of micro-mesh in capturing lake trout and Yellowstone cutthroat trout across early life stages (age-0, age-1, and age-2). Additionally, we opportunistically collected data on other small-bodied species, including longnose sucker, longnose dace, and redside shiner. Juvenile lake trout occurred below the thermocline at all sites with the highest catch occurring in the West Thumb (Figure 1). Cutthroat trout were predominantly captured above the thermocline, with highest catches at sites in the West Thumb and the north shore of the lake near the Yellowstone River outlet.

Cutthroat Trout Spawning in the Upper Yellowstone River

Concurrent with the lake trout decline was a substantial increase in the number of cutthroat trout spawning in the upper Yellowstone River watershed south of Yellowstone Lake. During backcountry trips in 2019 and 2023, we found large numbers and sizes of cutthroat trout that had migrated from Yellowstone Lake to Atlantic Creek, Thorofare Creek, and many other remote tributaries, highlighting the spatial extent to which the recovery of the cutthroat trout is impacting this ecosystem. Cutthroat trout of Yellowstone Lake migrate 30+ miles into the remote Upper Yellowstone/Thorofare backcountry streams where they spawn and then return to Yellowstone Lake. This happens relatively quickly, with the run starting in early/mid-June and ending by mid/late July. Given that many outfitters and backpacking anglers are again using the area, it appears the fishery may be improving.

YELLOWSTONE LAKE RESEARCH

Lake Trout Acoustic Telemetry

Since 2011, acoustic telemetry has been used to study lake trout movements and use of spawning areas in Yellowstone Lake. This information has been helpful in targeting adult lake trout for removal, especially when adults congregate from mid-August through early October for spawning. During 2023, 264 lake trout were surgically implanted with acoustic transmitters, however, 142 of these were recaptured

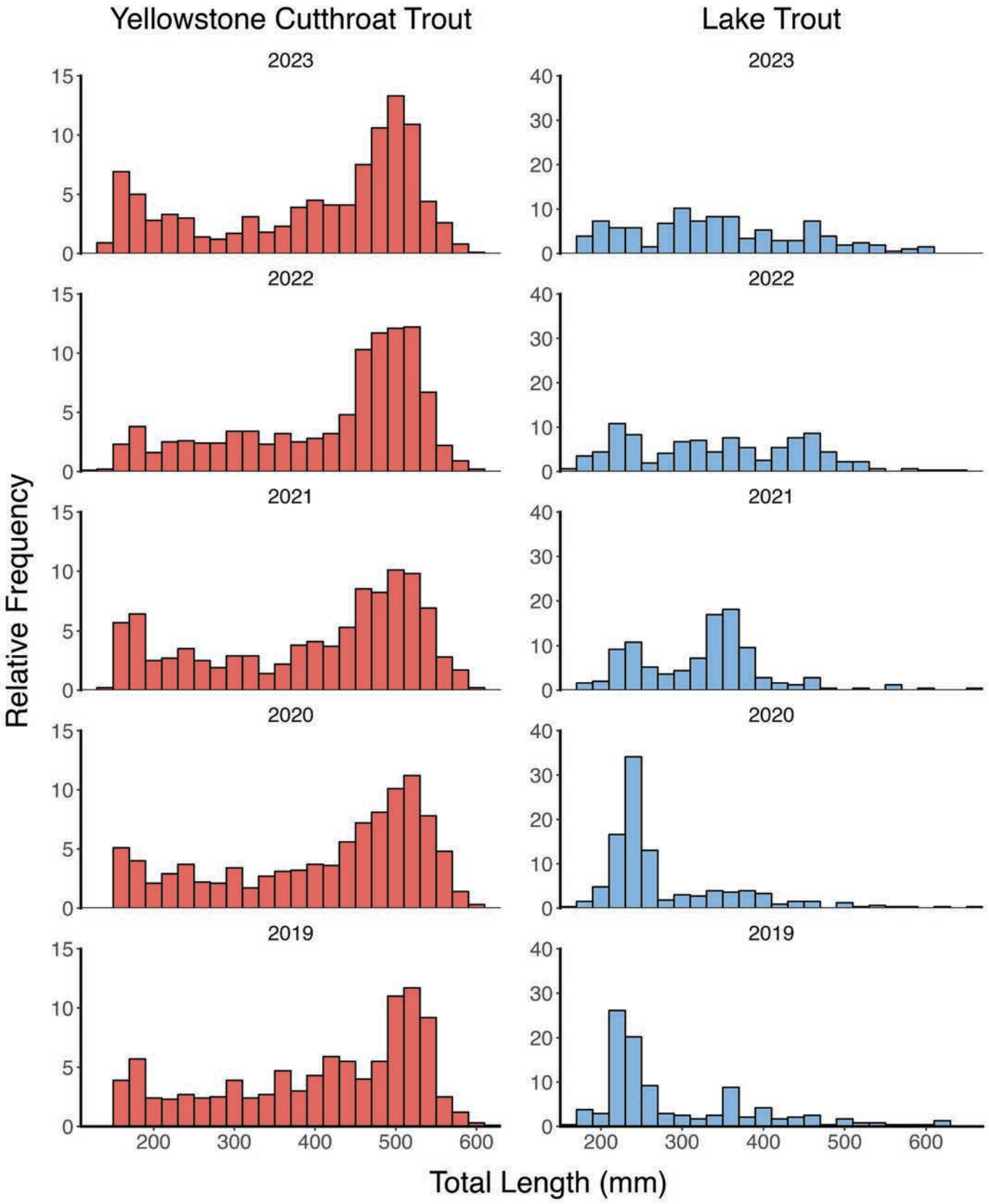


Figure 6. Length frequency plots of cutthroat trout (red; left panel) and lake trout (blue; right panel) caught in the annual standardized gillnet assessment 2019 - 2023.

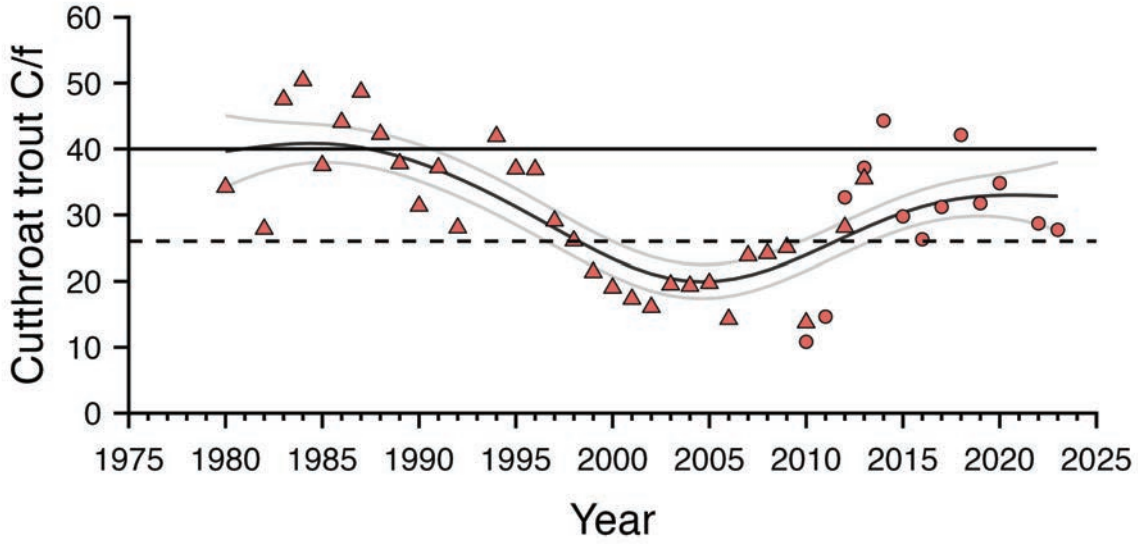


Figure 7. Recovery of Yellowstone cutthroat trout estimated by annual standardized gill-netting assessments on Yellowstone Lake, 1980 – 2023. Horizontal lines represent the primary (solid line) and secondary (dashed) conservation targets (desired conditions) for cutthroat trout following the suppression of invasive lake trout. Data points represent the average catch-per-unit-effort (C/f) of cutthroat trout each year. Triangles represent historical methods, and circles represent contemporary methods. The curved line is a General Additive Model fit to the data points and shading around it represents the error (95% confidence interval) associated with the model. *Special thanks to Dr. Christopher Guy, U.S. Geological Survey, Montana Cooperative Fishery Research Unit, for creating this figure.*

in gill nets throughout the season. In addition, about 100 lake trout with active acoustic tags from previous years remained in the lake of which 51 were removed via gillnetting. Lake trout habitat across Yellowstone Lake was searched 2 to 3 times per month throughout the summer and 2 to 3 times per week during peak spawning activities from mid-September through early October. Tracking of lake trout using boat-mounted hydrophones and an acoustic receiver relocated 232 of these fish in 2023 at least once, and as many as 12 times for a couple of individuals. This information was relayed to gill netting crews the same day it was obtained to more efficiently target fish aggregations for removal. Summaries of telemetry data are used to monitor use of spawning areas and predict where new, previously unknown spawning sites may be located.

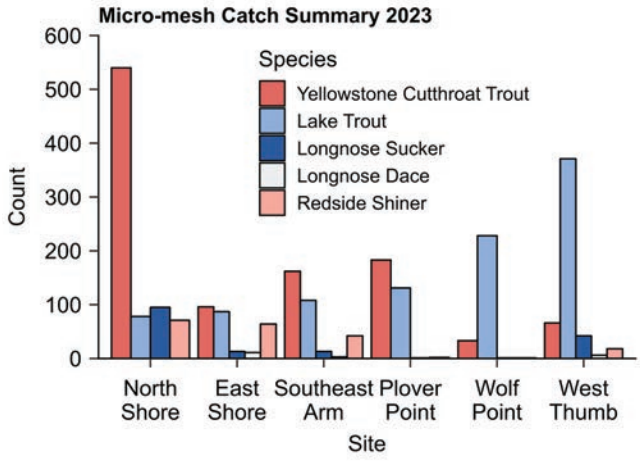


Figure 8. Number of small-bodied fish caught in micromesh gillnets at six sites around Yellowstone Lake in mid-August 2023. Refer to Figure 1 for site locations.

Lake Trout Reproductive Potential

We sought evidence for reproductive compensation following more than a decade of intensified suppression gillnetting and a concurrent decline in adult lake trout. During 2021-2023, gonadal tissue was collected from 262 lake trout (less than 300 to more than 800 millimeters [mm] total length) to determine stages of maturity among seven 100-mm size classes, and to estimate the proportion of the population that spawns annually. Gonadal tissue was also collected from 261 mature females to investigate fecundity. Results of this study will be compared to other reproductive studies conducted prior to the decline in adult lake trout to quantify possible changes in their reproduction potential through time. Results may be used to refine benchmarks for gillnetting effort and long-term goals for lake trout population abundance.

Juvenile Lake Trout Ecology

Stock-recruitment models suggest that survival rates for pre-recruit lake trout (ages 0 and 1) are 4–6 times higher in Yellowstone Lake than in their native range. Lake trout embryos and fry experience minimal predation in Yellowstone Lake, and the ongoing gill-net suppression program typically does not capture these fish until they reach age 2. Statistical catch-at-age models have not indicated a decline in juvenile

Fisheries Biologist Andriana Puchany with a Yellowstone cutthroat trout from the Upper Yellowstone River near Hawks Rest, south of Yellowstone National Park. (NPS Photo: T. Koel)

lake trout abundance under current suppression efforts. To further understand this phenomenon, current research is analyzing 800 otoliths and 1,000 dietary samples from juvenile lake trout. This study focuses on key population metrics in Yellowstone Lake, including hatch dates, distribution, relative abundance, age, growth, and diet shifts. The findings are anticipated to enhance our understanding of the factors influencing lake trout recruitment success and explore potential methods for its reduction.

Yellowstone Cutthroat Trout Population Dynamics

Large trap nets were used in 2022 and 2023 to capture live cutthroat trout (greater than 400 mm) for tagging. Tagged cutthroat trout will allow us to estimate population size and survival. A total of 8,385 cutthroat trout have been tagged. We recorded 456 recaptures in 2022 and 1,065 recaptures in 2023. Recaptures occurred in trap nets (45.3%), gill nets (46.7%), and by recreational angling (8.0%). Gonad samples were collected in 2022 and 2023 to better understand the reproductive ecology of cutthroat trout. Gonad samples are used to estimate fecundity (the number of eggs a spawning female produces), age at maturity, and spawning periodicity (the probability that adult fish will spawn each year). Estimates of population size, survival, and reproductive parameters are vital components for the population model that is being developed for cutthroat trout in Yellowstone Lake. The population model will be used to assess the status of the population, investigate how climate change and lake trout influence the population, and guide future management actions.

Assessment of Yellowstone Cutthroat Trout Genetics

To assess the genetic diversity of cutthroat trout in Yellowstone Lake, genetic samples were collected from cutthroat trout

Student Conservation Association Fisheries Intern Sadie Ainsworth sampling spawning Yellowstone cutthroat trout on the upper Yellowstone River south of Yellowstone National Park in the Bridger-Teton Wilderness, Wyoming. (NPS Photo: T. Koel)

in Yellowstone Lake and from adult and juvenile cutthroat trout in spawning streams throughout the watershed. Genetic samples from Yellowstone Lake will be used to assess the overall genetic diversity of the population and to identify whether genetically distinct sub-populations exist in Yellowstone Lake. Genetic samples from spawning streams will be used to determine whether individual spawning populations are genetically distinct. We have collected 987 genetic samples: 160 from Yellowstone Lake and 827 from 42 tributaries throughout the watershed. All genetics samples have been sent to the University of Wyoming for sequencing.

Cutthroat Trout Individual Growth Pre- and Post-Lake Trout

Since 1953, structures used for age estimation in cutthroat trout, such as scales and otoliths, have been collected, analyzed, and stored in a repository, amounting to over 20,000 specimens spanning 70 years. A subset of these structures, representative of various size classes, is currently undergoing re-analysis using computer imaging software. This process involves measuring the length to each annulus to facilitate annual growth calculations (Figure 9). There is strong

Montana State University Graduate Researcher Michelle Briggs with one of the nearly 10,000 Yellowstone cutthroat trout that have been tagged to estimate abundance and survival in Yellowstone Lake. (NPS Photo: T. Koel)

evidence indicating that the annual growth of cutthroat trout individuals has significantly increased after the lake trout driven decline of the cutthroat trout population. This is believed to have contributed to an increased abundance of large cutthroat trout (>400mm), which now can have weights twice as much as prior to the expansion of the lake trout population. The existing recovery benchmarks outlined in the 2010 native fish conservation plan do not account for these potential shifts in individual growth, therefore this study aims to refine growth estimates, evaluating temporal variations. The results will aid in adjusting cutthroat trout recovery benchmarks to incorporate changes in growth, increased individual weights, and overall biomass.

Nutrient Monitoring and Lake Metabolism

Monitoring nutrients in lakes is a critical tool for assessing and preserving water quality and ecosystem health. Changes in nutrient concentrations can impact various aspects of the ecosystem, including algal biomass, dissolved oxygen concentrations, and other ecosystem processes. In 2023, we began monitoring nutrient concentrations and water quality in Yellowstone Lake at four historic sites (South Arm, Southeast Arm, Southeast of Stevenson Island, and West Thumb) every two to four weeks from early June to mid-October. We collected ammonium, soluble reactive phosphorous, total nitrogen, total phosphorous, and chlorophyll a concentrations (indicator of algal biomass). During each visit, we recorded a temperature profile and several water quality variables such as conductivity, turbidity, dissolved oxygen, and Secchi disk depth. We also constructed data stations that measured dissolved oxygen, temperature, light, wind speed, and wind direction to calculate lake metabolism at these four sites. Lake metabolism quantifies energy transformation and provides insights into the function and health of a lake ecosystem. It measures the flow of photosynthesis and respiration in a lake. Stations were deployed at each site from early June to mid-October 2023. This assessment of nutrient concentrations and lake metabolism will allow us to detect changes influenced by factors such as fish abundance, increased nutrients, changes in climate, and management actions (e.g., carcass or pellet deposition).

NATIVE FISH CONSERVATION IN STREAMS AND SMALL LAKES

Westslope Cutthroat Trout and Arctic Grayling

Several projects have been implemented to expand the ranges of native westslope cutthroat trout and Arctic grayling to contend with a changing climate, warming waters, and nonnative species in the Yellowstone ecosystem. We have established westslope cutthroat trout or Arctic grayling, or both, to 108.2 stream km (67.2 miles) and 113.7 lake hectares (281 acres) in the Gallatin and Madison watersheds in the past two decades (Figure 1). The headwater project areas were created by constructing artificial (log or concrete) barriers, modifying bedrock waterfalls, or using existing falls that were naturally impassible by invasive fish located downstream. Nearly 200,000 westslope cutthroat trout and more than 400,000 Arctic grayling have been stocked across four project areas since 2007 (Table 1).

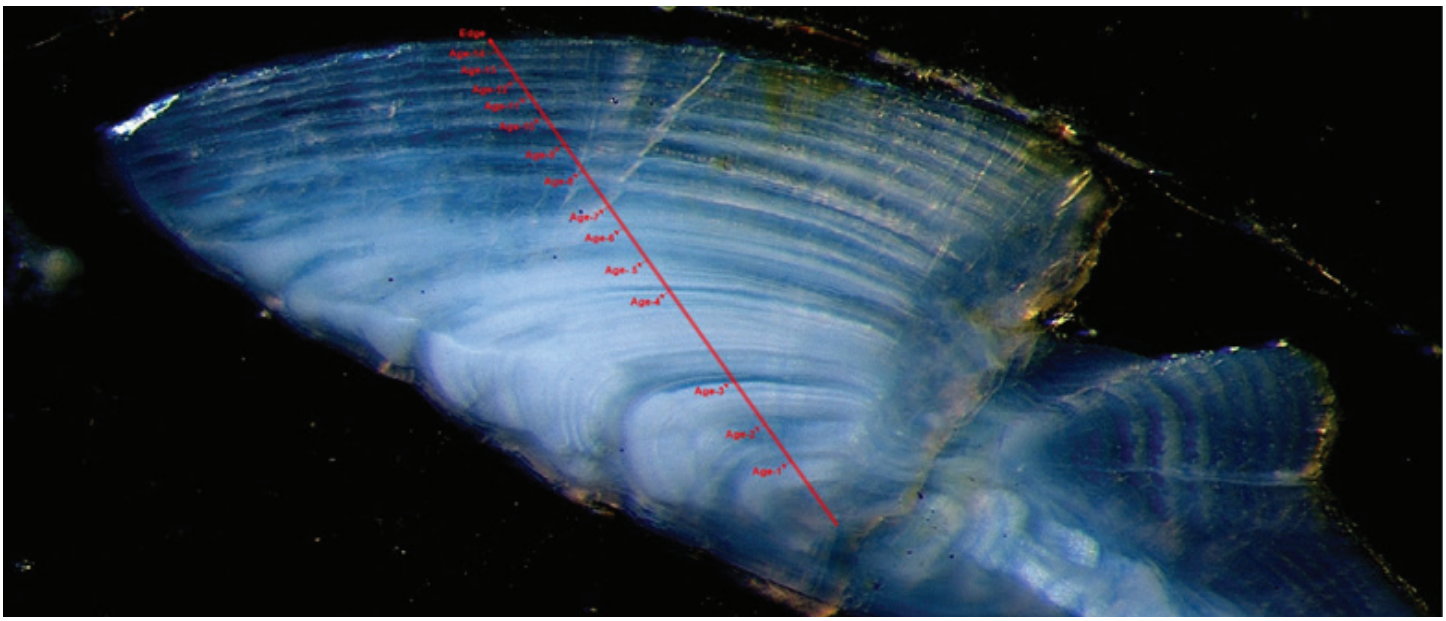


Figure 9. Magnified section of an otolith (ear bone) from a 14-year-old Yellowstone cutthroat trout from Yellowstone Lake with annuli marked in red.

Arctic grayling have become large and abundant in Ice Lake of the upper Gibbon River watershed. (Photo: P. Weamer)

A project recently completed in the upper Gibbon River drainage includes Grebe, Wolf, and Ice lakes, and the Gibbon River upstream of Virginia Cascades. Removals of nonnative fish occurred autumn 2017 - 2020, and more than 100,000 westslope cutthroat trout embryos and fish, and more than 170,000 Arctic grayling fry were stocked during 2017 - 2021 (Table 1); an additional 7,000 grayling fry were stocked in Grebe Lake in 2023. Angling has been highly successful for both species post-stocking, and natural reproduction was first documented for westslope cutthroat trout in 2022 and for Arctic grayling in 2023. Downstream dispersal of both species indicates the upper Gibbon River may serve as a fish source for the lower Gibbon and Madison rivers. Sites were established in 2023 to monitor native fish recovery and fish captured by electrofishing and angling were equipped with orange Floy tags to estimate abundance, survival, and movement patterns. Anglers who recapture tagged fish in Yellowstone are encouraged to report tag numbers and locations to assist with monitoring efforts.

East Fork Specimen Creek (Figure 1) had westslope cutthroat trout stocked during 2007 - 2012 following rotenone treatments to remove nonnative trout (Table 1). Although post-project surveys through 2016 detected only genetically pure westslope cutthroat trout in the restoration area, surveys in 2019 indicated that hybrid trout had reinvaded lower East Fork Specimen Creek—probably by breaching the log barrier that was constructed in 2008. To curtail the invasion, 3.7-miles of lower East Fork Specimen Creek was retreated in 2021 to remove hybridized fish and preserve genetically pure westslope cutthroat trout farther upstream. Although the log barrier withstood a 500-year flood in 2022, a new

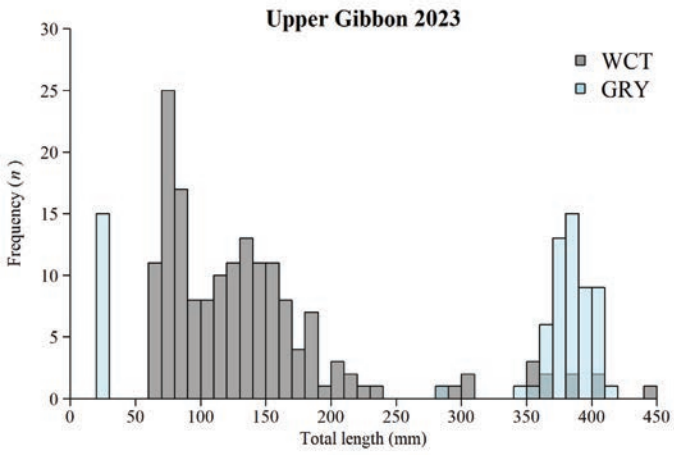


Figure 10. Total length frequencies of westslope cutthroat trout (WCT) and Arctic grayling (GRY) sampled in the upper Gibbon River and Grebe, Wolf, and Ice lakes in 2023 by angling, electrofishing, and visual surveys indicates that natural reproduction of both species has occurred.

Westslope cutthroat trout restored to Grayling Creek. (Photo: S. Farrand)

permanent barrier is needed on the Specimen Creek main stem to protect genetically pure westslope cutthroat trout in upper East Fork Specimen Creek , and to restore westslope cutthroat trout to North Fork Specimen Creek in the future. Population estimates collected on hybridized cutthroat and sculpin in North Fork Specimen Creek in autumn 2023 will provide baseline data for native fish restoration efforts there in the future.

Yellowstone Cutthroat Trout

In addition to Yellowstone Lake and its tributary streams, Yellowstone cutthroat trout are found throughout many of the stream systems in Yellowstone National Park. It is the dominant trout species in the Snake and Yellowstone river drainages, including the Lamar River watershed. These populations range in life histories from large river migrants that travel miles to spawn each year to resident headwater fish that spend their entire life in just several hundred meters of stream. Efforts to preserve and restore these riverine populations have been largely centered in the northeastern portion of the park. The main threat to their persistence continues to be nonnative fish. In 2023, we used a variety of tactics to help protect native Yellowstone cutthroat trout populations to ensure they continue to thrive into the future.

In Soda Butte Creek, the fish toxicant rotenone was deployed in park waters to remove nonnative brook trout that had reinvaded the system following the historic floods of 2022. It is unknown where the brook trout originated, but they needed to be removed prior to spawning in autumn 2023. Yellowstone fisheries crews worked with crews from the United States Forest Service and Montana Fish, Wildlife, and Parks to determine the spatial extent of the invasion, develop an action plan, and ultimately chemically treat Soda Butte Creek from the Yellowstone National Park boundary downstream to Ice Box Falls. Prior to chemical treatment, crews electrofished the stream and collected over 1,000 Yellowstone cutthroat trout and moved them to a holding location outside of the treatment area. Chemical treatment took place on August 16, and the stream was clear of chemical on August 17. At this time, the salvaged Yellowstone cutthroat trout were released back into the waters of Soda Butte Creek. The treatment appears to have been a success as all sentinel fish held in cages through the treated waters died within a few hours of receiving chemical. Continued monitoring of the system via electrofishing and eDNA sampling will take place over the next several years to confirm that all brook trout have been eliminated from Soda Butte Creek.

Monitoring of Yellowstone cutthroat trout populations and mechanical suppression of nonnative rainbow trout continued in the Lamar River and Slough Creeks. Fisheries crews worked in conjunction with the Yellowstone Fly Fishing Volunteer Program to coordinate research and

Table 1. Completed restoration projects for westslope cutthroat trout (WCT), Arctic grayling (GRY), and Yellowstone cutthroat trout (YCT), with restoration area size, years areas were treated with rotenone to remove nonnative or hybridized trout and restocked with native species, and numbers of eyed embryos and fish stocked into restoration areas through 2023.

Restoration area	Size[1]		Treatment years	Species restored	Stocking years	Embryos stocked	Fish stocked
	Stream (km)	Lake (ha)					
Westslope Cutthroat Trout/Arctic Grayling							
East Fork Specimen Creek[2]	13	2.8	2006, 2008-2009, 2021	WCT	2007-2012	WCT: 15,398	WCT: 2,964
Goose and Gooseneck lakes	4.8	17.0	2011	WCT	2013-2014, 2018	--	WCT: 15,000 GRY: 18,049
Grayling Creek	56.3	--	2013-2014	WCT, GRY	2015-2018	WCT: 58,873 GRY: 150,000	WCT: 943 GRY: 60,000
Gibbon River (upper)[3]	34.1	93.9	2017-2020	WCT, GRY	2017-2021, 2023	WCT: 24,190	WCT: 78,000 GRY: 177,200
Yellowstone Cutthroat Trout							
Elk, Lost, and Yancy creeks	9.6	--	2012-2014	YCT	2015-2016, 2018	YCT: 2,000	YCT: 1,170
Soda Butte Creek[4]	24.0	--	2015-2016, 2023	YCT	--	--	--
Total:	141.8	113.7					
WCT/GRY:	108.2	113.7				GRY: 150,000 WCT: 98,461	GRY: 255,249 WCT: 96,907
YCT:	33.6	--				YCT: 2,000	YCT: 1,170

[1]Stream length in kilometers (km) and lake area in hectares (ha)
[2]Includes High Lake
[3]Includes Grebe, Wolf, and Ice lakes
[4]YCT captured and held prior to treatment and released following nonnative brook trout removals

Yellowstone fisheries crew electrofishing upper Soda Butte Creek to capture Yellowstone cutthroat trout and move them to a secure holding area prior to application of rotenone to kill invasive brook trout. The cutthroat were returned to the stream following the treatment. (NPS Photo: J. Frank)

removal of nonnatives from these streams. In the Lamar River, fisheries crews electrofished through the Lamar Valley. In this section of river, a total of 103 Yellowstone cutthroat trout were sampled and 4 rainbow and hybrid trout were removed. The combined efforts of angling and electrofishing removals are maintaining low numbers of hybrid trout in the Lamar River Valley.

Fisheries crews also sampled the upper two meadows of Slough Creek from the north park boundary to the southern end of the second meadow. This was the first survey of this area following the 2022 floods. While Yellowstone cutthroat trout were captured throughout all sample areas, catch numbers were significantly lower than previous years (Figure 11). Prevalence of hybrid trout in the two meadows were 0% and 7% in the Third Meadow and Second Meadow, respectively. The First Meadow was not sampled in 2023 because of equipment transport issues. Lower Slough Creek downstream of the campground was sampled via electrofishing. Although few fish were captured, at least half of them were hybrids. This fact continues to highlight the severe negative impacts of the Buffalo Creek rainbow trout invasion of lower Slough Creek and the lower Lamar River. We are currently working with partners to initiate removal of the Buffalo Creek rainbow trout population.

YELLOWSTONE FLY FISHING VOLUNTEER PROGRAM

The Yellowstone Fly Fishing Volunteer Program utilizes "fly fishing for science" to aid fisheries biologists in their efforts to identify, maintain, enhance, and restore native fish populations within Yellowstone National Park. The program was conceived in 2002 as a way Yellowstone's biologists could acquire information about fish populations without having to travel to distant locations throughout the park and sample them using electrofishing or other sophisticated gear. The program was canceled for five recent years due to a loss of volunteer housing, the covid pandemic, and the 500-year flood, but it was reinstituted with a new coordinator in 2023.

A total of 53 volunteers donated 1,173 hours of their time during 2023 to capture, tag, and record Yellowstone cutthroat trout, invasive rainbow trout, and their hybrids in Slough Creek and the Lamar River as part of pilot study to assess the use of angling as a capture method for long-term fish population monitoring. Nonnative rainbow trout and their hybrids were dispatched during the program to help bolster native fish recovery efforts. The volunteers also sampled Ice Lake in the upper Gibbon River watershed to garner valuable data about its thriving native grayling population. Volunteers

Yellowstone cutthroat trout captured by electrofishing, moved to a safe holding location, and returned to Soda Butte Creek following a rotenone treatment to remove invasive brook trout in August 2023. (NPS Photo: J. Frank)

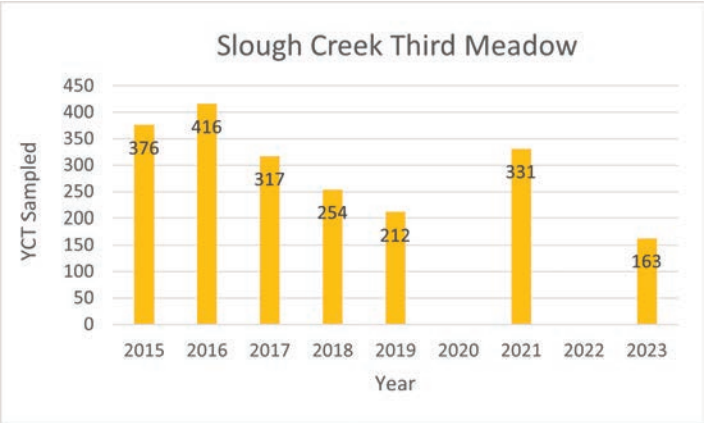


Figure 11. Total number of Yellowstone cutthroat trout (YCT) caught by electrofishing in the third meadow of Slough Creek, 2015-2023. No sampling occurred 2020 or 2022. Abundance of Yellowstone cutthroat trout declined followed the 500-year flood event of 2022.

Yellowstone Fly Fishing Volunteer Program Coordinator Paul Weamer guided anglers to sample and tag numerous cutthroat, rainbow, and hybrid trout in lower Slough Creek and the lower Lamar River in 2023. (Photo by: J. Bergan)

caught and recorded data from about 200 fish in 2023, aiding in the effort to preserve and protect Yellowstone's amazing native fish through fly fishing.

PROJECTS BY GRADUATE STUDENTS 2023

During 2023, the following graduate students assisted the Native Fish Conservation Program with research efforts.

Michelle Briggs (Doctor of Philosophy candidate) Committee chair: Dr. Christopher Guy, USGS Cooperative Fisheries Research Unit, Department of Ecology, Montana State University. Title: Current status of Yellowstone cutthroat trout in Yellowstone Lake and responses to ongoing lake trout invasion. Status: Field work and analyses ongoing.

Drew MacDonald (Master of Science candidate) Committee Chair: Dr. Christopher Guy, USGS Cooperative Fisheries Research Unit, Department of Ecology, Montana State University. Title: Evaluating age 0-2 lake trout densities at confirmed spawning sites in Yellowstone Lake. Status: Field work and analyses ongoing.

Isabella Sadler (Doctor of Philosophy candidate) Committee chair: Dr. Lusha Tronstad, Invertebrate Zoologist, Wyoming Natural Diversity Database, University of Wyoming. Committee co-chair: Dr. Annika Walters, U.S. Geological Survey, Wyoming Cooperative Fish and Wildlife Research Unit, Department of Zoology and Physiology, University of Wyoming Title: Nutrient dynamics related to suppression of invasive lake trout in Yellowstone Lake. Status: Field work and analyses ongoing.

Cody Vender (Master of Science candidate) Committee Chair: Dr. Christopher Guy, USGS Cooperative Fisheries Research Unit, Department of Ecology, Montana State University. Title: Evaluating cutthroat trout individual growth before and after the lake trout invasion of Yellowstone Lake. Status: Field work and analyses ongoing.

Keith Wellstone (Master of Science candidate) Committee Chair: Dr. Alexander Zale, USGS Cooperative Fisheries Research Unit Leader, Department of Ecology, Montana State University. Title: Assessment of sampling methods for monitoring fish populations in the Lamar River watershed. Status: Analyses ongoing.

PUBLICATIONS IN SCIENTIFIC JOURNALS 2023

University of Wyoming Graduate Researcher Isabella Sadler downloading data from a research buoy for analysis of nutrient concentrations and metabolism on Yellowstone and Lewis lakes. (NPS Photo: D. MacDonald)

Glassic, H. C., D. D. Chagaris, C. S. Guy, L. M. Tronstad, D. R. Lujan, M. A. Briggs, L. K. Albertson, T. O. Brenden, T. E. Walsworth, and T. M. Koel. 2023. Yellowstone cutthroat trout recovery in Yellowstone Lake: Complex interactions among invasive species suppression, disease, and climate change. *Fisheries* (*In press*). https://doi.org/10.1002/fsh.10998

Glassic, H. C., C. S. Guy, L. M. Tronstad, M. A. Briggs, L. K. Albertson, D. R. Lujan, and T. M. Koel. 2023. Decomposition rates of suppression-produced fish carcasses in a large, deep, high-elevation lake in North America. *Fishes* 8:385. https://doi.org/10.3390/fishes8080385

Glassic, H. C., C. S. Guy, L. M. Tronstad, D. R. Lujan, M. A. Briggs, L. K. Albertson, and T. M. Koel. 2023. Invasive predator diet plasticity has implications for native fish conservation and invasive species suppression. *PLOS One* 18:e0279099. https://doi.org/10.1371/journal.pone.0279099

Glassic, H. C., J. R. Junker, C. S. Guy, D. R. Lujan, L. M. Tronstad, M. A. Briggs, L. K. Albertson, T. O. Brenden, T. E. Walsworth, and T. M. Koel. 2023. Invasive predator alters energy flux without changing food web functional state or stability. *Functional Ecology* (*In review*).

Koel, T. M., P. D. Doepke, D. J. MacDonald, N. A. Thomas, C. W. Vender, H. C. Glassic, A. S. Poole, C. S. Guy, and A. V. Zale. 2023. Aerial application of organic pellets eliminates Lake Trout recruitment from a primary spawning reef in Yellowstone Lake. *North American Journal of Fisheries Management* 43:505–516. https://doi.org/10.1002/nafm.10872

Tronstad, L. M., D. R. Lujan, M. A. Briggs, L. K. Albertson, H. C. Glassic, C. S. Guy, and T. M. Koel. 2024. Novel technique for suppressing an invasive apex predator minimally alters nitrogen dynamics in Yellowstone Lake, Wyoming, USA. *Hydrobiologia*. https://doi.org/10.1007/s10750-023-05450-w

Poole, A. S., T. M. Koel, A. V. Zale, and M. A. H. Webb. 2023. Rotenone induces mortality of invasive Lake Trout and Rainbow Trout embryos. *Transactions of the American Fisheries Society* 152:3–14. https://doi.org/10.1002/tafs.10394

Stewart, K. P., T. E. McMahon, T. M. Koel, and R. Humston. 2023. Current and historical patterns of recruitment of Yellowstone cutthroat trout in Yellowstone Lake, Wyoming, as revealed by otolith microchemistry. *Hydrobiologia* 851:7-24. https://doi.org/10.1007/s10750-023-05245-z

Treanor, H. B., T. M. Koel, A. R. Puchany, and M. A. H. Webb. 2023. Don't count your eggs before they resorb: Early collection of ovarian follicles inflates fecundity estimates of lake trout in Yellowstone Lake. *North American Journal of Fisheries Management* (*In press*).

Tronstad, L. M., D. L. Preston, K. Cook, A. Holley, P. Farnes, T. M. Koel, and S. Hotaling. 2023. Despite a century of warming, increased snowfall has buffered the ice phenology of North America's largest high-elevation lake against climate change. *Environmental Research Letters* (*In review*).

Back row: Austin Lisowski, Grant Christian, Lauren Mason-Sarantopulos, Brian Ertel, Jonathan Crabill, Ben Kujawa, Matt Shaughnessy, Haley Taylor, Cody Vender, Andi Puchany, Drew MacDonald, Todd Koel

Front row: Amelia Cook, Mia Shipp, Michelle Briggs, Sadie Ainsworth, Rachel Penders, Pat Bigelow, Jax Vernacchia, Sean Adams

Back cover photo: American white pelicans over Yellowstone Lake at sunrise. (NPS Photo: A. Puchany)

For a complete list of our publications, please visit: www.nps.gov/yell/learn/fishreports.htm

Suggested citation: Koel, T.M., P.E. Bigelow, M.A. Briggs, B.D. Ertel, D.J. MacDonald, A.R. Puchany, I.G. Sadler, C.W. Vender, and E.P. Weamer. 2024. Native Fish Conservation Program, Yellowstone National Park, Report for 2023. National Park Service, Yellowstone Center for Resources, Yellowstone National Park, WY, USA, YCR-2024-02.