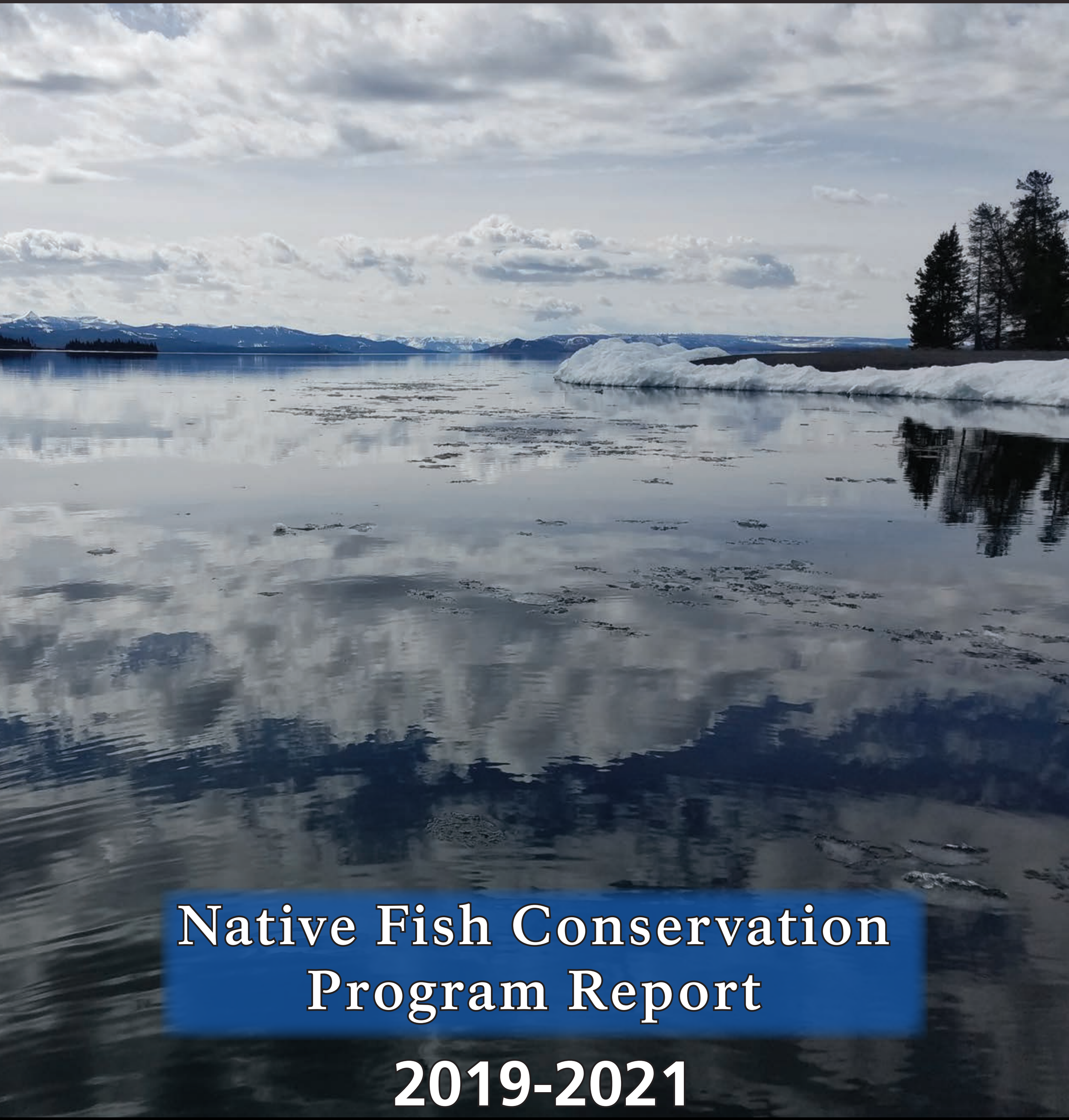
Yellowstone National Park
Native Fish Conservation Program 2019-2021
Wyoming, Montana, Idaho

Yellowstone Center for Resources
National Park Service
Department of the Interior



Native Fish Conservation Program Report

2019-2021

Yellowstone Lake on the opening day of fishing season in 2019. Photo: J. Koel

Background

Yellowstone National Park supports some of the most pristine aquatic ecosystems on Earth. The high plateau upon which Yellowstone lies includes the Continental Divide between drainages of the Pacific and Atlantic oceans. From the park emerge streams that join to become three of America's most important waterways: the Yellowstone River, the Missouri River and the Snake River. At the heart of Yellowstone lies Yellowstone Lake, which at an altitude of 7,730 feet, surface area of 136 square miles and depth of 400 feet, 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 National Park 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-1950's more than 300 million fish were stocked by managers to park waters, including waters that supported native fish. Which led to extensive establishment of non-native populations. Initially, harmful effects of non-natives were not known. 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 (figure 1.)

This report documents the conservation actions, long-term monitoring, and research conducted to conserve Yellowstone's native fish by the NPS and its collaborators during 2019 through 2021. 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

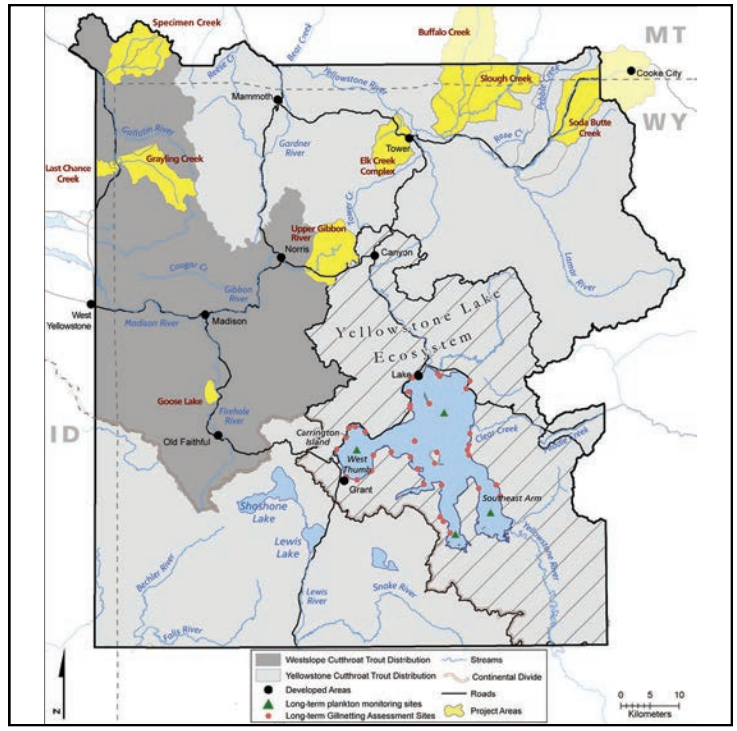


Figure 1. Yellowstone National Park with watersheds supporting native arctic grayling and westslope cutthroat trout (dark gray, Gallatin and Madison watersheds) and Yellowstone cutthroat trout (light gray, Snake and Yellowstone). Native fish conservation project areas outside of Yellowstone Lake are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

Lewis and Shoshone lakes in the upper Snake River drainage of Yellowstone. During the century that followed, lake trout became introduced and invaded Yellowstone Lake and were first detected there in 1994. Because lake trout pose serious threats to the native cutthroat trout population and the natural ecology of Yellowstone Lake, we have suppressed the population by gillnetting since 1995. Over the past 26 years more than four million lake trout have been gillnetted. Suppression actions that 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 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 in mid-May and the gillnetting continued until mid-October during 2019-2021. A total of six specialized boats were used for gillnetting including the contractor-owned boats Kokanee, Patriot, and Northwester and the NPS boats Cutthroat, Freedom, and Hammerhead. Experienced gillnetting crews processed 96,889 units of gillnet effort in 2019, 93,689 units in 2020, and 94,568 in 2021, (an average of 95,049 100-m net nights) surpassing effort benchmarks set by population modeling. Each day during the gillnetting seasons, approximately 40 miles of gillnet were fishing lake trout. Each

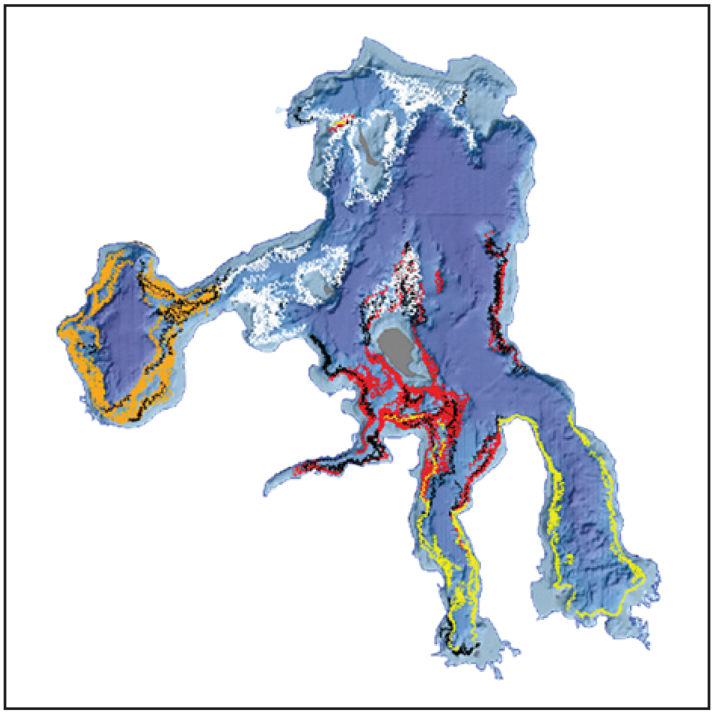


Figure 2. Locations of gillnets set to capture lake trout May – October 2020. Colors represent sets by specific boats throughout the season.

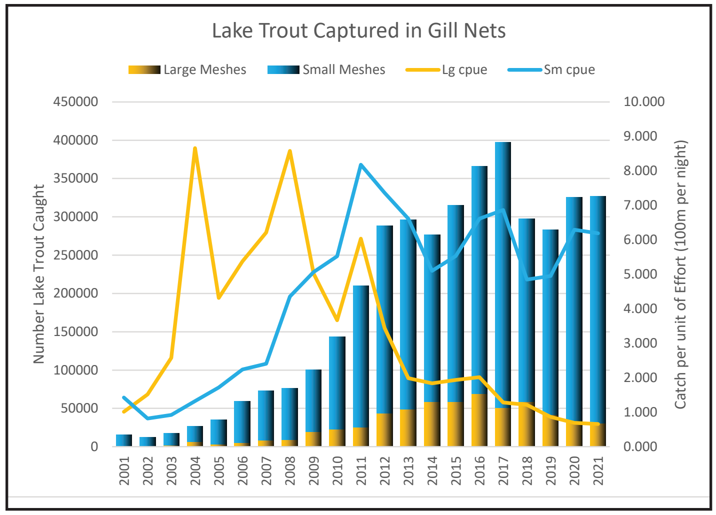


Figure 3. Number of lake trout gillnetted (bars) and catch-per-unit of effort (lines) during 2001-2021. Blue represents the smaller mesh sizes (1 to 1.5-inch bar) which tend to catch juveniles, and gold represents the larger mesh sizes (1.75 to 2.5-inch) which tend to catch adults.

year, gillnets totaling more than 6000 miles in length, nearly 1/4 the circumference of the earth, were set and lifted from the lake.

Gillnets during 2019-2021 were distributed across most of the lake that was < 180 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 (Figure 2). All size classes of lake trout were targeted. The combined total suppression effort removed 282,892 lake trout in 2019 (CPUE = 2.9), 325,943 lake trout in 2020 (CPUE = 3.5), and 326,783 lake trout in 2021 (CPUE = 3.5)(Figure 3). Overall, there were nearly one million lake trout killed during 2019 - 2021.

Lake Trout Population Modeling

Total abundance of age-2 and older lake trout were estimated using a statistical catch-at-age model. Estimates made during 2019-2021 suggest that our sustained gillnetting efforts have caused a > 80% decline in abundance of older (age-6+) lake trout since a peak in 2012 (Figure 4). As a result, the larger, older lake trout have become more difficult to

The spawning habitat around Carrington Island in the West Thumb of Yellowstone Lake was treated with organic pellets in October 2019 and 2020 to kill lake trout embryos and reduce recruitment from the area.

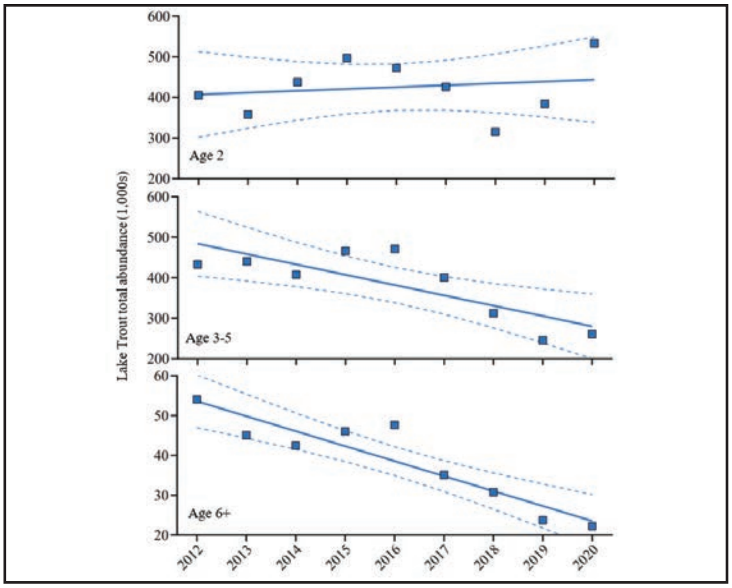


Figure 4. Abundances of age-2, age-3 to age-5, and age-6+ lake trout at the start of the year from 2012 through 2020 estimated using a statistical catch-at-age (SCAA) model. Blue lines represent simple linear regression models with 95% confidence intervals (dashed lines). There was no decline in age-2 abundance. Age-3 to age-5 abundance and age-6+ abundance declined significantly.

catch. Mid-sized lake trout ages 3-5 have also declined during this period, however, recruitment of young age-2 lake trout has been variable among years but remained unchanged despite the reduction in adults. The lake trout population is demonstrating resilience, necessitating continued high levels of gillnetting suppression for at least another 4-5 years to drive the population down to an abundance of < 100,000 fish.

Lake Trout Telemetry

Since 2011, acoustic telemetry has been used to learn more about 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 gather in autumn for spawning. Over the 2019-2021 seasons, 438 lake trout were surgically implanted with acoustic transmitters. Typically, all lake trout habitat was covered 2 to 3 times per week during peak spawning activities mid-September through early October.

Of the 438 tagged lake trout, 3 were recovered by anglers and 213 (49%) were recaptured via gillnetting throughout the netting seasons. Tracking from 2019 through 2021 relocated 429 tagged lake trout, with several relocated 10 or more times. Two fish were relocated 19 times each. Since the battery life for each tag is at least two seasons, some of these fish were tagged prior to 2019. This information is generally relayed to gill netters the same day it is collected to facilitate their ability to target groups of these fish. Summary data at the end of the season is used to suggest putative spawning sites for further investigation.

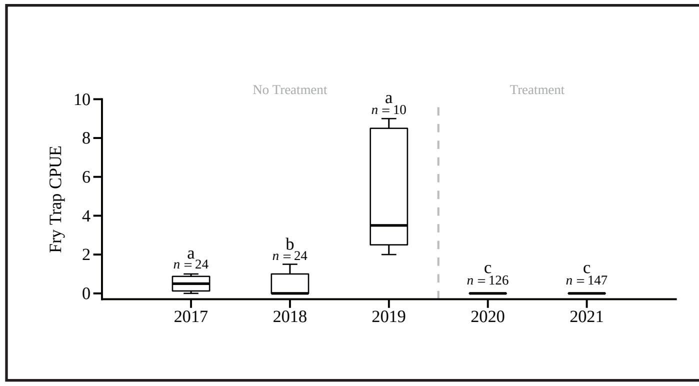


Figure 5. Box plots of the number of lake trout fry captured in traps (blue squares represent individual trap sets) at Carrington Island when no organic pellets were applied (No treatment; 2017-19) and after organic pellets were applied (Treatment; 2020-21). Sample sizes (n =) per year are shown above each box and different letters (a, b, or c) above each box indicate a significant difference in lake trout fry catch rates among years.

Lake Trout Embryo Suppression

Over the last several years suppression methods that cause lake trout embryo mortality have been evaluated with an overall goal of finding methods that could effectively complement gillnetting to suppress the lake trout population. Organic pellets made of soy and wheat gluten placed on spawning substrate after lake trout spawned has been the most effective method. We completed large scale experimental pellet treatments in early October of 2019 and 2020 by treating the entire spawning site at Carrington Island (Figure 1). To evaluate the effect of these full site treatments on embryo mortality, traps that capture lake trout fry were placed on the substrate in the spring when fry hatch. With low effort in the spring of 2017 (24 trap sets), 2018 (24 trap sets), and 2019 (10 trap sets) (prior to any pellet treatments) several lake trout fry were captured at Carrington Island (Figure 5). However, each spring following the treatments, fry trapping at a much greater level of effort in 2020 (126 trap sets) and 2021 (147 trap sets) captured only one fry, even though adult lake trout had returned to spawn each year. These results indicate that organic pellet treatments can cause high mortality of lake trout embryos across Carrington Island or potentially other similar spawning areas on Yellowstone Lake.

Gillnetting Assessment of Cutthroat Trout and Lake Trout

Cutthroat trout and lake trout in Yellowstone Lake are monitored annually by standardized lake-wide gillnetting (Figure 1) to assess the relative abundance and size structure of both species. The average number of cutthroat trout caught in 100 meters of net per night (CPUE) in 2021 was 7.9, continuing a slight increasing trend since 2011 (Figure 6). Cutthroat trout size structure has stayed relatively constant since 2019 with most of the catch > 400 mm length and a noticeable peak in smaller fish around 200 mm (Figure 7). Lake trout CPUE was

Migratory, spawning cutthroat trout from Yellowstone Lake caught from Atlantic Creek, a large tributary of the upper Yellowstone River in the Bridger-Teton Wilderness, Wyoming in July 2019.

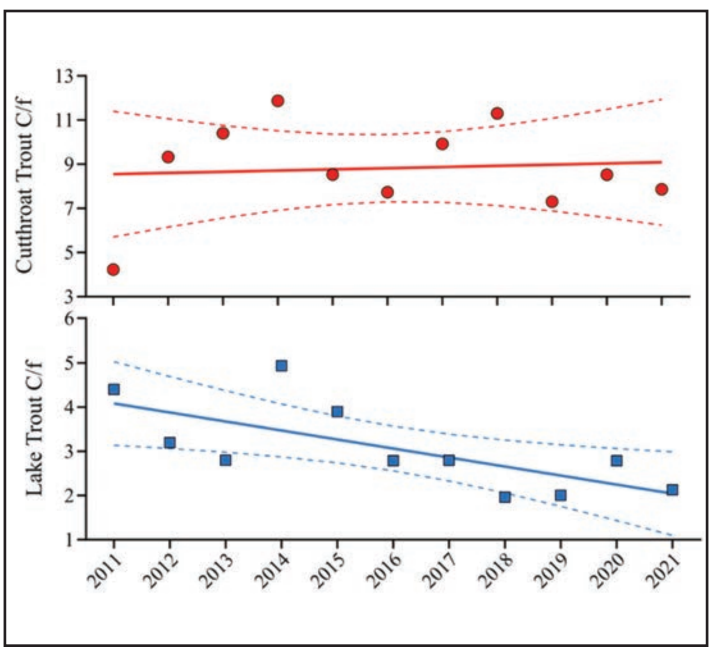


Figure 6. Catch-per-unit-effort (CPUE) of cutthroat trout (top panel; red circles) and lake trout (bottom panel; blue squares) caught in 100 m of gillnet per night during the annual standardized gillnet assessment survey in Yellowstone Lake, 2011–2021. The red and blue lines represent simple linear regression models with 95% confidence intervals (dashed lines).

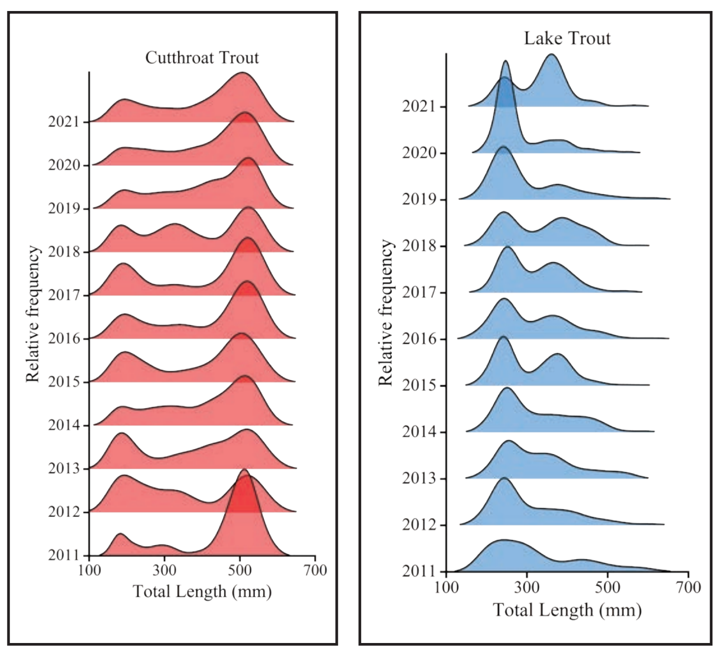


Figure 7. Length frequency plots of cutthroat trout (red; left panel) and lake trout (blue; right panel) caught in the annual standardized gillnet assessment 2011 - 2021.

2.1 in 2021, continuing a long-term decline in this survey since 2011. This is a 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 in 2021 (Figure 7).

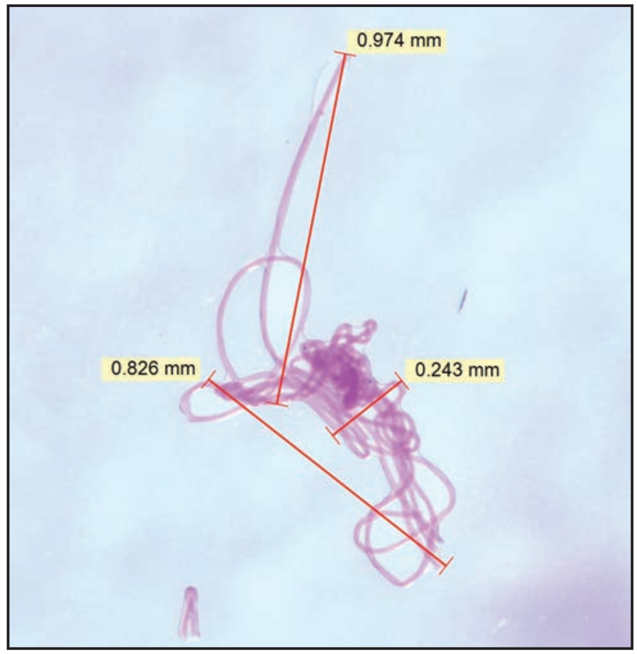
Emerging Threats to Yellowstone Lake

Discovery of Nonnative Cisco

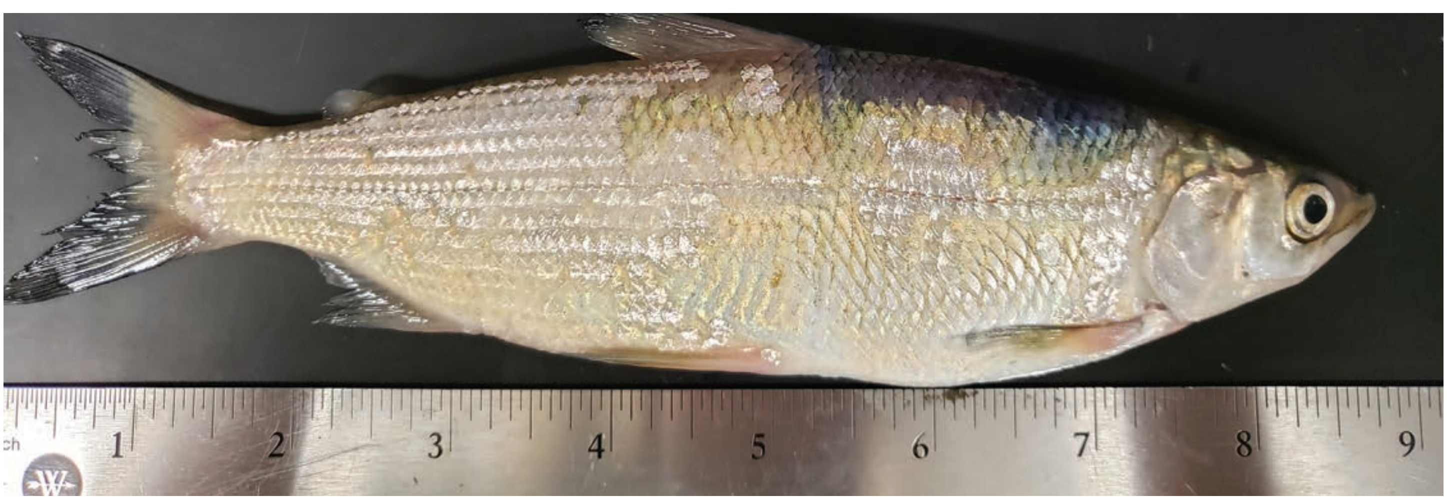
A cisco, which is a member of the Salmonid family of fishes and not native to Yellowstone Lake, was caught during gillnetting operations north of Stevenson Island in August 2019 (Figure 1). The cisco was an age-3 female and otolith microchemistry analysis indicated it was hatched in Yellowstone Lake, meaning that parents and siblings are likely present. Someone illegally introduced cisco because no natural pathway exists for this species to reach Yellowstone Lake. We have implemented monitoring for cisco population expansion using gillnetting, sampling for larvae, and sampling for cisco environmental DNA. Because cisco coevolved with lake trout and are their preferred prey in their native range within the Laurentian Great Lakes, we are also examining the stomachs of lake trout gillnetted from Yellowstone Lake. During 2019-2021 we examined nearly 20,000 stomachs of large lake trout and found no cisco, indicating that abundance within the lake currently is low. If cisco become abundant and expand across Yellowstone Lake, they would compete directly with cutthroat trout for zooplankton and other food resources, while providing additional prey for the invasive lake trout.

Discovery of Microplastics

Microplastics are small (<5 millimeters) colored plastic particles that have been found in aquatic and terrestrial ecosystems throughout the world, including the Arctic, Amazon, and 98% of protected areas (e.g., national parks and wilderness) sampled in the western United States. When conducting ecology studies on Yellowstone Lake in 2020, microplastics were found in lake water samples and in three trophic levels of the aquatic food web, including amphipods, cutthroat trout, and lake trout. The origins of microplastics in Yellowstone Lake are unknown, but they were most likely introduced by atmospheric deposition directly to the lake, or indirectly from the lake watershed via tributary transport of snowpack run-off. At this time, we cannot determine the effect of microplastics on individual organisms or the ecosystem. Total quantities of microplastics in Yellowstone Lake are unknown, so we are currently unable to compare magnitudes with other large-lake ecosystems in North America. Future studies will investigate this. The microplastics found in Yellowstone Lake were the first reported in Yellowstone National Park.



Microplastic particles from the Southeast Arm of Yellowstone Lake in 2020. Photo: S. Driscoll, Department of Ecology, Montana State University.


Nonnative cisco caught in a gillnet in August 2019.

Native Fish Conservation in Streams & Small Lakes

Westslope Cutthroat Trout & Arctic Grayling Restoration

Due to a changing climate and the predicted continued warming of streams and lakes in the Yellowstone ecosystem, we have undertaken several projects to expand the range of native Arctic grayling and westslope cutthroat trout (Figure 1; Table 1). Most recently, a project was completed in the upper Gibbon River drainage above Virginia Cascades, including Grebe, Wolf, and Ice lakes. Nonnative fish removal began in autumn 2016 and continued through 2020. Restocking of Arctic grayling and westslope cutthroat trout began immediately in the upper reaches of the drainage in the lakes and connected streams (Table 2). Angling success for westslope cutthroat trout has been high, and we have documented natural reproduction in tributaries to Grebe Lake.

East Fork Specimen Creek, a tributary of the Gallatin River (Figure 1; Table 1), was originally treated in 2008 to remove nonnative brown trout and hybridized cutthroat trout. Native westslope cutthroat trout were then reintroduced (Table 2). Post-project surveys found only pure westslope cutthroat trout in the restoration area through 2017. However, surveys in 2018 and 2019 found that hybrid cutthroat/rainbow trout invading lower East Fork Specimen Creek by passing a log barrier we had constructed. To curtail this invasion, a 3.7-mile reach of lower East Fork Specimen Creek was retreated with the piscicide rotenone in 2021 to remove the hybridized fish and preserve the westslope cutthroat trout population in the headwaters.

Over the past two decades we have restored 64.2 stream miles and 281 lake acres to native westslope cutthroat trout and/or arctic grayling in the Gallatin and Madison watersheds (Figure 1; Table 1). The headwater restoration areas were created by construction of artificial (log or concrete) barriers, modification of bedrock waterfalls, or use of existing falls that were naturally impassible by invasive fish located downstream. Overall, nearly 200,000 westslope cutthroat trout (eggs and fish) and nearly 400,000 arctic grayling were stocked across four large restoration areas in the park (Table 2).

Yellowstone Cutthroat Trout Preservation in Northern Yellowstone

Yellowstone cutthroat trout is the dominant trout species in Yellowstone's Northern Range. The Yellowstone River downstream of the Lower Falls at Canyon, and the Lamar River, it's largest tributary (Figure 1), support large-river cutthroat trout that make long-distance spawning migrations each year. The system also supports an abundance of genetically-pure, stream-resident cutthroat trout in headwater tributaries, however, introduced nonnative rainbow and brook trout continue to invade and pose a major threat. We have been aggressively suppressing nonnative trout in these drainages by a must-kill angling regulation, electrofishing, construction of barriers, and rotenone treatments. Our focus has been on the Lamar River and Slough Creek where cutthroat trout monitoring and suppression of rainbow and hybridized trout occur annually. During 2019-2021, rainbow and hybrid trout accounted for 6.6% of our annual catch on the Lamar River. On Slough Creek, sampling in the third meadow produced 2.3% and 2.1% rainbow and hybrid trout in 2019 and 2021, respectively. This low prevalence of rainbow and hybrid trout is an indication that our suppression actions are preserving the native cutthroat trout in these streams. Despite this, Buffalo Creek, a large tributary of Slough Creek, has been

Table 1. Completed restoration projects for Arctic grayling (AGR), westslope cutthroat trout (WCT), and Yellowstone cutthroat trout (YCT) with years each area was treated with rotenone to remove nonnative or hybridized trout

Restoration Area	Treatment Years	Species	Stream (miles)	Lake (acres)
East Fork Specimen Creek[1]	2006, 2008-2009, 2021	WCT	8	7
Goose and Gooseneck Lakes	2011	WCT	-	42
Elk, Lost, and Yancy Creeks	2012-2014	YCT	5.9	-
Grayling Creek	2013-2014	WCT and AGR	35	-
Soda Butte Creek	2015-2016	YCT	10	-
Upper Gibbon River[2]	2017-2020	WCT and AGR	21.2	232
Totals			**80.1**	**281**
[1]Includes High Lake				
[2]Includes Grebe, Wolf, and Ice lakes.				

Table 2. Total number of eyed-embryos and native fish, including Arctic grayling (AGR), westslope cutthroat trout (WCT), and Yellowstone cutthroat trout (YCT) introduced into restoration areas through 2021.

Restoration Area	Stocking Years	Embryos	Fish
East Fork Specimen Creek[1]	2007-2012	WCT: 15,398	WCT: 2,964
Goose and Gooseneck Lakes	2012-2018		WCT: 15,000
			AGR: 18,049
Elk, Lost, and Yancy Creeks	2015-2018	YCT: 2,000	YCT: 1,170
Grayling Creek	2015-2018	WCT: 58,873	WCT: 943
		AGR: 150,000	AGR: 60,000
Upper Gibbon River[2]	2017-2021	WCT: 24,190	WCT: 78,000
			AGR: 170,200
Totals		YCT: 2,000	YCT: 1,170
		WCT: 98,761	WCT: 96,907
		AGR: 150,000	AGR: 248,249
[1]Includes High Lake			
[2]Includes Grebe, Wolf, and Ice lakes.			

identified as the ultimate source of rainbow trout invading the Lamar River watershed. Future actions by the park and cooperating agency partners will mitigate for this rainbow trout threat.

Volunteer Angler Report Card Trends

Angling remains a popular pastime for those visiting, living near, or working in Yellowstone National Park. There was an average of 44,680 (44,070-45,290) special use fishing permits issued to the four million visitors each year from 2019 to 2020. With this permit, anglers also receive a volunteer angler report card. This card is an opportunity for anglers to share their catch information, observations made, and opinions with park managers. During 2019 and 2020, an average of 43,200 anglers caught 362,500 fish and kept 16,500, releasing 95% of fish caught. Anglers spent an average total of 158,800 days fishing each year. Anglers caught native cutthroat trout more often than other fish species. Native fish (cutthroat trout, arctic grayling, and mountain whitefish) comprised 61% of all fish caught parkwide (Figure 8). Cutthroat trout comprised 57% of the angler catch. Rainbow trout were the second most frequently caught fish at 13%, followed by brown trout 12%, lake trout 8%, and brook trout 5%.

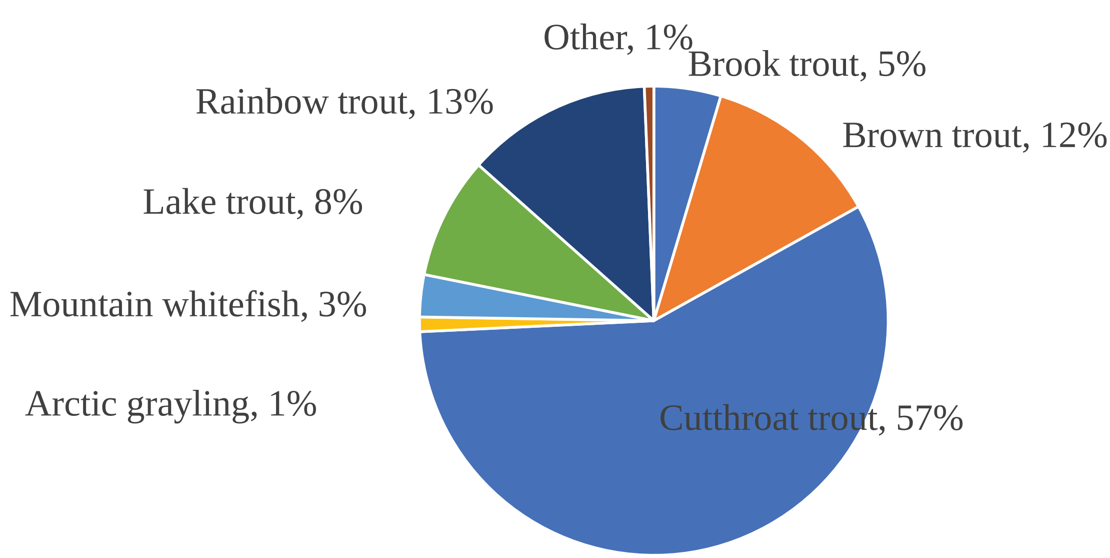


Figure 8. Relative proportions of fish species caught by anglers parkwide. Native fish, including arctic grayling, cutthroat trout, and mountain whitefish comprised 61% of all fish caught.

Yellowstone stream fish restoration crew collecting gametes from westslope cutthroat trout for stocking to streams around Grebe and Wolf lakes in the upper Gibbon River.

Hickey Brothers Research, LLC contract gillnetting crews removing invasive lake trout from Yellowstone Lake.

PROJECTS BY GRADUATE STUDENTS

During 2019-2021, the following graduate students assisted the Native Fish Conservation Program with research efforts.

Michelle Briggs (Master of Science) Committee chair: Dr. Lindsey Albertson, Department of Ecology, Montana State University. Title: Non-target effects of a novel invasive species management strategy: Benthic invertebrate responses to lake trout embryo suppression in Yellowstone Lake, Wyoming. Status: Graduated 2020

Michelle Briggs (Doctor of Philosophy candidate) Committee chair: Dr. Chris 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.

Colleen Detjens (Master of Science) Committee Chair: Dr. Alexander Zale, USGS Cooperative Fisheries Research Unit Leader, Department of Ecology, Montana State University. Title: Use of eDNA to estimate abundances of spawning Yellowstone cutthroat trout in Yellowstone National Park, Wyoming, USA. Status: Graduated 2020

Hayley Glassic (Doctor of Philosophy) Committee chair: Dr. Chris Guy, USGS Cooperative Fisheries Research Unit, Department of Ecology, Montana State University. Title: Assessment of the Yellowstone Lake food web during lake trout suppression and Yellowstone cutthroat trout recovery reveals alternative conservation benchmarks. Status: Graduated 2022.

Kurt Heim (Doctor of Philosophy) Committee Chair: Dr. Thomas McMahon, Department of Ecology, Montana State University. Title: Mechanisms of rainbow trout hybridization with native cutthroat trout in the Lamar River of Yellowstone National Park. Status: Graduated 2019

Dominique Lujan (Master of Science) Committee chair: Dr. Lusha Tronstad, Invertebrate Zoologist, Wyoming Natural Diversity Database, University of Wyoming. Title: Effects of lake trout suppression methods on lower trophic levels in Yellowstone Lake, Wyoming. Status: Graduated 2020

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

Andriana Puchancy (Master of Science) Committee Chair: Dr. Alexander Zale, USGS Cooperative Fisheries Research Unit Leader, Department of Ecology, Montana State University. Title: Success of westslope cutthroat trout and arctic grayling conservation translocations in Yellowstone National Park, Montana and Wyoming, USA. Status: Graduated 2021

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: Field work and analyses ongoing

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(BACK COVER) Yellowstone cutthroat trout caught from Yellowstone Lake near Gull Point on the opening day of the fishing season, 2019. Photo: J. Koel

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*All photos are NPS unless noted.