Preservation of Yellowstone Lake Cutthroat Trout

Yellowstone Cutthroat Trout Long-term Monitoring

In streams throughout the park and elsewhere in the Yellowstone cutthroat trout's natural range, populations have been compromised by introgression with non-native rainbow trout or other cutthroat trout subspecies (Kruse et al. 2000; Behnke 2002). The cutthroat trout of Yellowstone Lake and its associated drainage have remained genetically pure primarily because of isolation provided by the Lower and Upper Falls of the Yellowstone River, located 25 km downstream from the lake. In addition, purity has been maintained because of the fortuitous failure of early attempts to introduce several non-native species (Varley 1981). The genetic purity of these Yellowstone Lake cutthroat trout makes them extremely valuable; however, the population has been exposed to three stressors, including non-native lake trout (Kaeding et al. 1996), the exotic parasite *Myxobolus cerebralis* (the cause of whirling disease; Koel et al. 2006*a*), and the effects of a continued drought across the Intermountain West.

The presence of lake trout in Yellowstone National Park is the result of the intentional stocking of the historically fishless Lewis and Shoshone lakes in 1890 (Varley 1981). In the mid-1980s, lake trout were moved illegally from Lewis Lake to Yellowstone Lake (Munroe et al. 2005; Stott 2004) where, as top-level predators, they consume native cutthroat trout. The park places a high priority on preservation and recovery of this cutthroat trout population because of its importance in maintaining the integrity of the Greater Yellowstone Ecosystem, arguably the most intact, naturally functioning ecosystem remaining in the continental United States. Grizzly bears (*Ursus arctos*), bald eagles (*Haleaeetus leucocephalus*), and many other avian and terrestrial species use cutthroat trout as an energy source, especially in the Yellowstone Lake area (Schullery and Varley 1995).

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

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

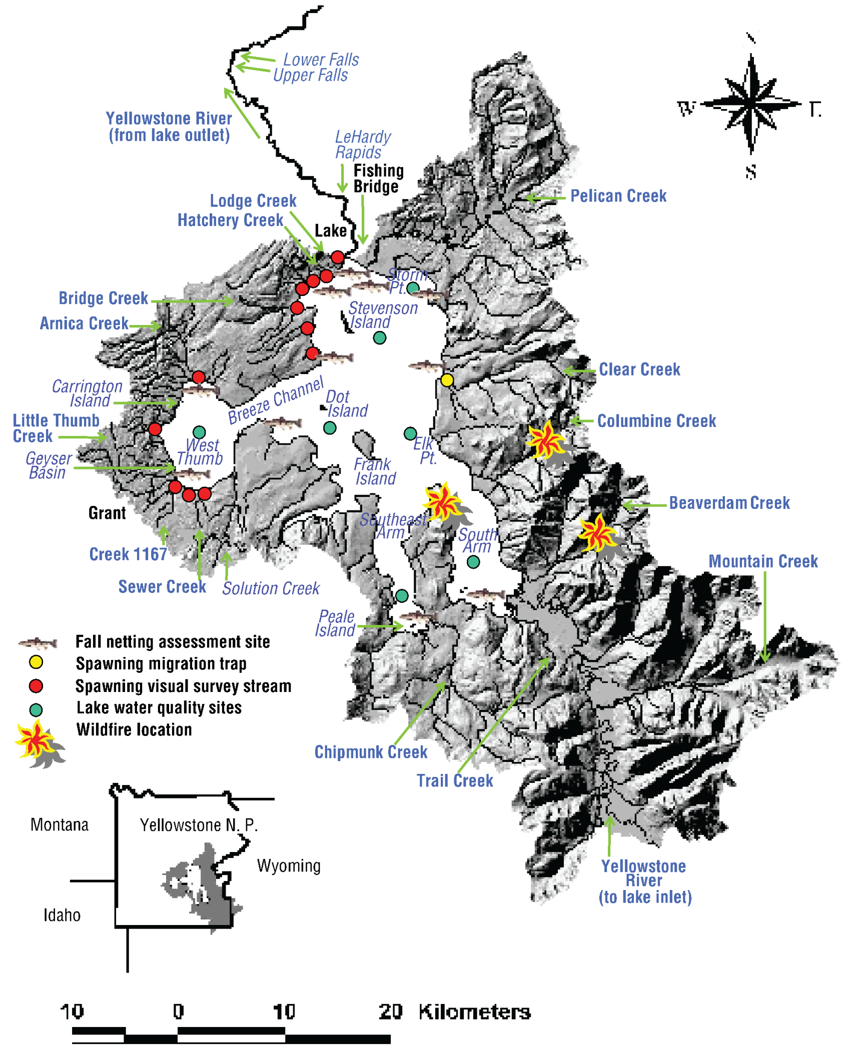

Figure 5. Yellowstone Lake and several major tributary drainages within Yellowstone National Park.

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

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

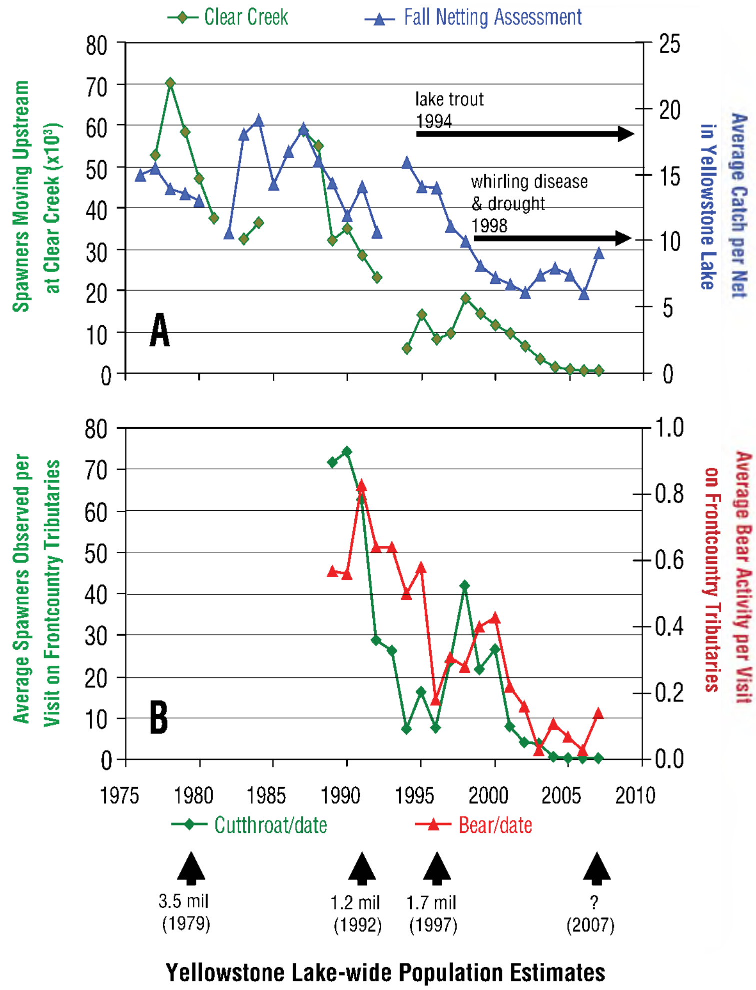

Figure 6. (A) Total number of upstream-migrating cutthroat trout counted at the Clear Creek spawning migration trap and mean number of cutthroat trout collected per net during the fall netting assessment on Yellowstone Lake (1976–2007) and (B) mean number of cutthroat trout and mean activity by black bears and grizzly bears observed during weekly spawning visual surveys of 9–11 tributaries along the west side of Yellowstone Lake between Lake and Grant, 1989–2007. On Yellowstone Lake, population estimates were made using mark-recapture during 1979 (Jones et al. 1980) and sonar technology during 1992 and 1997 (McClain and Thorne 1993; Ruzycki et al. 2003). Cutthroat trout abundance within the lake was approximately 3.5 million in 1979 (>350 mm length), but fell to 1.2 and 1.7 million (>100 mm length) in 1992 and 1997, respectively. No lake-wide estimate is available for the current population.

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

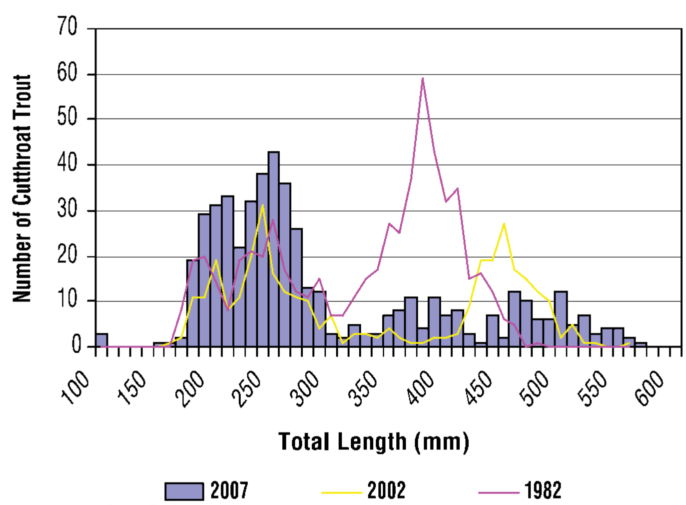

Figure 7. Length-frequency distributions of cutthroat trout collected during the fall netting assessment on Yellowstone Lake following high (2007), moderate (2002), and no (1982) predation pressure by non-native lake trout. The 1982 cutthroat trout population was free from most threats and had a healthy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

Status of Cutthroat Trout in the Upper Yellowstone River

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

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

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

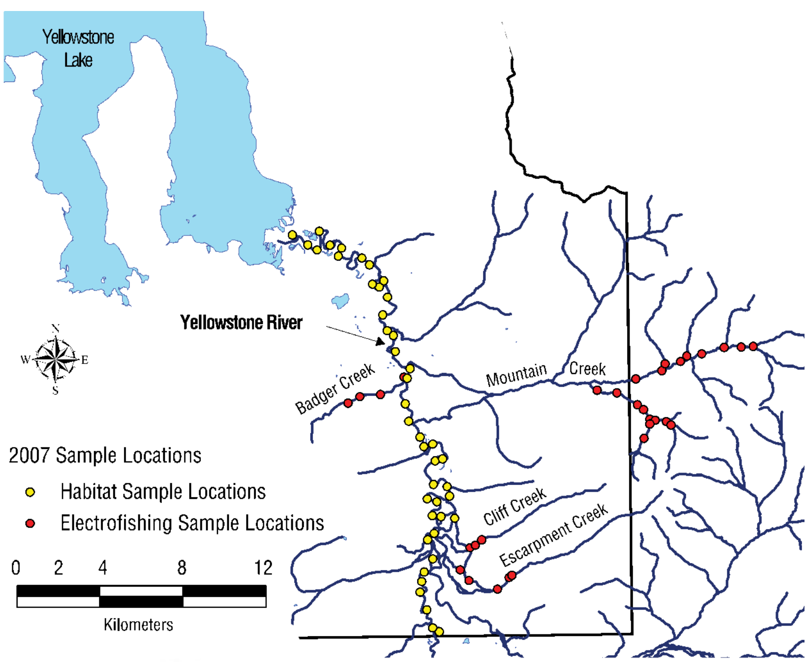

Figure 8. Locations of habitat and electrofishing surveys in the Yellowstone River drainage upstream of Yellowstone Lake in 2007.

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

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

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

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

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

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

Multiple Stressors Affect Cutthroat Trout

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

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Lake Trout Suppression Program

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

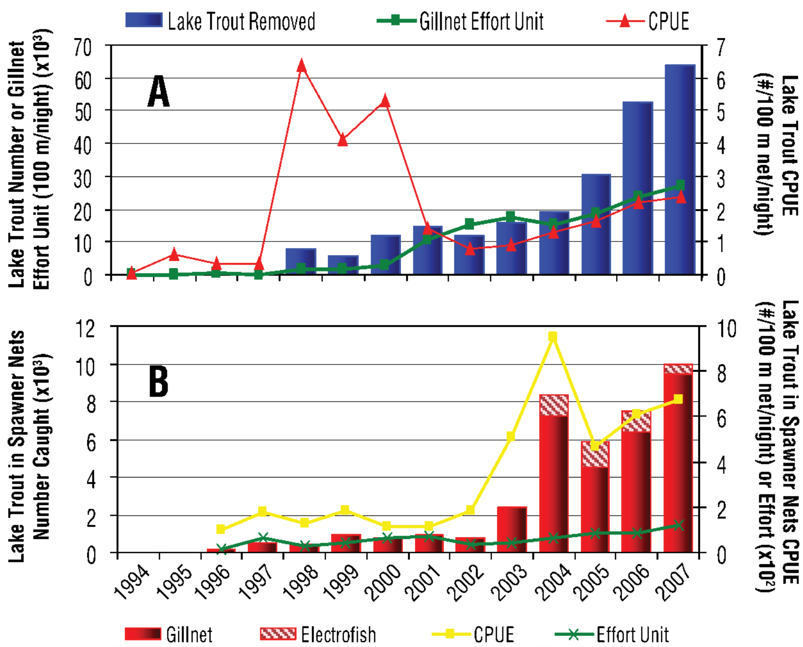

Figure 9. (A) Number of lake trout removed, gillnet units of effort (1 unit = 100 m of net/night), and lake trout catch per unit of effort obtained with control nets, 1994–2007. (B) Number of mature lake trout removed by gillnetting and boat-mounted electrofishing near Yellowstone Lake spawning locations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

NPS/STACEY SIGLER

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

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

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

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

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

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

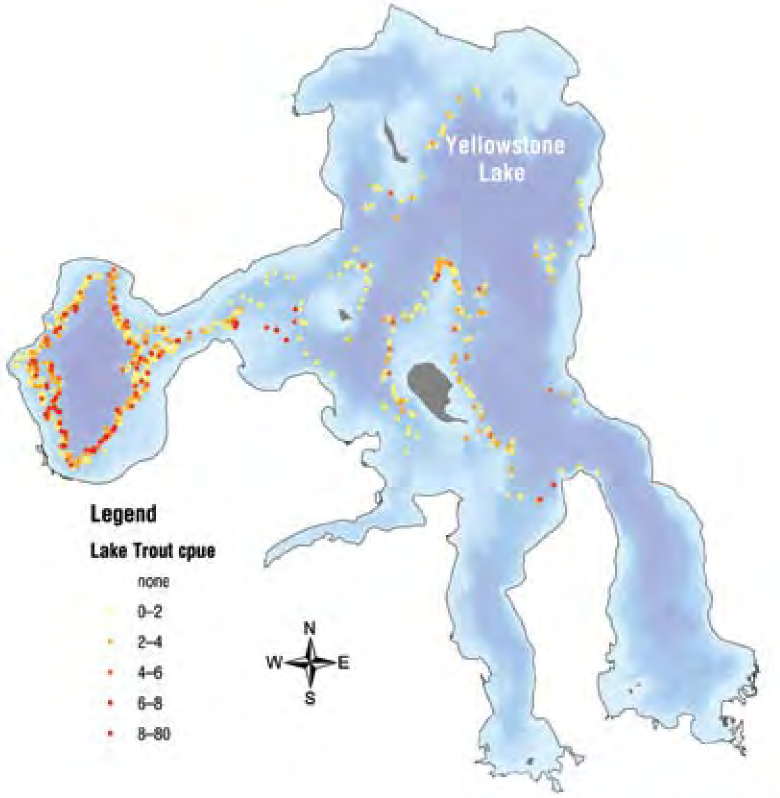

Figure 10. Catch-per-unit-effort (1 unit = 100 m of net set per night) of lake trout by gillnets set on Yellowstone Lake, 2007.

Lake Trout Control Netting

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

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

NPS/AUDREY SQUIRES

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

NPS/PHILIP DOEPKE

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

Lake Trout Spawner Removal

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

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

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

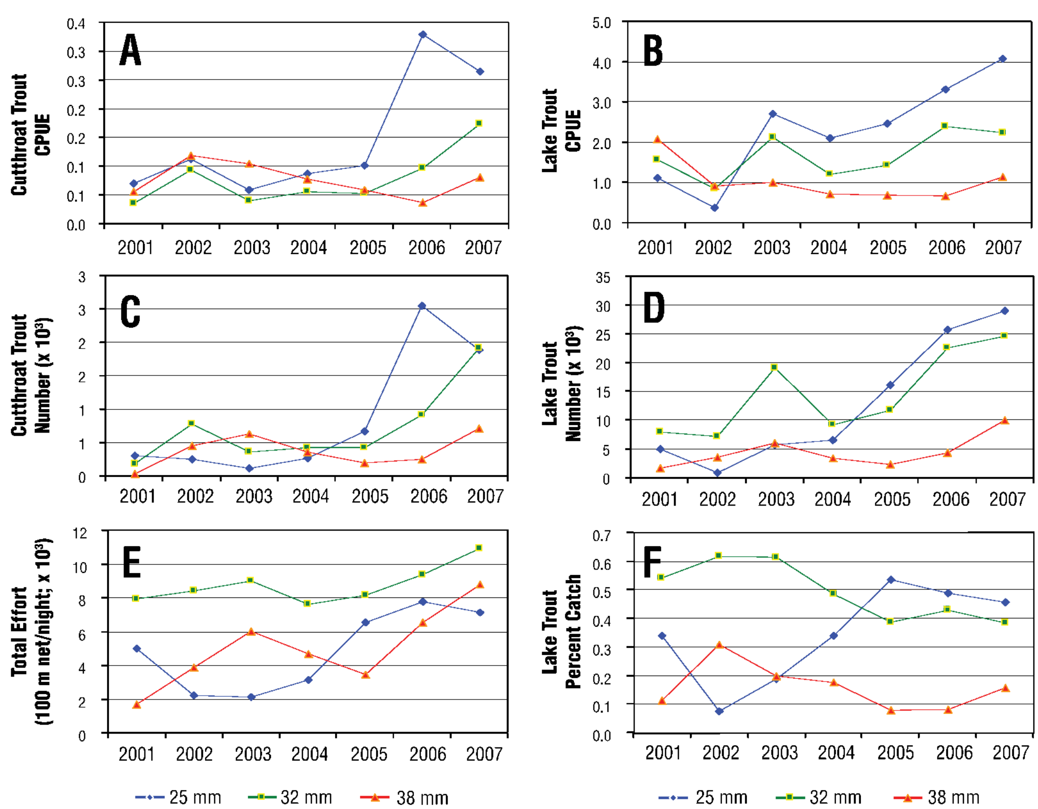

Figure 11. (A, B) Catch-per-unit-effort (1 unit = 100 m of net set per night), (C, D) total catch, (E) total effort of both lake trout and cutthroat trout and (F) percent of total catch of lake trout among three gillnet mesh sizes used on Yellowstone Lake, 2001–2007.

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

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

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

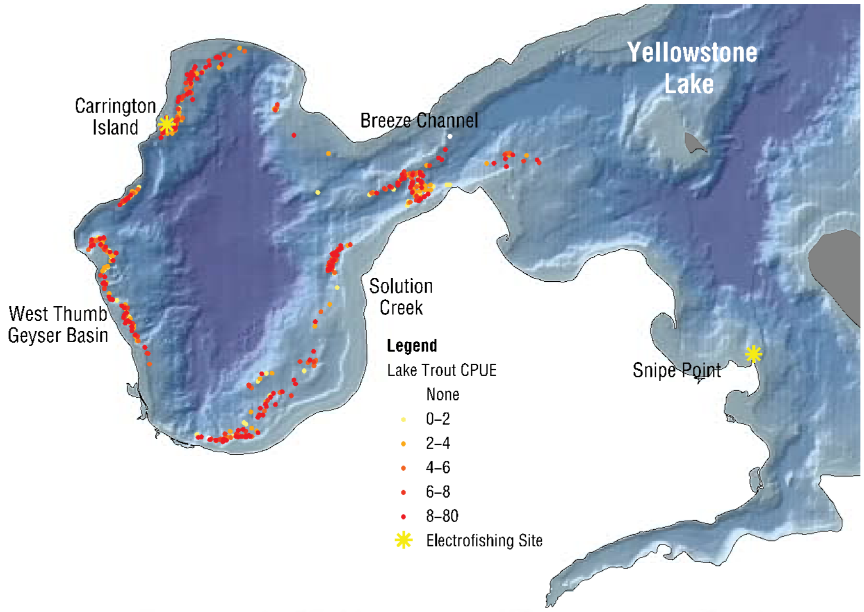

Figure 12. Catch-per-unit-effort (1 unit = 100 m of net set per night) for gillnets and locations of sites electrofished during the spawning season, 2007.

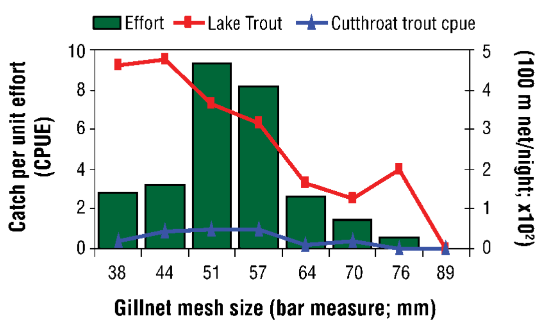

Figure 13. Catch-per-unit-effort for lake trout and cutthroat trout and total effort (1 unit = 100 m of net set per night) by gillnet mesh size for control nets used on Yellowstone Lake, 2007.

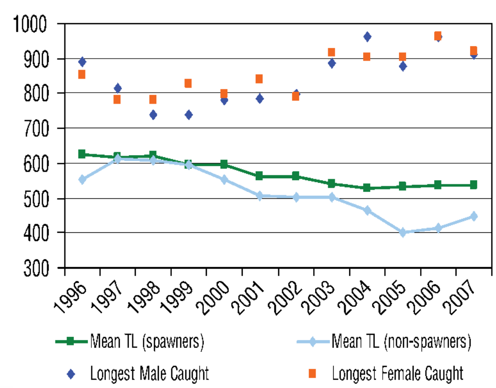

Figure 14. Mean and maximum total length (TL) of mature male and female lake trout caught near spawning areas in Yellowstone Lake, 1996–2007.

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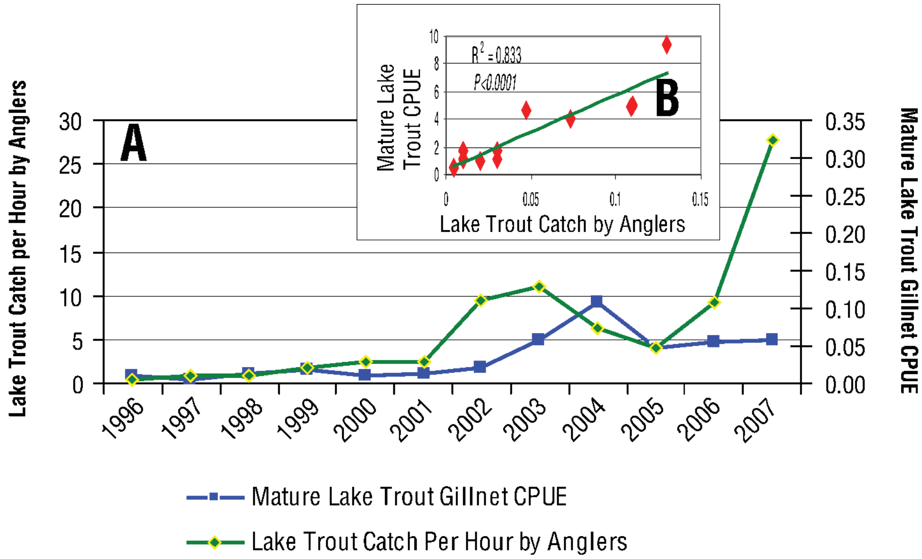

Figure 15. (A) Lake trout catch per hour by anglers and catch-per-unit-effort for gillnets set during the spawning season on Yellowstone Lake, 1996–2007. (B) Relationship between lake trout catch per hour by anglers and the catch-per-unit-effort of spawning lake trout the following year.

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

Electrofishing of Lake Trout Fry

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

Accidental Catch of Cutthroat Trout

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