



In Cooperation with the National Park Service, Glacier National Park

2010 Summary Report

Preservation of Native Bull Trout in Glacier National Park: Continued Experimental Suppression of Non-native Lake Trout in Quartz Lake, Glacier National Park

Vincent S. D'Angelo^{*1}, Clint C. Muhlfeld¹, Brady J. Miller¹, and Carter R. Fredenberg¹



*Corresponding author: vdangelo@usgs.gov

¹ USGS Northern Rocky Mountain Science Center, Glacier Field Station, Glacier National Park, West Glacier, Montana USA 59936

Abstract

After 14,000 years of dominance, Glacier's greatest native aquatic predator is at high risk of extirpation in several lakes along the western slopes of the Continental Divide. The decline of threatened bull trout *Salvelinus confluentus* in Glacier National Park (GNP) is directly attributed to the invasion and establishment of nonnative lake trout *Salvelinus namaycush* from Flathead Lake, which consistently displace bull trout in systems where they have been introduced. This research project was developed to aid in the development of an action plan by experimentally assessing the feasibility of reducing the nonnative lake trout population in Quartz Lake. The goals of this four-year research (2009-2012) project are to assess the demographics of the lake trout population, and use this information to inform and implement experimental removal and control alternatives to reduce or eliminate competitive interactions in the Quartz Lake system and other lakes in GNP. This progress report includes results from the spring and fall 2010 sampling periods.

Background

Invasive species threaten the biodiversity of aquatic ecosystems worldwide, and are considered the second greatest threat to biodiversity in North America (Vitousek et al. 1997). Invasions of introduced taxa often disrupt the structure and function of ecosystems, reduce biological diversity among native species, and impose huge economic costs. Therefore, understanding how to reduce or eliminate exotic species in native ecosystems is critical for conserving native aquatic species and ecosystems.

Lake trout are large, long-lived, top-level predators native to deep, cold, oligotrophic lakes of Canada and northern parts of the United States, including the Great Lakes (Behnke 2002). During the late 19th and early 20th century, lake trout were widely introduced into lakes and reservoirs outside their native range (Crossman 1995). More recently, the species has expanded its range in the western United States through dispersal and unauthorized translocations (Behnke 1992). Bull trout and lake trout have similar morphologies, diets, and growth rates, and occupy similar trophic positions as top-level predators, resulting in strong potential for competitive or predatory interactions. In the Pacific Northwest, native bull trout populations have declined in all systems where lake trout have been introduced (Donald and Alger 1993; Fredenberg 2002; Martinez et al. 2009).

Introduced to Flathead Lake in 1905, non-native lake trout have dispersed to many additional lakes in the wider Flathead watershed, including nine lakes west of the Continental Divide in GNP that historically supported bull trout (Frendenberg 2002; Downs et al. 2011). Fredenberg (2002) reported a broad bull trout decline and a corresponding increase in nonnative lake trout from 1969 to 2000 in four lakes (Logging, Bowman, Harrison, Kintla) in Glacier National Park (GNP). In the same study, bull trout catch data in Quartz Lake remained constant because it was the only lake where lake trout were absent (Frendenberg 2002). Similarly, recent bull trout redd surveys (2003-2010) show significant declines in adult abundance in many GNP streams, with some counts representing less than 10 reproducing individuals (Downs et al. 2011). Combined, these data show that several native bull trout populations have drastically declined in western GNP with several adfluvial populations at imminent risk of extirpation due to adverse interactions with invasive lake trout.

Study Area

Quartz Lake (lake area, 352 hectares; max depth ~ 83 meters; Figure 1) in the North Fork Flathead watershed in GNP currently hosts the most viable and un-impacted bull trout population remaining among the larger lakes in GNP and thus provides a model of a fully functioning native aquatic ecosystem. In addition to the threatened bull trout, Quartz Lake also supports populations of native westslope cutthroat trout *Oncorhynchus clarkii lewisi* (a Species of Special Concern in Montana), mountain whitefish *Prosopium williamsoni*, longnose sucker *Catostomus catostomus*, largescale sucker *Catostomus macrocheilus*, sculpin *Cottus spp.*, and redbside shiner *Richardsonius balteatus*. Nonnative lake trout were first detected in Lower Quartz Lake in 2003 and Quartz Lake in 2005 (Frendenberg et al. 2007).

The conservation concern is that invading lake trout will likely overwhelm and replace bull trout within 10-20 years in this system, as they have done in all other lakes where they have invaded in GNP (Fredenberg 2002; Downs et al. 2011). Delaying measures to suppress this expanding population will likely result in the proliferation of invasive lake trout, making control of this voracious predator more difficult in the future. Continued lake trout reproduction and population expansion Quartz Lake may severely and perhaps permanently compromise native fish and wildlife in the entire Quartz Lake chain, including effects on osprey, otters, eagles, loons, and bears. In response to this threat, GNP, the USGS Northern Rocky Mountain Science Center (NOROCK), and the Glacier National Park Fund initiated this cooperative research project in 2009 to develop conservation measures to protect this important aquatic and terrestrial ecosystem.

Several high gradient cascades in the narrow canyon between Lower Quartz and Middle Quartz lakes may act as intermittent barriers during high flow events, but no permanent natural fish passage barriers are present in the Quartz drainage. In 2004, a reinforced gabion weir barrier was constructed on Quartz Creek approximately ~100 yards downstream of Middle Quartz Lake to protect native fish populations from continued invasion of lake trout from downstream sources. This structure was damaged in 2006 by high water and currently serves as a partial barrier to fish dispersal. The long term functionality of this barrier is critical to the success of lake trout suppression in Quartz Lake, and consequently, GNP plans to retrofit and repair this structure to ensure that it is completely impassable at all flows.

Methods

Gill netting took place during the spring (3 June – 2 July) and fall (14 September – 27 October) of 2010. Spring gill netting typically involved netting on a Monday-Friday basis while fall netting was nearly continuous. During both netting periods, we measured the total length (TL, mm) of each captured lake trout. We recorded weight (g) and removed otoliths (sagittae) for at least twenty individuals per 25 mm length class of juvenile lake trout and for all potential adult lake trout (>400 mm TL). Otoliths and weights were also taken from any incidentally killed bull trout or westslope cutthroat trout. Otoliths were cleaned, prepped for dry storage according to the methods reported by Stafford et al. (2002). All lake trout were killed and their air bladders were punctured before they were returned to the lake as biomass.

Spring 2010

Spring 2010 objectives were:

- 1) Begin generating a lake trout population estimate in Quartz Lake using a lake-wide, randomized gill netting design;
- 2) Continue juvenile lake trout suppression via non-random maintenance gill netting (see below) in highly productive juvenile hotspots identified by 2009 catch data;
- 3) Implant sonic telemetry tags in adult male lake trout captured via angling or gill

netting;

- 4) Begin a mark-recapture for adult (≥ 400 mm) bull trout to obtain a population estimate.

Gill nets used in spring 2010 were typically 300 meters in total length, and consisted of three 100 meter long by 2 meter high monofilament net panels. Mesh sizes per 100 meter panel were uniform and consisted of 2", 2.25", 2.5", 3" or 3.5" stretch monofilament mesh. Random netting locations were assigned using a 200 m square grid imposed on satellite imagery of Quartz Lake. The 200 meter grid size ensured that each grid was large enough to contain a 300 m gill net and that the number of resulting random netting locations would sufficiently cover the surface area of Quartz Lake. Each grid was assigned a unique number and field crews selected daily netting locations using a random number generator, with gill netting occurring once per location. After the first week, adjustments to netting locations were made in the field to avoid shallow areas (< 30 m) assumed to be preferable bull trout habitat. Random nets were set at all hours of the day and night and were generally deployed for 4-6 hours in depths ranging from 16.0 to 77.5 m. "Maintenance" netting was non-random and involved longer soak times, and occurred primarily in two bays on the west end of Quartz Lake with nets deployed for up to 24 hours in depths ranging from 29.4 to 76.2 m (Figure 1). Tag implantation and telemetry methods were identical to those described in Muhlfeld and Fredenberg (2010).

Fall 2010

Fall 2010 gill netting operations (14 September – 27 October) were identical in methods and scope to those conducted in fall 2009 (Muhlfeld and Fredenberg 2010) with crews also documenting the recapture of marked bull trout from spring 2010. Efforts focused on two ongoing objectives:

- 1) Identify the timing and location of lake trout spawning to maximize efficiency of adult lake trout suppression with minimal bull trout mortality;
- 2) Continue juvenile lake trout suppression using maintenance sets in productive areas identified in 2009 and spring 2010.

Initially, only maintenance netting and adult telemetry were conducted. The approach to maintenance netting was identical to that of spring 2010, but 3" and 3.5" mesh sizes were not used due to high bull trout mortality potential. Beginning in mid-October, larger mesh sizes were deployed to capture adult-sized lake trout (> 400 mm TL) that congregated on two primary spawning locations, identical to those observed in 2009 (Figure 2; Muhlfeld and Fredenberg, 2010). Gill nets used to capture adult lake trout were typically 200 m in total length, consisting of two 100 m long by 2 m high monofilament net panels. Mesh sizes per 100 m panel were uniform and consisted of 3.5", 4", 4.5" or 5" stretch monofilament mesh. Nets were set from approximately 1900-0400 hours and for 1-2 hours per set to reduce bull trout by-catch mortality. Set depths on spawning grounds were typically 4-40 m. Less often, nets were randomly deployed to determine if other areas were being used as spawning sites.

Results

Telemetry

Sonic tags were surgically implanted in six presumably mature lake trout (mean total length, 620 mm; mean weight, 2538 g; Table 1) caught by experienced lake trout anglers during spring 2010. Two additional fish were captured and tagged during the fall of 2010 bringing the total number of tagged fish to nine, including one fish originally tagged in spring 2009 (Table 1).

Tagged adults were widely distributed throughout Quartz Lake during September and early October but began to congregate near avalanche chutes 2 and 3 in mid-October in preparation for spawning (Figure 2). Recurring avalanches within these chutes have deposited mass amounts of large cobbles and boulders, creating colluvial deposits at the base of each chute. These deposits are typically between 5 to 20 m deep and extend close to 100 m from shore. We believe that the combination of shallow water and consistent wind action allow surface and subsurface flows to continually clean and maintain sediment-free and well oxygenated substrates in these areas.

The mean total water depth where tagged fish were observed was 27 m, and the mean surface water temperature at each fish's location was 11.9°C (Table 1). Four of nine (44%) sonic-tagged adult lake trout were recaptured with gill nets on or near the colluvial deposits at the base of the avalanche chutes during the fall of 2010. This recapture rate was not as high as that of 2009, when 10 of 11 (91%) tagged fish were recaptured. One hypothesis that may explain this difference is that spawning locations were known a priori in 2010 and we began netting in these areas earlier than in 2009, perhaps disrupting the spawning congregation and reducing the likelihood of capturing tagged fish. Future work will assess the effectiveness of adult removals on the demographic characteristics (e.g., growth, survival, recruitment) of the lake trout population.

Lake Trout Suppression

A total of 50.4 km of nets were deployed in 2010 including 23.2 km during the spring and 27.2 km during the fall, resulting in a total of 696 lake trout captured and killed (640 juveniles, 56 adults, Table 2). Spring efforts removed a total of 400 lake trout using a combination of random and maintenance netting locations, including 399 juveniles and 1 adult lake trout (Table 2). During the fall of 2010, 296 lake trout were captured and killed, including 241 juvenile lake trout caught primarily during maintenance netting and 55 adult fish captured by 3.5-5.0" mesh on spawning grounds (Table 2).

Total juvenile lake trout captured in spring differed between random ($N = 265$) and maintenance ($N = 134$) netting (Table 2). Random nets did not capture any adult lake trout, and only one adult lake trout was captured in maintenance netting, probably due to the small mesh sizes used. The lake trout catch per unit effort (CPUE; fish/hr./100m panel) for all spring nets, as well as randomized spring nets, generally declined over the five week period, suggesting a high exploitation rate on the target size lake trout for 2-2.5" mesh (Figure 3). Larger mesh sizes (3.0-

3.5”) were deployed only during the first two weeks of spring netting due to high bull trout mortality potential.

When considering all 2010 data, lake trout CPUE varied among mesh sizes with 4.0” and 5.0” mesh being the most effective, followed by 2.0” and 2.5” mesh sizes (Figure 4). The 4.0” and 5.0” mesh sizes were deployed exclusively on lake trout spawning grounds during fall 2010 and captured exclusively adult-sized lake trout (> 400 mm) while the 2.0” and 2.5” mesh sizes caught primarily juvenile lake trout. The 2010 length frequency histogram of the total lake trout catch shows a strong cohort in the 300-400 mm range (Figure 5) which comprised 75% of the total lake trout catch in 2010. Age estimates are not presently available (otolith analysis in progress), but we believe these fish are a continuation of the strong 250-350 mm size class visible in the 2009 total lake trout length frequency histogram (Figure 5) that consisted of age 4, 5, and 6 year old fish based on 2009 otolith analysis and comprised 60% of the total 2009 catch (Muhlfeld and Fredenberg 2010). The dominance of this size range could partially be a result of our frequent use of small mesh (2.0-2.5”), but the growth of this size class from 2009 to 2010 suggests that it is the result of strong recruitment between 2003 and 2005. As this well represented group continues to grow, we plan to adjust mesh sizes to ensure continued exploitation.

Although only 4 of 9 tagged fish were recaptured, results from fall of 2010 were encouraging. Netting for spawning lake trout took place October 4-27, 2010. We observed a decrease in the average length of lake trout caught on spawning grounds from 2009 (648 mm) to 2010 (590 mm). Heavy exploitation of the 600-750 mm size class during 2009 likely explains this difference; while the frequencies of other size classes remained similar between 2009 and 2010, the frequency of this size class was reduced dramatically from 62.8% of the total adult catch in 2009 to only 26.7% in 2010 (Figure 6). Netting efforts may also be disrupting the sex ratio of adult lake trout, which increased from an approximately 2:1 male to female ratio in 2009 to a 3:1 male to female ratio in 2010 (Figure 6).

Bycatch

We captured a total of 123 bull trout via gill netting, 94 (76%) of which were classified as adults (≥ 400 mm) and 29 (24%) as juveniles. Bull trout CPUE was highest in 4.0”, 4.5” and 3.5” mesh sizes; 4.0” and 4.5” were deployed exclusively during fall 2010 while 3.5” was deployed during the first two weeks of spring 2010 and the first two weeks of fall spawner netting (Figure 7). A total of 67 adult sized bull trout were captured during spring angling, 2 of which were incidentally killed.

A total of 43 bull trout were incidentally killed by gill netting throughout 2010 (35% of total bull trout captured), including 29 adult sized fish (31% of total adults; Table 2) and 14 juveniles (48% of total juveniles). Several things may explain the lower overall mortality rate for bull trout adults with respect to juveniles; short net set periods for random spring net sets and spawner net sets that typically captured adults; shallower depths of spawner net sets and colder water temperatures during the fall; and use of a “Frasier” aeration recovery tank in the boat. Nets deployed randomly in the spring and large mesh sizes deployed over lake trout spawning

grounds in the fall (3.5-5.0") accounted for the majority of total bull trout mortalities (72 %; Figure 8) as well as total adult bull trout mortalities in 2010 (90%; Table 2).

Other native fishes that were incidentally captured in 2010 included: longnose suckers ($N = 467$; length range, 175-675mm), largescale suckers ($N = 76$; length range, 195-621mm), mountain whitefish ($N = 240$; length range, 100-452mm), and westslope cutthroat trout ($N = 44$; length range, 215-426mm). Mortalities for these species included 6 (14% of total) westslope cutthroat trout, 12 (3%) longnose suckers, and 62 (26%) mountain whitefish.

Adult Bull Trout Population Estimate

During the spring of 2010 anglers caught and marked 64 adult sized bull trout (≥ 400 mm), 2 of which were confirmed mortalities, making the total number of marked bull trout 62. During the fall, we recaptured 53 bull trout ≥ 400 mm, 6 of which were marked. Using Bailey's Nearly Unbiased Estimator [$N = ((M)(C+1))/(R+1)$] (Jensen 1989) and 95% binomial confidence intervals obtained as described by Krebs (1999), we estimate that there are 478 adult sized bull trout in Quartz Lake as of 2010 (95% CI: 291, 1348) (Table 3). Extrapolating adult bull trout numbers from redd counts as described in Al-Chokhachy et al. (2005; 2.68 bull trout per redd) and doubling the result to account for alternate year spawning produced an estimate of 220 bull trout ≥ 400 mm based on 2009-2010 redd counts in Quartz and Rainbow Creeks (Table 3). Data collected from the upper Flathead system in the 1980s and 90s suggest that 3.2 bull trout per redd may be accurate; this approach estimated 264 bull trout ≥ 400 mm in Quartz Lake (B. Shepard, Montana Department of Fish, Wildlife and Parks, unpublished data; Table 3).

Research has shown that due to observer error and life history variability, the number of bull trout per redd varies at the stream and/or watershed scale (Dunham et al. 2001; Al-Chokhachy et al. 2005), and that population estimates based on redd counts can exclude fish smaller than the average spawner size (Al-Chokhachy et al. 2005). Although the 220 estimate is thus likely biased low, it still suggests that our mark recapture based estimate of 478 may be high, with the true number likely lying between 291 and 478 bull trout ≥ 400 mm.

Bull Trout Mortality Mitigation Plan 2011

Based on our results from the previous two years and our initial bull trout population estimate, we developed a work plan for 2011 designed to reduce future bull trout mortality in Quartz Lake while continuing nonnative lake trout suppression. First, we looked for patterns in depth, mesh size (Figures 7 and 8), and soak time associated with increased rates of bull trout capture or mortality for each sampling event (spring maintenance, spring random, fall spawner etc.). If changes were warranted for a specific sampling event (see Table 4 below), adjusted bull trout CPUE and mortality rates (dead bull trout/hr./100m panel) were calculated for the subset of 2010 data that excluded nets with depths, soak times or mesh sizes conducive to high bull trout take. These rates were then multiplied by the projected 2011 effort (identical to 2010) to predict the number of bull trout caught and killed in 2011 for each sampling event.

Projected Bull Trout Take

Including angling and gill netting, we anticipate capturing 164 bull trout with 28 incidental mortalities throughout 2011, including 134 adults captured and 15 adults killed (Table 4). We expect roughly the same amount of angler effort as in 2010 and therefore do not expect the number of bull trout captured ($N = 67$), or killed ($N = 2$), to change substantially. Overall, we predict that adjustments to gill netting methods in 2011 will reduce the total gill netting catch from 143 in 2010 to 97 in 2011, with mortalities falling from 43 to 26. Spring random netting killed the most bull trout of any sampling event in 2010 and we plan to adjust our approach substantially. Projections for spring random netting excluded sets < 30 m average depth, > 5 hours soak time, and 3.0-3.5" net panels, and will ideally reduce mortality from 16 in 2010 to 7 in 2011. Bull trout mortality during spring maintenance netting was very low in 2010 ($N = 3$) and we plan to avoid setting nets < 30 m average depth (Table 4) to ensure low mortality in 2011 as well. No changes were made in our approach to fall maintenance netting, but limiting the maximum soak time to 12 hours would likely be beneficial.

Fall spawner netting accounted for 13 (45%) adult bull trout mortalities in 2010, and we plan to adjust our approach in 2011. Initial projections for spawner netting excluded the 3.5" mesh size, due to the high bull trout mortality potential and relatively low lake trout CPUE (Figures 4,7,8), but the combined use of 4.0", 4.5" and 5.0" mesh sizes at 2010 effort levels projected 12 adult bull trout mortalities and 45 bull trout captured. Removing 4.0" mesh from spawner netting greatly reduced projected bull trout catch and mortality, but is not practical since 4.0" mesh has been very efficient at capturing lake trout during the course of this study (Figure 4). Therefore, we averaged the projections from these two strategies to obtain results shown in Table 4. These results reflect the limited use and careful monitoring of 4.0" mesh during the fall 2010; soak times for 4.0" mesh will be limited to one hour, and if high bull trout mortality is observed, we will discontinue the use of 4.0" mesh panels. Ideally, we will reduce bull trout mortality during spawner netting from 13 in 2010, to 8 in 2011. Overall, we believe these efforts will ensure the continued suppression of lake trout with more informed and intensive oversight of bull trout bycatch to reduce mortality in this valuable stronghold.

Acknowledgements

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Tables

Table 1. Descriptive data for tagged adult lake trout during the 2010 season.

Frequency	Tagged	End Status	# Times Tracked	Sex	Length (mm)	Weight (g)	Mean Depth (m)	Mean Surface Temp (°C)
70.3-5-4-5	Spring 2009	Alive	3	M	736	4436	25	10.6
70.4-7-7	Spring 2010	Alive	4	M	685	2082	14	10.4
71.4-6-4-8	Spring 2010	Dead	2	M	551	1590	46	11.1
71.4-7-8	Spring 2010	Dead	4	F	712	3556	20	16.3
72.4-6-5-5	Fall 2010	Alive	1	M	576	1610	N/A	N/A
72.5-8-7	Spring 2010	Dead	3	M	734	3950	40	12.2
73.5-8-8	Spring 2010	Alive	6	M	680	3154	12.6	11.3
74.3-3-4-4	Spring 2010	Dead	7	M	689	2638	28	11.6
76.5-6-5-8	Fall 2010	Alive	0	M	585	1720	N/A	N/A
Mean (SD)					652 (70)	2538 (930)	27 (13)	11.9 (2.0)

Table 2. Netting statistics for 2010 stratified by sampling event; random = randomly deployed 2.0-3.5" mesh size, maintenance = 2.0-2.5" mesh deployed in known areas of juvenile productivity, spawner netting = 3.5-5.0" mesh deployed in suspected lake trout spawning areas.

	Total Juvenile LKT	Total Adult LKT	Adult BLT Morts (≥ 400 mm)	Total BLT Morts
Spring 2010				
Random	265	0	11	16
Maintenance	134	1	2	3
Total	399	1	13	19
Fall 2010				
Maintenance	230	1	1	11
Spawner	11	54	15	13
Total	241	55	16	24
2010 Total	640	56	29	43

Table 3. Estimates of the number of adult sized bull trout ($\geq 400\text{mm}$) in Quartz Lake, 2010, using Bailey's Nearly Unbiased Estimator (95% binomial confidence interval) on mark recapture data and extrapolations based on 2009-2010 redds in Quartz and Rainbow Creeks.

Method	<i>N</i> BLT ≥ 400 mm
Mark Recapture	478 (291,1348)
Redd Counts	220 ¹
Redd Counts	262 ²

¹(2.68 x *N* redds, Al-Chokhachy et al. 2005, estimate doubled to account for alternate year spawning)

²(3.20 x *N* redds, B. Shepard, Montana Department of Fish, Wildlife and Parks unpublished data)

Table 4. Projected bull trout (BLT) take under the 2011 work plan, Quartz Lake, GNP.

	Projected Effort (100 m panel-hrs. or angler hrs.)	Projected BLT Catch	Projected BLT Morts	Projected Adult BLT Catch	Projected Adult BLT Morts
Spring 2011					
Random	783	17	7	10	2
Maintenance	389	15	2	12	2
Angling	127	67	2	67	2
Total Netting	1,172	32	9	22	4
Angling	127	67	2	67	2
Fall 2010					
Maintenance	1851	31	9	15	1
Spawner	255	34	8	34	8
Total	2106	65	17	49	9
2011 Total	3278	164	28	138	15

Figures

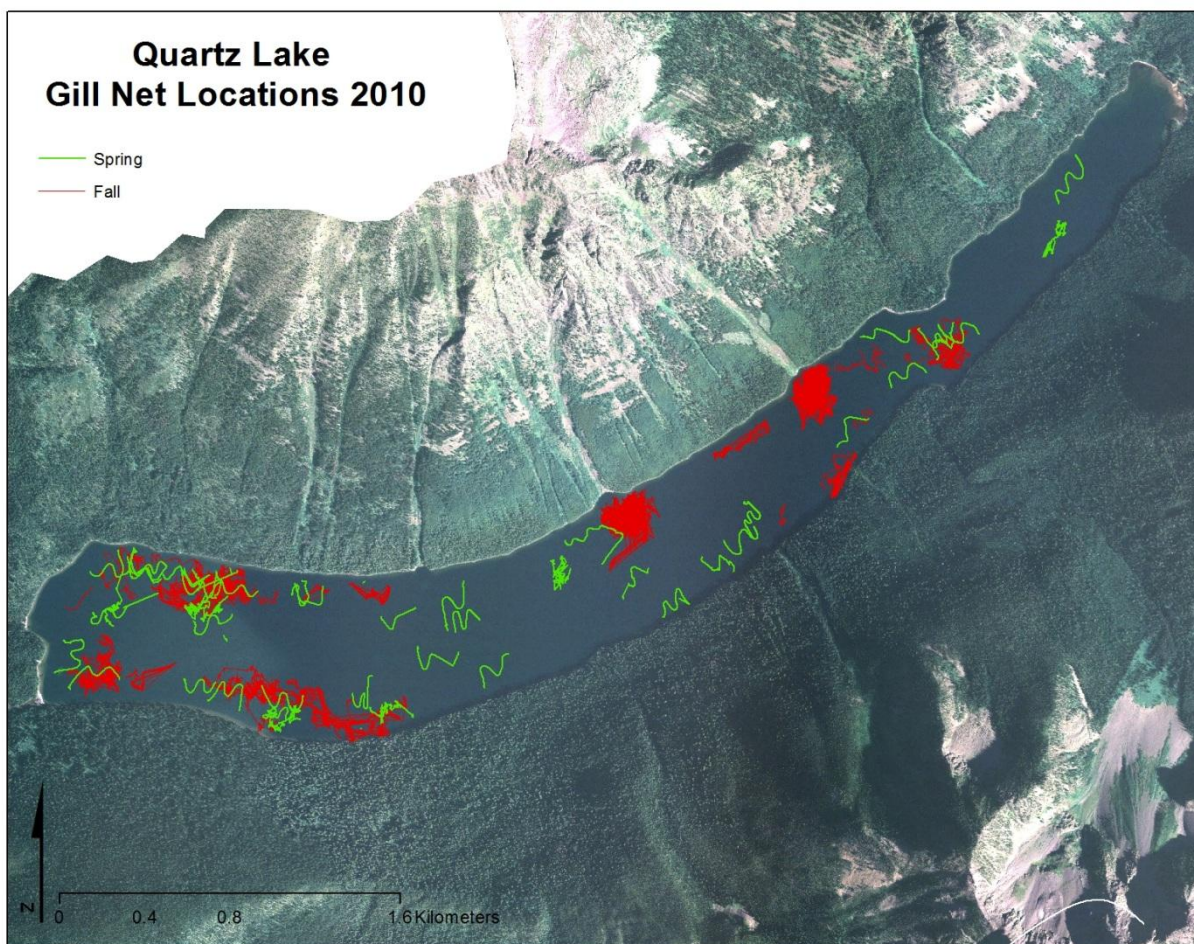


Figure 1. Quartz Lake, Glacier National Park, showing gill net locations ($N = 199$; total length, 50,566 meters) for spring (green lines) and fall (red lines) 2010.

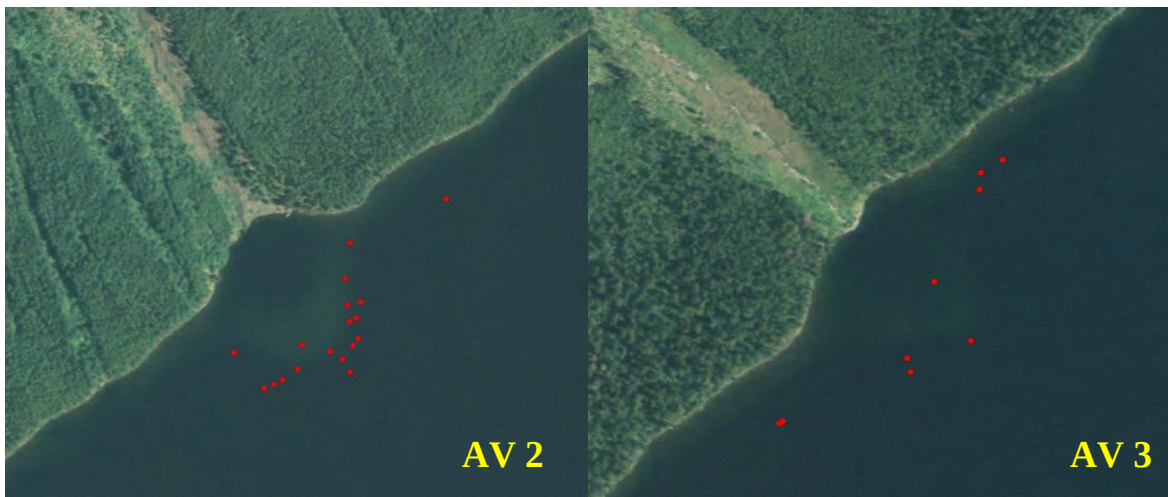
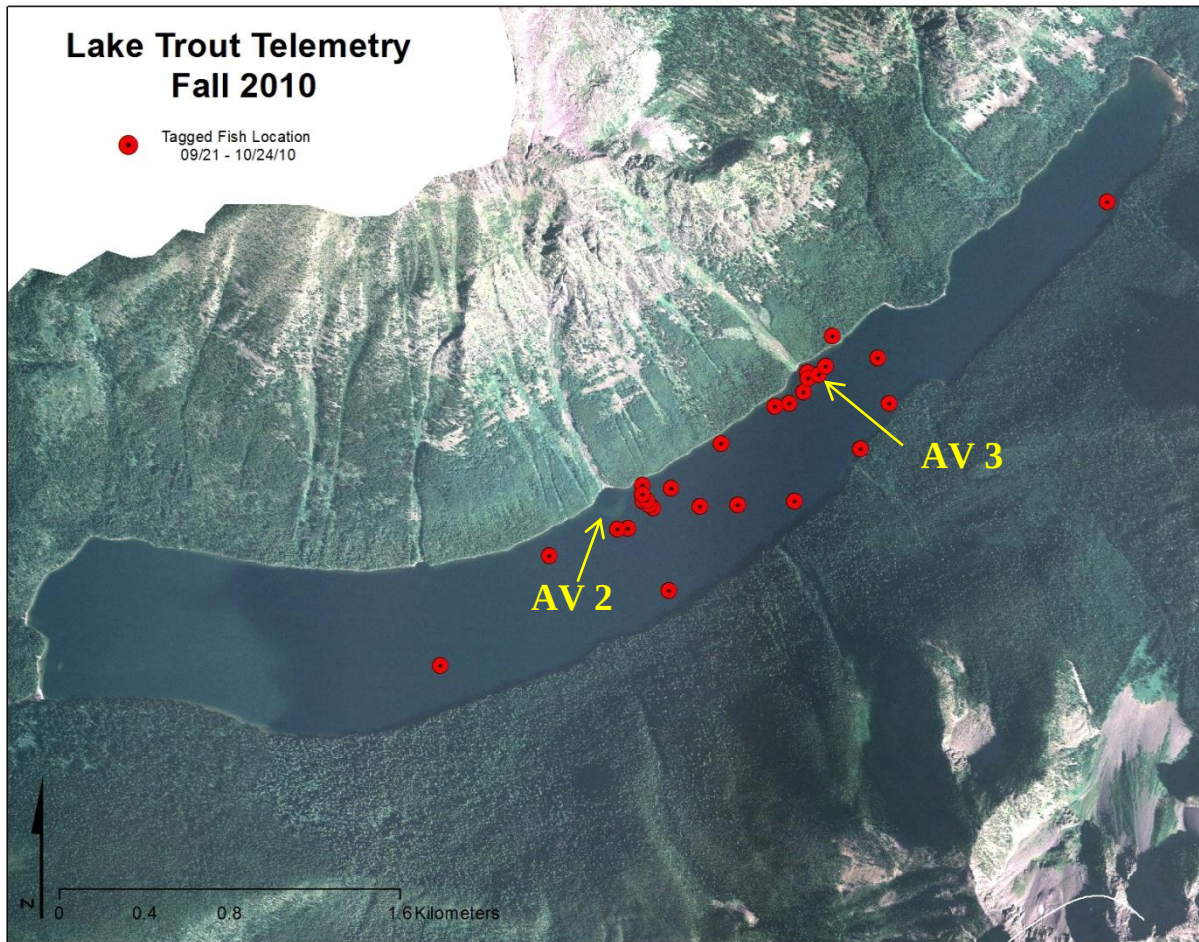


Figure 2. Top image - lake-wide locations of individually tracked adult lake trout September 21 to October 24, 2010. Avalanche chutes 2 and 3 (AV 2, AV 3) are shown in yellow. Bottom images - magnified views of avalanche chutes 2 and 3. Spawning lake trout were typically found near the deep edges of rock reefs at the base of avalanche chutes during the day, whereas at night they moved to the shallow areas of the reefs to spawn.

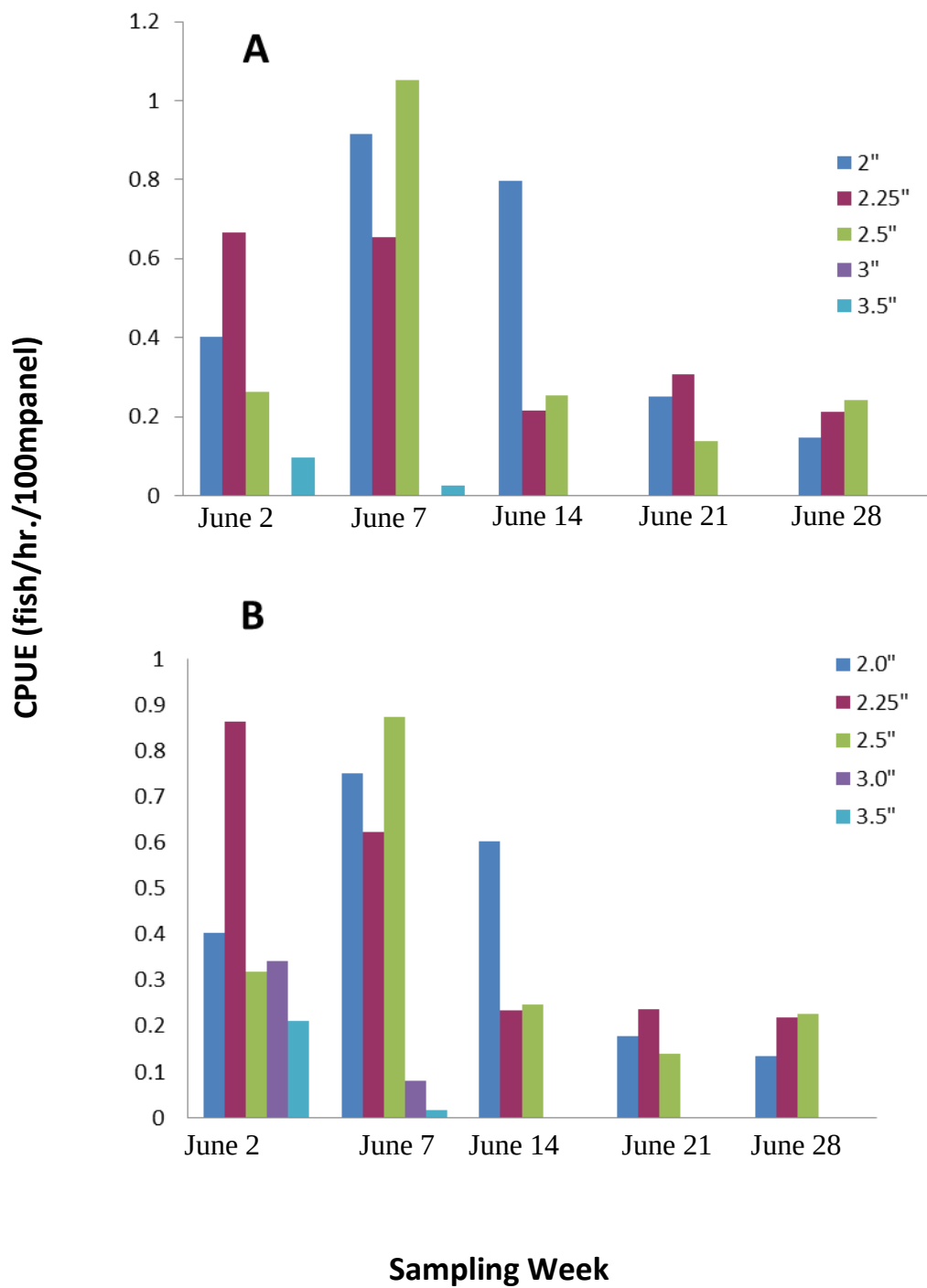


Figure 3. Catch per unit effort (CPUE) for randomized net locations (A) and all net sets (B) for the five weeks (Monday-Friday) of spring netting 2010.

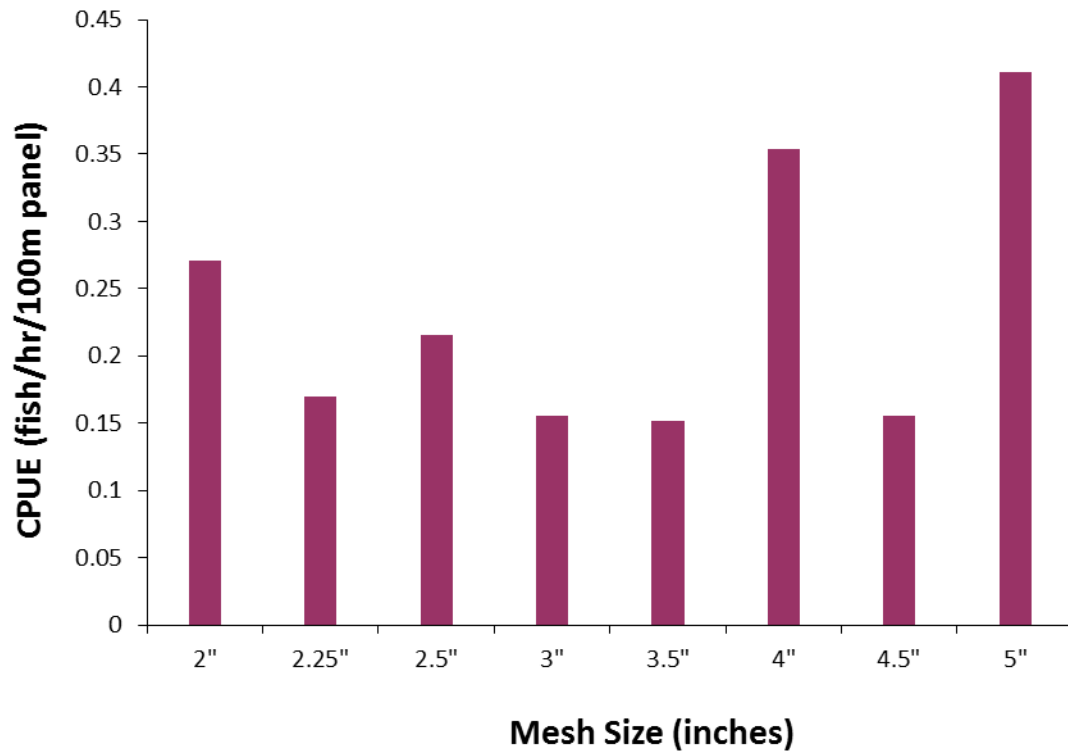


Figure 4. Catch per unit effort (CPUE) for all lake trout in Quartz Lake, 2010.

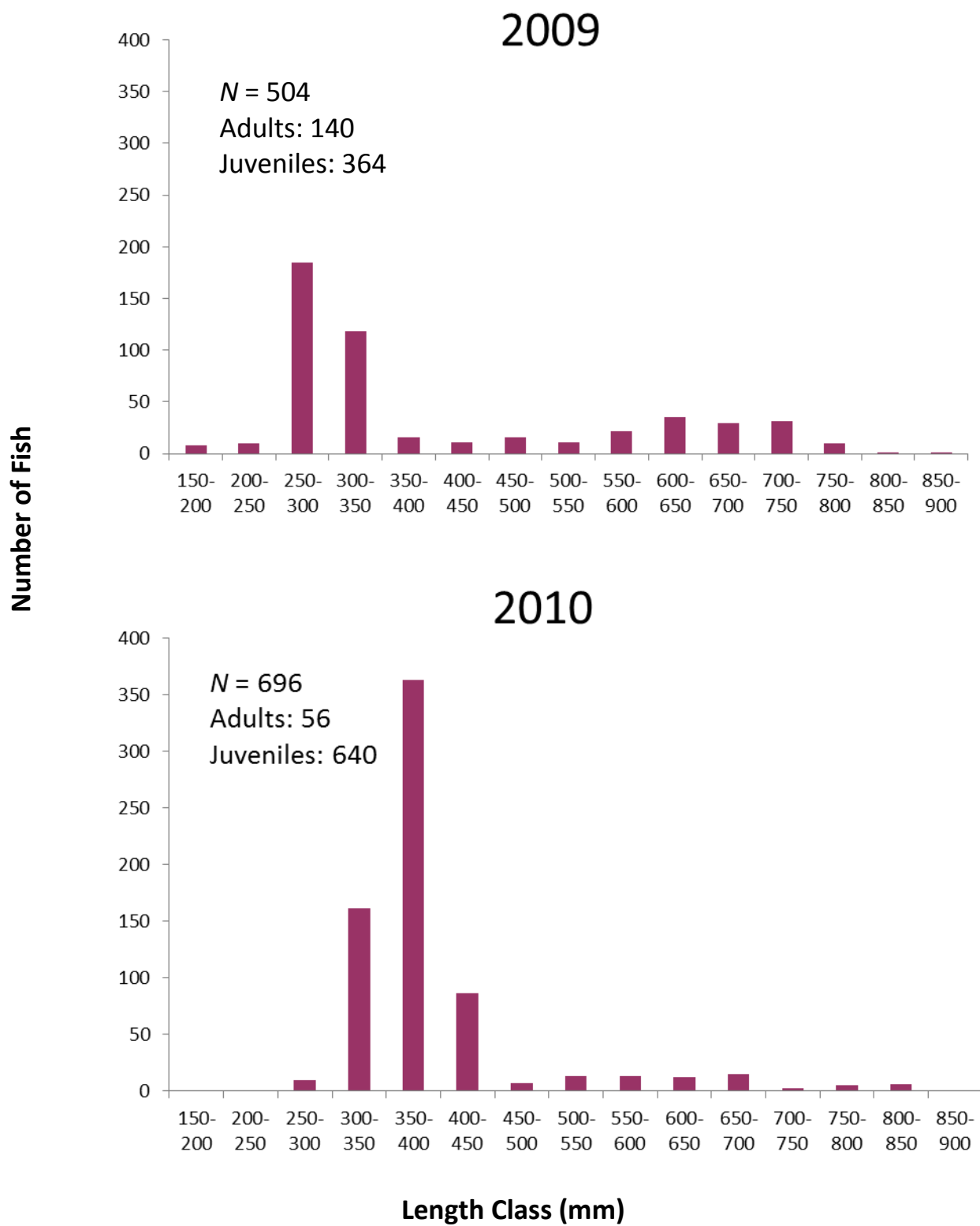


Figure 5. Comparative length frequency distributions of lake trout captured in Quartz Lake in 2009 and 2010.

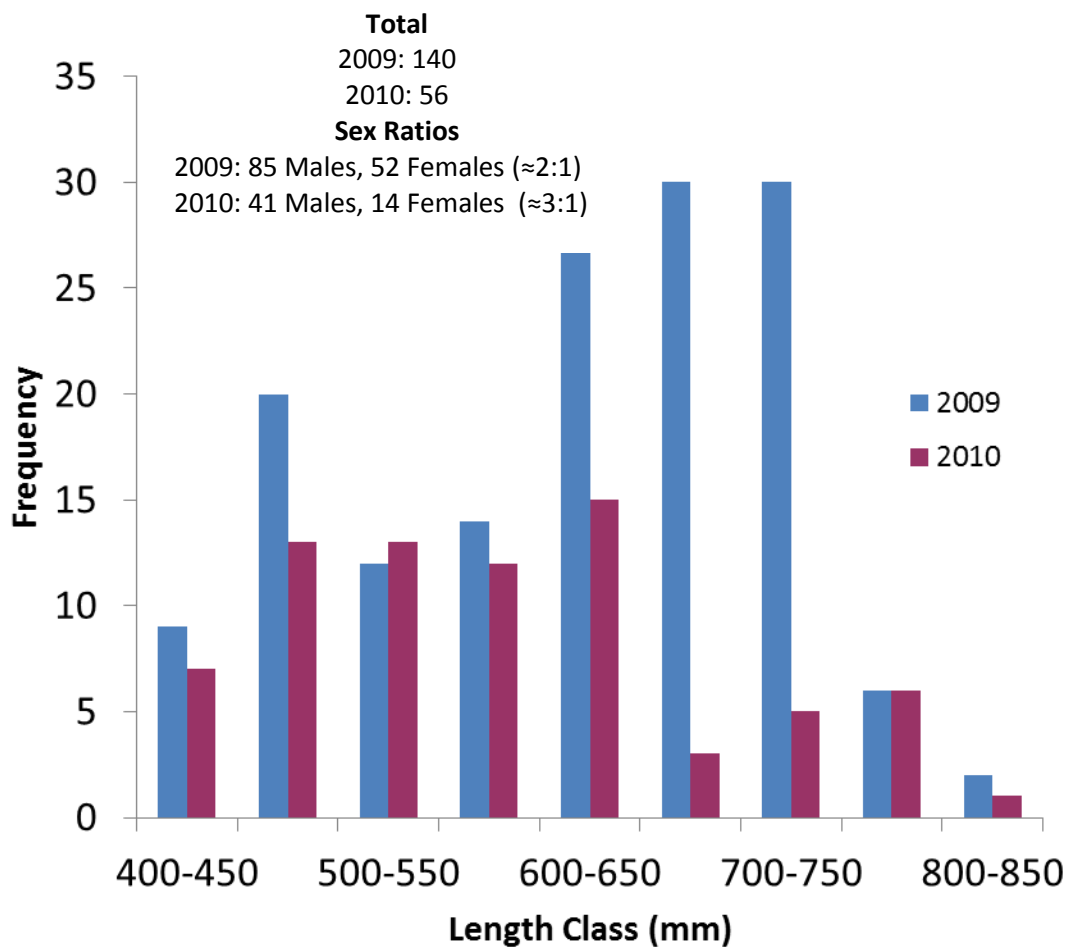


Figure 6. Length frequency histogram for adult lake trout 2009-2010, with total captured and sex ratios for each year.

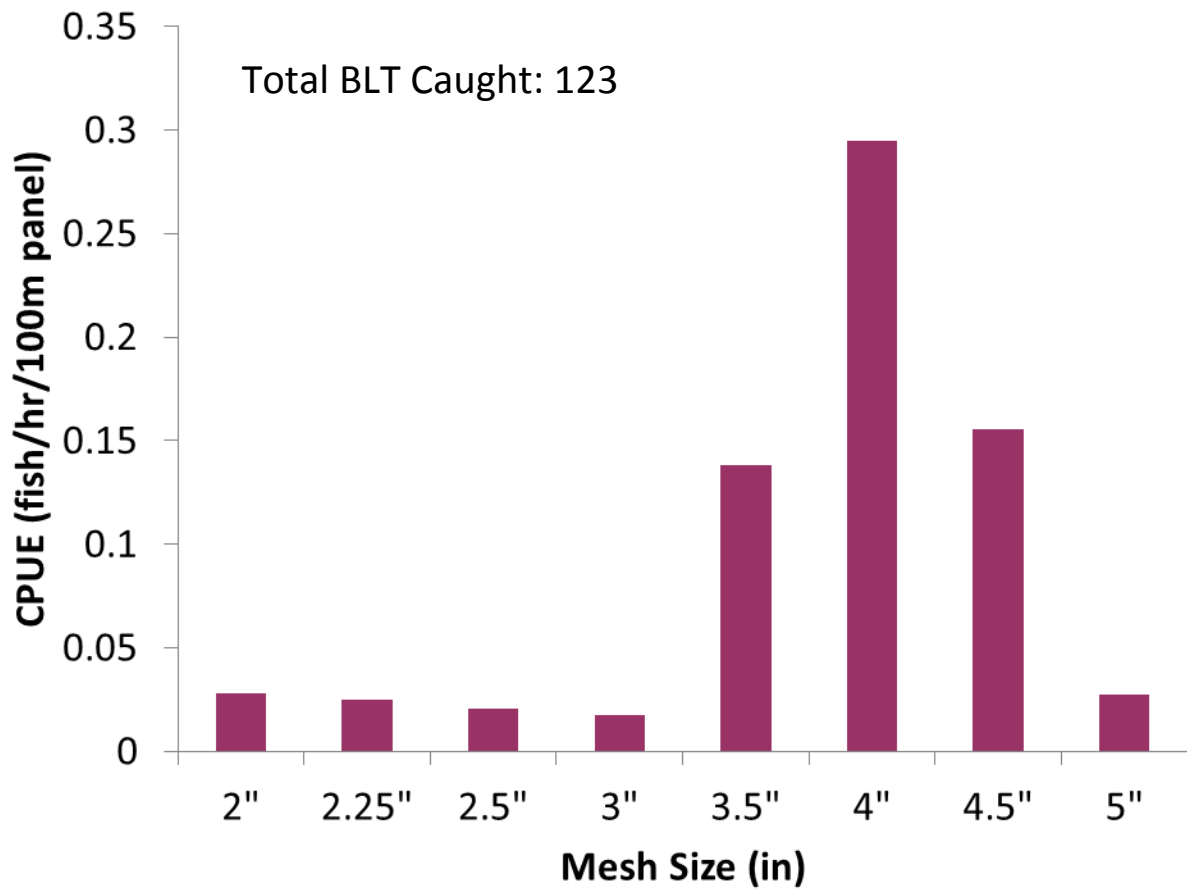


Figure 7. Bull trout catch per unit effort (CPUE) stratified by mesh size for spring and fall 2010.

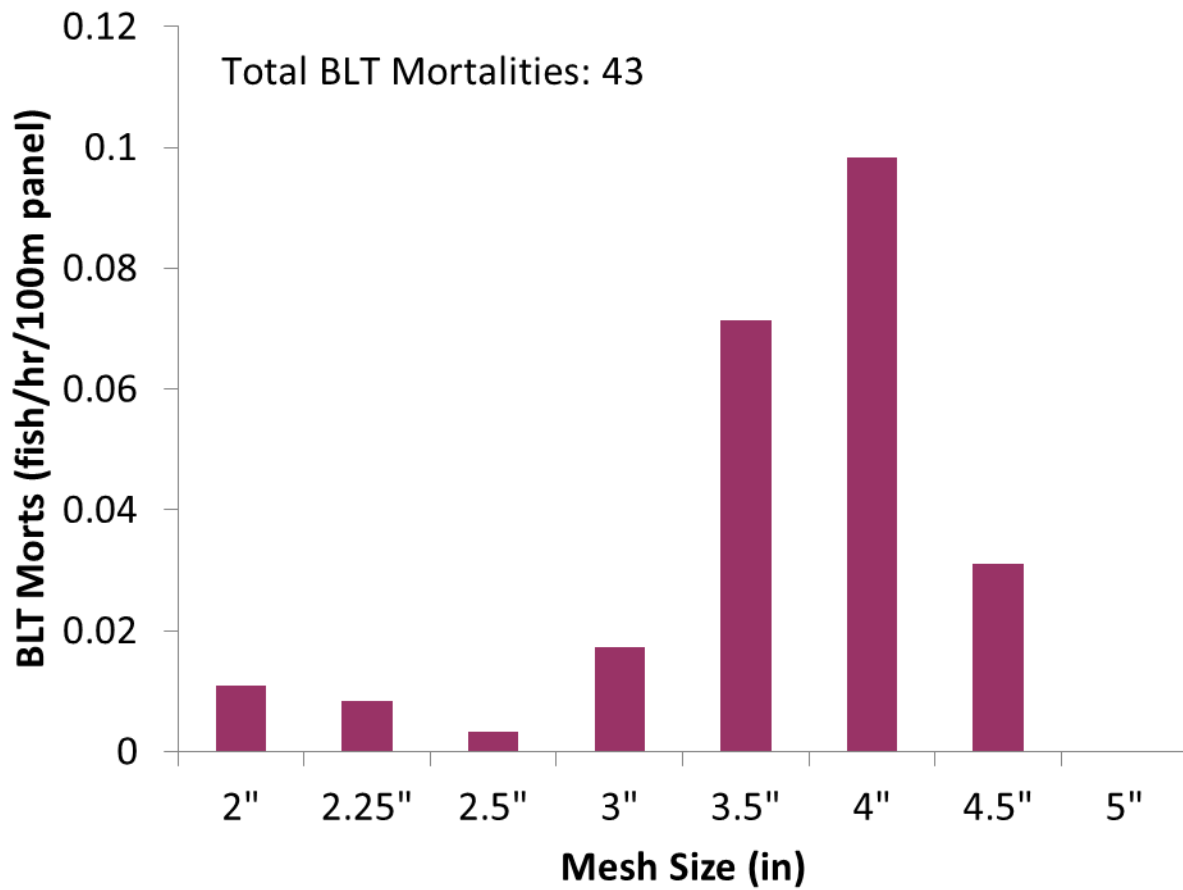


Figure 8. Bull trout mortality by mesh size for spring and fall 2010.