Review and recommendations for the upper Yellowstone River fisheries assessment project

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INTRODUCTION

Salmonids exhibit a complex variety of life history movements. These movements occur from spatial, seasonal, and ontogenetic separation of optimal habitats for growth, survival, and reproduction (Northcote 1997). With the current trend to preserve genetically pure populations of inland cutthroat trout *Oncorhynchus clarkii* by isolating them above impassable barriers (Novinger and Rahel 2003; Colyer et al. 2005), we must understand that life history movements are fundamental determinants of population performance and central to fish ecology and management (Winemiller and Rose 1992). Telemetry studies have shown that salmonid species may make long migrations (Schmetterling 2001; Meka et al. 2003) or remain within a small area if habitat is optimal (Young 1996; Muhlfeld et al. 2001). Understanding of these complex movement patterns within drainages is a key to proper management and conservation of fish populations.

Intraspecific variations in life history characteristics have been documented for anadromous and potamodromous fishes across extensive geographic scales (L'Abee-Lund et al. 1989; Gresswell et al. 1994) and within the same drainage basin (Riget et al. 1986; Varley and Gresswell 1988; Hogen and Scarnecchia 2006). One life history type may be dominant for a species or even a particular population, but utilization of a combination of strategies is an important determinant of fish distribution and overall population health and survival. A review of potamodromy in salmonids showed that 16 of the 19 species examined displayed fluvial (occurring completely within a river) or fluvial-adfluvial (occurring within a river and spawning tributaries) migration patterns, 17 of the 19 also displayed lacustrine-adfluvial (occurring between a lake and tributary streams) movement, and 4 displayed allacustrine (occurring between a lake and outlet streams) movement (Northcote 1997). While fluvial headwater populations have natural limits on population size and sustainability in comparison to fish located in lower elevation, higher order streams (Wilcox and Murphy 1985; Allendorf and Leary 1988; Kruse et al. 2000), they are less susceptible to invasion of non-native species and anthropogenic influences (Varley and Gresswell 1988; Kruse et al. 2000). Yellowstone cutthroat trout *Oncorhynchus clarkii bouvieri* are an example of a species that uses multiple spawning migrations patterns across its range and within individual watersheds (Varley and Gresswell 1988; Kaeding and Boltz 2001). The occurrence of multiple migration patterns within a watershed suggests local adaptation to diverse habitats over time (Gresswell et al. 1994).

Yellowstone cutthroat trout evolved as the only trout species within the Yellowstone River and Snake River drainages above Shoshone Falls (Behnke 1992). With the exception of westslope cutthroat trout *Oncorhynchus clarkii lewisi*, the Yellowstone subspecies covered the largest geographic distribution of all inland cutthroat subspecies (Behnke 2002). Yellowstone cutthroat trout are believed to have derived in the Columbia River basin and passed from Pacific Creek to Atlantic Creek (Columbia to Missouri drainage) on Two Ocean Plateau just south of Yellowstone National Park in the Bridger-Teton Wilderness (Jordan 1892). This is thought to have occurred when the meadow between these two creeks, just 1/8 mile apart, was flooded. From here they descended into Yellowstone Lake and throughout the Yellowstone River basin (Jordan 1892).

More recently distribution and abundance of Yellowstone cutthroat trout has declined greatly throughout its historic range (Behnke 2002). These declines are most severe in high-order, low-elevation streams where human impacts are greatest (Gresswell and Varley 1988; Kruse et al. 1997). The subspecies has been petitioned for, and denied listing as a threatened species under the Endangered Species Act in 1998 and 2004 (USFWS 2001, 2006). Although cutthroat trout are sensitive to changes in environmental conditions, the main cause for their decline has been the introduction of non-native species (Campton and Utter 1985; Kruse et al. 1997, 2000). Cutthroat trout are highly susceptible to hybridization with rainbow trout *Oncorhynchus mykiss* and replacement by brown trout *Salmo trutta*, brook trout *Salvelinus fontinalis*, and lake trout *Salvelinus namaycush* (Behnke 2002). Although a large portion of their current range is found within federally protected lands, Yellowstone cutthroat trout are still affected by nonnative fish introductions.

Cutthroat trout in Yellowstone National Park and the surrounding wilderness areas are not subject to the anthropogenic influences that affect many cutthroat populations, but are not immune to the effects of nonnative species introductions. Introduction of novel predators to lakes has had devastating effects on indigenous fish fauna (Ruzycki et al. 2003; Balirwa et al. 2007). From 1881 trough 1955 over 16 million non-native fish were stocked in Yellowstone Park waters (Varley 1981). Despite stocking 6,800 rainbow trout and 12,000 landlocked salmon in Yellowstone Lake (Varley 1981), Yellowstone cutthroat trout remained the only salmonid species in the Lake basin until lake trout were discovered in 1994. A study of otolith microchemistry indicates that initial introduction most likely took place in the mid- to late1980's (Munro et al. 2005). Lake trout are known to prey on native fish in lakes where they have been introduced, and can have a substantial negative impact on cutthroat trout populations (Ruzycki et al. 2003). In 1998, the organism that causes Whirling Disease was discovered in the Lake. The finding was made in adult cutthroat trout in the Lake, indicating that the disease had been present for several years before detection. The disease has caused major declines in salmonid populations in the American west and cutthroat trout are highly susceptible to the disease. In several Yellowstone Lake tributaries, the spawning run of cutthroat trout has declined over 98%

since the mid-1980's (Koel et al. 2007). These declines are most likely due to a combination of the impacts from lake trout, whirling disease, and a decade of severe drought (Koel et al. 2005). The discovery and effects of these two non-native invaders was of great concern for Yellowstone National Park fisheries biologists.

Cutthroat trout play a significant role in the Yellowstone Lake ecosystem by providing an important trophic link to the terrestrial community (Ruzycki et al. 2003). Cutthroat trout have a predominately shallow water distribution and spawn in tributary streams exposing them to an increased risk of predation. In the Yellowstone Lake system, up to 42 bird and mammal species are believed to use cutthroat trout as a food source (Varley and Schullery 1995). Conversely, lake trout have a deep water distribution and do not use tributary streams to spawn. Therefore, lake trout are not considered to be a viable replacement for cutthroat trout.

Fishes in Yellowstone National Park have been studied extensively since the late 1800's. In 1889, David Starr Jordan was commissioned to visit the Park, "for the purpose of procuring exact data preliminary to the work of introducing trout and other fishes" (Jordan 1891). During the expedition he visited many of the waters in and around Yellowstone Park, including Yellowstone Lake and the upper Yellowstone River documenting trout in many waters. Although his expedition did not visit any tributaries of the upper Yellowstone, Jordan states, "Common report says that all are well stocked with trout" (Jordan 1891). Since then, cutthroat trout in the Yellowstone Lake basin have been studied extensively. Spawning runs of cutthroat trout have been documented in 68 of the 124 known tributaries of Yellowstone Lake (Jones et al. 1986). Some of these streams, such as Clear, Pelican, and Arnica creeks, have been monitored since the mid-1940's. Cutthroat trout homing to natal streams, returning to the same stream in successive or later years has been documented in Yellowstone Lake tributaries (Ball 1955; Cope 1957; McCleave 1967; Jones et al. 1986).

Yellowstone Lake cutthroat trout display all four spawning life history migrations discussed earlier: lacustrine-adfluvial, fluvial, fluvial-adfluvial, and allacustrine. Within the Yellowstone Lake basin, the lacustrine-adfluvial migration pattern is most common (Gresswell et al. 1994), but is relatively rare over the entire Yellowstone cutthroat trout distribution (YCT status review Feb. 2006). Because of this, effective conservation of this metapopulation of cutthroat trout requires a comprehensive understanding of their life histories. For the most part, cutthroat trout spawn between April and August in the tributaries of Yellowstone Lake (Ball 1955; Gresswell et al. 1997). Spawners spend from 1 to 3 weeks in the stream before returning to Yellowstone Lake (Gresswell et al. 1997). Upon emergence, most fry begin to migrate downstream to Yellowstone Lake, but some may over-winter and migrate the following summer as fingerlings (Ball and Cope 1961). The exception to this appears to be Pelican Creek, the second largest tributary to Yellowstone Lake, where spawners have been reported to over-winter and many fry move downstream in their second and third years (Bulkley and Benson 1962). Despite the plethora of data existing on Yellowstone cutthroat trout in the Yellowstone Lake basin, the largest tributary to the lake, the upper Yellowstone River, remained relatively unstudied. Because of its remoteness, over 30 miles to the nearest road in some areas, no comprehensive assessment of the cutthroat trout in this region had been undertaken. The lack of fisheries knowledge in this region and recent attempts to list the Yellowstone subspecies as a threatened or endangered species lead to the initiation of a complete fisheries assessment of the upper Yellowstone River basin.

Our study used a combination of radiotelemetry, underwater census, electrofishing, and habitat assessment to examine the life-history and distribution of Yellowstone cutthroat trout in the upper Yellowstone River basin. The objectives of this project were to determine the spawning life history movements, distribution, and habitat use of Yellowstone cutthroat trout in the upper Yellowstone watershed. Based on insight gained through previous studies of other tributaries of Yellowstone Lake potamodromous salmonids, we hypothesized that cutthroat trout in the upper Yellowstone River basin would (1) exhibit extended rearing and multiple life history characteristics, (2) migrate long distances to spawn, (3) spawn over a wide range of locations in the main-stem and tributaries, and (4) fluvial populations would be present in the system. Knowledge gained through this study will provide insight to methods that will help guide management decisions of Yellowstone cutthroat trout in this region and throughout their range.

METHODS

Assessment of movement patterns

STUDY AREA

The Yellowstone River begins in northwestern Wyoming in the Bridger-Teton Wilderness Area and flows north into Yellowstone National Park to its confluence with Yellowstone Lake. The river exits the lake and continues to flow north, northeast to its confluence with the Missouri River, 1,113 km from its source. The project study area consisted of the upper Yellowstone River and tributary streams from its headwaters on the southeast and northwest slopes of Younts Peak to its mouth at Yellowstone Lake. From the confluence of the North and South forks (9.2 km and 11.4 km respectively) the Yellowstone River flows 73 river kilometers to its mouth at Yellowstone Lake. The basin contains over 200km of tributary streams and covers an area about 1,244 km^2 (Figure 1). We also included Yellowstone Lake, several tributaries located in the Southeast Arm of the lake, and the Yellowstone River from the Yellowstone Lake outlet to the Upper Falls in radio tracking events.

The upper reaches of the Yellowstone River consist of riffle-pool complexes that flow through steep forested slopes consisting of lodgepole pine *Pinus contorta*, whitebark pine *Pinus albicaulis*, douglas fir *Psuedotsuga menziesii*, and blue spruce *Picea pungens*. The lower two-thirds of the upper River consists of long runs, glides, and pools. The over-story is similar in structure to the upper reaches lacking only whitebark pine, but the under-story includes fields of willow *Salix spp.* and grasses. Burned patches from 1988 and 2003 fires are located throughout the watershed. Native fish species in the system include Yellowstone cutthroat trout and longnose dace *Rhinichthys cataractae*. Nonnative species include redside shiner *Richardsonius balteatus*, longnose sucker *Catostomus catostomus*, lake chub *Couesius plumbeus*, and lake trout.

Our primary method for examining the movements of adult Yellowstone cutthroat trout was radiotelemetry. From 2003 through 2005, National Park Service and Wyoming Game and Fish personnel surgically implanted 13-g radio-transmitters into cutthroat trout in the Yellowstone River and several tributaries. Transmitters were programmed with one of three duty cycles, (6 months on, 12 h on), (12 months on, 12 h on), and (3 months on, 8 h on). The use of varying duty cycles allowed us to assess movement during periods of heavy migration potential over several years as well as movement throughout an entire year. This aided in determining spawning migration movements and winter habitat use. Our tagging design called for equal distribution of implantation sites throughout the main-stem of the Yellowstone River, Thorofare Creek and tributaries, if logistically possible. Implantation dates were to be spread from May through September. Data from other spawning tributaries of Yellowstone Lake (i.e. Clear Creek, Pelican Creek, Arnica Creek, and Bridge Creek) indicated that lacustrine-adfluvial cutthroat trout have exited spawning tributaries by mid-July (NPS unpublished data). Therefore, tagging dates after August 1 were more likely to target resident cutthroat trout in the system. Spring run-off, ice cover on Yellowstone Lake, and bear closures all prevented entry at earlier dates.

Angling was our primary method of fish collection; however, fyke, trap, and gill-nets were used in the mouth of the Yellowstone River and approximately 0.4 km upstream. Five transmitters were placed in Yellowstone Lake at known locations and depths to test the accuracy of flight relocation data. All fish collected were measured (total length mm), weighed (g), sexed, and had their GPS location noted. Scale samples for aging, and fin clips for future genetic testing were collected from a subsample of fish during tagging operations.

For surgery, fish were anaesthetized with clove oil (1:10 clove oil:ethanol) and placed on their dorsum in a V-shaped operating table. Gills were irrigated with fresh water throughout surgery. A 2-cm long incision was made in the abdominal cavity just anterior of the pelvic girdle approximately 1-cm from the midventral line. A small hole was punctured about 3-cm to the posterior of the incision using a horse catheter to guide the trailing whip antenna through the body wall. The incision was closed with two or three sutures (Ethilon black monofilament nylon). Fish were held in live cars until equilibrium was reached and allowed to swim out on their own volition.

Fish movements were monitored weekly using a fixed wing aircraft and supplemented with ground truth trips as time permitted from May through August (Figure 2). Flights were conducted twice monthly for September and October, and monthly from November through April. Surveys of Yellowstone Lake were conducted using an aircraft outfitted with a directional Yagi antenna and boat using a handheld Yagi antenna as time and funding permitted. All tracking data were collected using an Advanced Telemetry Systems R4500 radio transmitter receiver and data logger. The data logger is capable of recording tag frequency, code number, date, time, signal strength, and GPS. Fish found overwintering in the Yellowstone River basin would be classified as resident fish.

For analysis, fish were grouped into four movement categories following those described by Kaeding and Boltz (2001). Group 1 consisted of fish relocated in Yellowstone Lake, Group 2 consisted of fish thought to have entered the lake. These fish showed a distinct downstream migration pattern until their signal was lost or fish whose signal was lost following the spawning season, but were found in the river system in subsequent years. Group 3 consisted of fish that displayed fluvial or fluvial/adfluvial movements, and Group 4 consisted of fish that were omitted from analysis because of either no or too few relocations to accurately determine life history type. We assigned known mortalities to either group 1, 2, or 3 based on movement patterns prior to death. If we could not determine movement patterns fish were placed into Group 4.

Cutthroat Trout Distribution

Study Area

The study area for this portion of the study consisted of the Yellowstone River within the Yellowstone National Park boundary and its tributary streams. Fisheries assessments were conducted on all waters and habitat assessment inventories were conducted on the Yellowstone River and Mountain and Howell creeks. The main-stem River covers 41 Rkm from its mouth at Yellowstone Lake to the Parks' southern boundary (Figure 3). Over these 41 Rkm the Yellowstone River gradient is low (0.8 m/Rkm) and consists of long runs and glides with few pools or riffles. Over-story is dominated by lodgepole pine and under-story consists of willow and grasses. The Mountain Creek drainage (Mountain Creek, Howell Creek, and several unnamed tributaries) cover approximately 176 square kilometers (Figure 3). Mountain Creek originates high in the Absaroka Mountains in the Teton and Shoshone National Forests over 3,200-m in elevation. The stream has a steep gradient down to entry of the Yellowstone River floodplain. Over-story is dominated by lodgepole pine and under-story is dominated by grasses and willow. Other tributaries sampled were Cabin, Trappers, Cliff, Escarpment, Badger, and Phlox creeks (Figure 1). Tributaries were generally high altitude, headwater streams with steep gradients down to entry of the Yellowstone River floodplain. Over-story is dominated by lodgepole pine and under-story is dominated by grasses and willow.

To determine cutthroat trout distribution in the main stem of the Yellowstone River within the Yellowstone National Park boundary, we sampled 500-m randomly selected sections in each river kilometer using both underwater census and electrofishing. For underwater census surveys, three snorklers drifted downstream through sample sections. Divers were spaced across the river in order to sample as much of the channel width as possible. Fish were identified to species, counted, and cutthroat trout were placed into one of four categories based on total length (<70 mm, 70 – 150 mm, 150 – 330 mm, and >330 mm).

Electrofishing surveys took place in the same sections as snorkel surveys using a 5-m long raft outfitted with electrofishing equipment. Electrofishing began a minimum of 30-min. after snorkel surveys to allow fish to redistribute if displaced by divers. Each section was sampled on two dates in September approximately 10 d apart to produce mark-and-recapture data for population estimates. Each fish collected was measured for total length (mm), weighed (g), and clipped for identification purposes. Scale samples for aging and tissue samples for future genetic analysis were collected from a sub-sample of captured cutthroat trout.

In tributary streams, distribution surveys were preformed in Trappers, Mountain, Howell, Phlox, Cliff, Escarpment, and Badger creeks and their tributaries. All streams were sampled during low flow periods (August to October) to increase the effectiveness of electrofishing and allow for migratory fish from Yellowstone Lake to leave the system. Each creek was divided into 1-km sections, and each kilometer was further divided into ten 100-m long reaches; one of the 10 reaches was randomly selected for sampling. Fish distribution and abundance was assessed using single-pass electrofishing with a backpack electrofisher, a method that has been shown to be an effective method for estimating fish abundance in mountain streams with sparse habitat (Kruse and Hubert 1998). Each site was sampled using one pass with the backpack electrofishing unit. Wyoming Game and Fish personnel performed similar surveys in waters outside the park boundary in Thorofare, Open, Dell, Atlantic, Elk, Coyote, and Hidden creeks.

Main-stem habitat assessments were conducted in all sample sites. Units were assigned riffle, run, glide, or pool designation by a trained observer. Thalweg depth and wetted width were measured (0.1-m) and dominant substrate was identified (bedrock, boulder, cobble, gravel, or fines) longitudinally, every 10-m throughout each sample section. Large woody debris (>3-m n length and 0.1-m in diameter) was counted and identified as single pieces or jams (> 20 pieces in contact). Undercut and unstable bank were measured for total length within each reach and dominant over and under-story were visually estimated. Stream gradient determined using maps in ArcGis (ArcMap version 9.2)

Tributary habitat sampling was conducted using a modified version of the National Forest Service R1/R4 Fish Habitat Assessment protocols (Overton et al. 1997). Within each reach, habitat units were identified to the pool/riffle level according to Frissell et al. (1996). Wetted width (0.1-m) and mean depth (0.01-m) were measured along transects every 10-m and mean values were determined for each habitat unit. Maximum pool and pool crest depths (0.01-m) were measured in each site. Length of undercut and unstable bank was measured and dominant substrate was visually categorized. Channel type was determined according to Rosgen (1994).

RESULTS

We successfully implanted transmitters in 152 of the 212 adult Yellowstone cutthroat trout captured from 2003 – 2005. Fish not implanted were either too small (n = 4), surgical mortalities (n = 2), or captured after our quota for an area was filled (n = 54). The majority of the tagged fish were captured by angling (n = 144), followed by gill-netting (n = 6), and fyke-netting (n = 2). Unfortunately, we were unable to tag an equal number of fish during spawning (May – July, n = 146) and post spawning season (August – October, n = 6). Almost half of the trout (n = 70) were implanted in the main stem Yellowstone River (Figure 4, Table 1). The remaining fish were implanted in tributaries of the mainstem (n = 74) or in Yellowstone Lake (n = 8). Fish implanted with transmitters averaged 460 mm in total length (SD 24.1, range 400 – 544 mm) (Figure 5). We found no significant differences in the total length of fish tagged in the main-stem Yellowstone River, tributaries of the River, or Yellowstone Lake (ANOVA, P = 0.25).

We were able to classify movement patterns for 95 (62.5%) of the 152 fish implanted with radio-transmitters. We classified 60 (63.2%) fish as Group 1, 31 (32.6%) as Group 2, and 4 (4.2%) as Group 3 (Table 2). Group 4 consisted of the 57 fish not used for analysis. Of these 57 fish, 39 were not relocated after initial tagging, 17 were mortalities, and one fish tagged in Yellowstone Lake at the mouth of the Yellowstone River never entered the river system. The 95 fish were relocated an average of 4.7 times (range of 1 to 29) over the four years of tracking flights. To test if tag implantation affected upstream migration distance during the year of implantation we combined groups 1 and 2 for analysis. We found that transmitter implantation had no significant effect on maximum upstream distance traveled within or between years (ANOVA, $P = 0.78$).

Spawn Timing

Date of entry and spawn date differed significantly for the two groups (t-test, $P = 0.04$, and $P = 0.001$ respectively) over all years, but exit date did not (t-test, $P = 0.71$). Mean date of river entry occurred on Julian day 169 (June 18; range 144 – 201) for Group 1 and Julian day 159 (June 8; range 144 – 189) for Group 2. Fish reached spawning grounds on Julian day 183 (July 2; range 154 – 224) for Group 1 and day 191 (July 10; range 154 – 228) for Group 2. Group 1 fish exited the river on Julian day 194 (July 13; range 165 – 255) and Group 2, Julian Day 197 (July 16; Range 152 – 266) (Table 3).

We found that spawn date (t-test, P = 0.35 Group 1, P = 0.75 Group 2) and river exit date (Kruskal-Wallis, P = 0.69 Group 1, ANOVA, P = 0.37 Group 2) did not differ significantly between years for either Group 1 or 2. Entry date did not differ for Group 2 (t-test, P = 0.98) but did differ significantly for river entry date for fish from Group 1 (t-test, P = 0.01) (Table 3). Scheffe's post-hoc multiple comparison tests showed no significant difference between 2003 and 2004, but did show significant differences between 2003 and 2005 as well as 2004 and 2005. Data showed fish were concentrated in the river system from mid-May through mid-July. Typically cutthroat trout returned to Yellowstone Lake by July 16 each year, but several returned to the lake as late as September 21 (Figure 6).

Spawn Location

Upstream migration distances did not differ for cutthroat trout for groups 1 and 2 (t-test, $P = 0.99$) or for Group 2 between years (Kruskal-Wallis, P = 0.05). However, migration distance did differ for Group 1 between years (Kruskal-Wallis, P = 0.01). This difference is most likely because of our implantation locations in the different years. For all waters, Group 1 fish migrated an average of 40.8 km (range 3.2 – 65.1 km) upstream from Yellowstone Lake to spawning sites while those from Group 2 traveled 45.4 km (range 11.7 – 65.9 km) (Figure 7 Table 3). Spawning grounds were identified in 11 locations throughout the basin (Figure 8). Few spawning areas were documented downstream of the Cliff Creek confluence with the Yellowstone River. Spawning trout were identified in 7 sites in the main-stem Yellowstone River and an additional 4 sites in tributary streams (Table 4). Trout in spawning condition were implanted in additional tributary streams, but spawning locations could not be identified.

Iteroparity was displayed by 29 fish from groups 1 and 2. Repeat spawners typically returned to the same spawning location as previous years. Of these 29 fish 2 were killed or dropped their transmitter shortly after beginning their upstream migration and were not considered for this portion of analysis. We also did not consider year 1 locations for 2 fish tagged after August 1 since these individuals were likely on post-spawn downstream migrations. On average, return spawners were found within 3.7 km (range 0 – 52 km) of their previous spawning location (Table 3). Only 2 of 27 fish that did not return in year 2 returned to spawn in year 3. Seven male fish returned to spawn in all three seasons.

We found no distinct migration pattern for fish from Group 3. All fish were implanted in the Yellowstone River, 3 within 2 km of the Parks south boundary and 1 south of the Park at Castle Creek. The fish implanted at Castle Creek moved to the Park boundary following the spawning period. Home ranges averaged 13.9 km (range 4.6 – 33 km) and no fish entered tributary streams. Spawning location and timing could not be determined as fish moved throughout their ranges throughout the season.

Distribution

Juvenile (fish ≤ 3 years old) and adult Yellowstone cutthroat trout were rare in the mainstem Yellowstone River. A total of 125 cutthroat trout were observed during underwater surveys in the 41 reaches of mainstem River (Figure 9). Juvenile cutthroat trout were observed on the stream substrate, aquatic vegetation, and stream margins. Adult cutthroat trout were mainly observed in deep water areas with unstable banks. Approximately 60% of all cutthroat trout >330 mm long (n = 70) were observed in only four of the 41 sections.

Electrofishing surveys mirrored the results of the underwater census survey in the mainstem. During the mark run, 130 cutthroat trout were captured in 39 sites (sites 32, 33, and 34) were omitted due to heavy lightning and unsafe conditions). We sampled 71 cutthroat trout in 40 sites (2 sites 40 and 41 were omitted due to weather conditions) during our recapture run. Unfortunately no fish from our mark run were recaptured making a population estimate impossible. Juvenile cutthroat trout were captured throughout the river with the exception of the 5km upstream of Yellowstone Lake. Adult cutthroat trout were less evenly distributed with 52% (13 of 25) being collected in only 3 reaches. Length frequency data indicate that the population consists mainly of juvenile fish with few adults found in the system (Figure 10).

Backpack electrofishing of tributary streams of the Yellowstone River within Yellowstone National Park produced cutthroat trout juveniles and adults. Cutthroat trout ranged from 26 to 305 mm in total length with the largest fish being captured in an unnamed tributary to Mountain Creek (Figure 11). Juvenile cutthroat trout were present below migration barriers in all streams surveyed with the exception of Cabin Creek. Migration barriers were defined as waterfalls or cascades with greater than a 1-m vertical drop or areas with 10% or greater gradient. Larger (> 200 mm), older cutthroat trout were present only in the headwater reaches without migration barriers in Mountain and Howell creeks, and an unnamed tributary to Mountain Creek. Small, mature fish were located in one spring tributary to Trappers Creek above a migration barrier. These fish were isolated in an approximately 1.5-km spring that traveled over a 2-m waterfall into Trappers Creek.

Habitat

Habitat characteristics of the mainstem Yellowstone River were somewhat homogenous. Features are consistent with what one would expect to find in a low gradient river system. The river is dominated by long run (72%) and glide (19%) habitat units throughout the 41 Rkm located within the Yellowstone National Park boundary (Table 6). Riffle (8%) and pool (1%) habitat made up only a small portion of the river. Over-story was dominated by lodgepole pine and under-story vegetation is dominated by willow and grasses. Wetted width averaged 40.7 m (range 20 – 70 m) and mean thalweg depth was 0.4 m. Substrate was a combination of cobble, gravel, and sand (Table 5).

Discussion

Efforts to implant cutthroat trout in even numbers throughout the drainage failed due to our inability to locate fish in all areas. We were also not able to capture and implant an equal number of fish during the spawning (n = 144) and post spawning (n = 8) periods. Logistical constraints prevented us from sampling reaches of the Yellowstone River above Woodard Canyon during implantation trips and a 4-km section of the Yellowstone River downstream of Cliff Creek was omitted from sampling due to high bear activity. Therefore implantation efforts were concentrated in areas where we were likely to detect lacustrine-adfluvial or fluvial-adfluvial fish. Later underwater census and electrofishing surveys detected small numbers of fluvial fish, indicating that this life history is present, but in low numbers. The paucity of adult cutthroat trout in the basin during indicates that our implantation efforts did not bias our results. Also, our inability to locate fish to tag after August 1 may have biased our tagging operations to favor lacustrine-adfluvial fish. This however, is unlikely, and the lack of fish present for tagging late in the season was most likely due to a true lack of resident fish in the main-stem river given the small number of fish >330 observed during underwater census and electrofishing surveys. Our inability to relocate 28% of our tagged fish after initial implantation was troubling and could be due to several factors. Fish may have quickly moved downstream into the lake and resided at depth greater than our detection range, remained in the river at depths greater than our detection range, been preyed or scavenged upon and tags moved out of the system, or transmitters may have malfunctioned.

The results of this basin-wide survey revealed insights into the complex life history characteristics of Yellowstone cutthroat trout in the upper Yellowstone River basin. Radio telemetry, underwater census, and electrofishing data collected from 2003 - 2006 indicate that cutthroat trout do remain in the river for extended rearing periods and multiple life history forms are present. Juvenile cutthroat trout, age 0 – 2, were collected throughout the mainstem River and tributary streams. Similar to other tributaries of Yellowstone Lake, the majority of cutthroat trout in the Yellowstone River exhibit the lacustrine-adfluvial life history. However, small groups of fluvial fish were also found in the basin. This has been previously documented in only one other tributary stream to Yellowstone Lake, Pelican Creek (Ball 1955; Gresswell and Varley 1988). These fluvial populations are found in both the mainstem Yellowstone River and several of its tributary streams. We could not determine spatial or temporal separation in the spawning migration of the two life history forms and no physical barriers were identified. The mechanism that causes some of these fish to migrate and others not to is unknown at this time.

We found that cutthroat trout traveled long distances and spawned throughout the basin. Telemetry data showed individual fish move up to 65 Rkm to spawning locations. Spawning locations were identified in the Yellowstone River, Mountain, and Thorofare creeks. Although we were unable to implant fish in all areas, later electrofishing surveys revealed the presence of cutthroat trout fry distributed throughout Trappers, Badger, Phlox, Howell, Cliff, Escarpment, Lynx, Atlantic, and Falcon creeks adding adds additional evidence that cutthroat trout not only migrate over a large area to spawn, but also spawn over a wide range of locations.

With the majority of fish in the Yellowstone River basin following the lacustrine-adfluvial life history, the River system most likely contributes significantly to the Yellowstone Lake population. To examine this closer, movement of juvenile cutthroat trout in the upper river basin should be examined in the future. To gain a better understanding of distribution and possible resident populations, headwater areas should be sampled more intensely. This area could be the last stronghold for Yellowstone cutthroat trout in this Yellowstone Lake system and all possible areas should be sampled. Understanding of the complex life history of cutthroat trout in the Yellowstone River is essential to developing proper management and conservation strategies within this watershed and for the subspecies. This study provides initial insight to developing these strategies.

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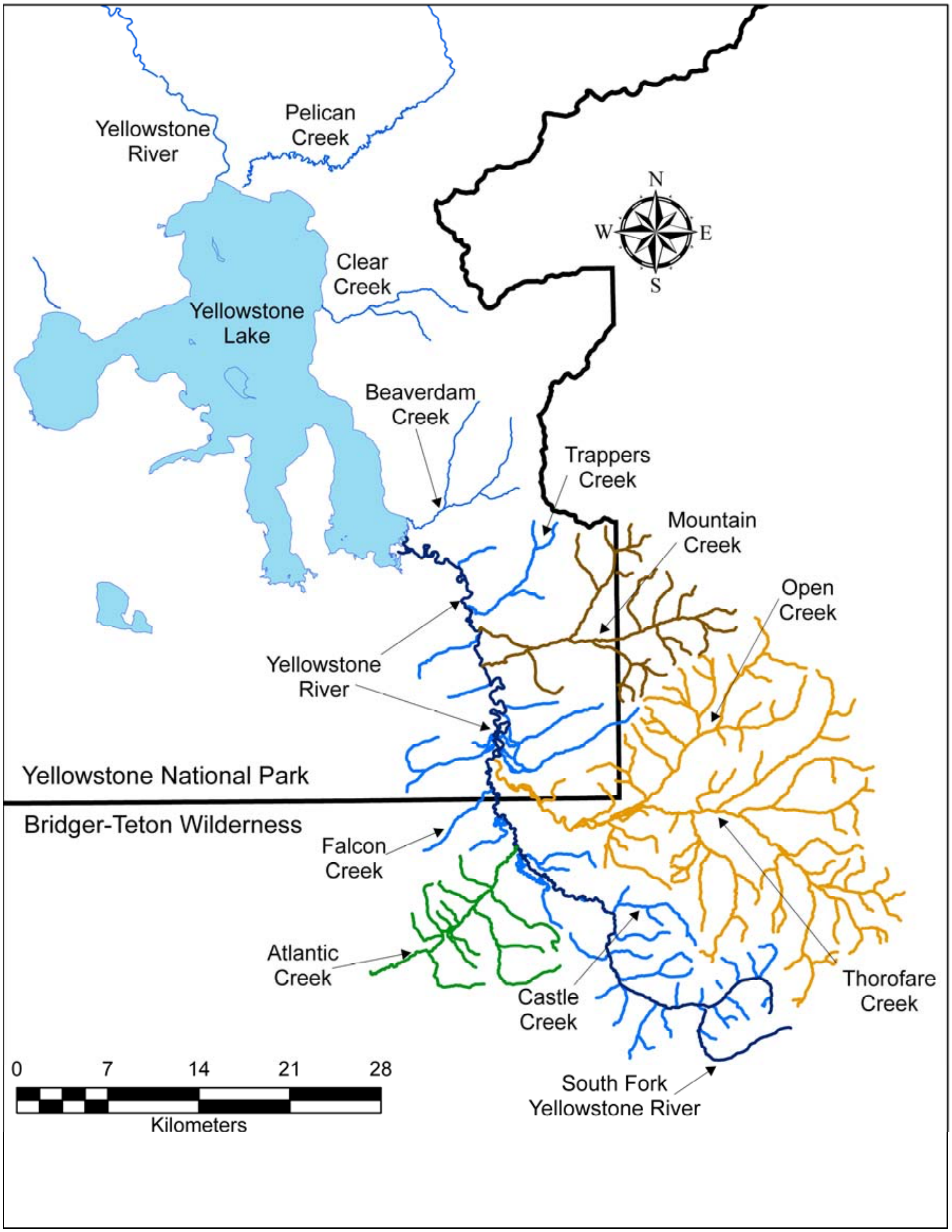

Figure 1. Upper Yellowstone River basin study area, Yellowstone National Park, Bridger-Teton Wilderness, Wyoming.

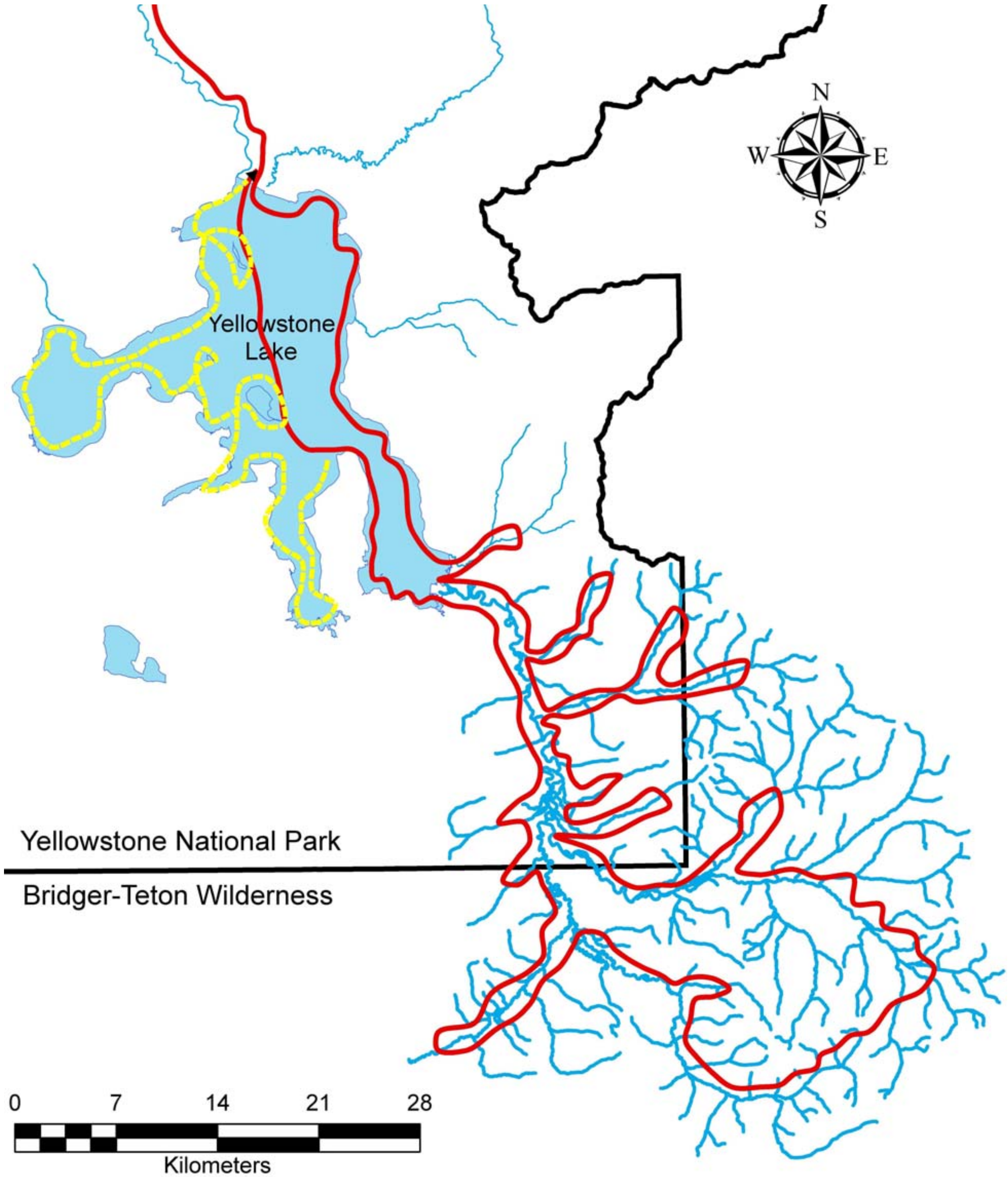

Figure 2. Tracking flight course. Flights were conducted in a fixed wing Super-Cub or Arctic Tern. Solid line indicates flight path taken in all years (2003 – 2006), dashed line indicates area added to flight path for 2005 and 2006.

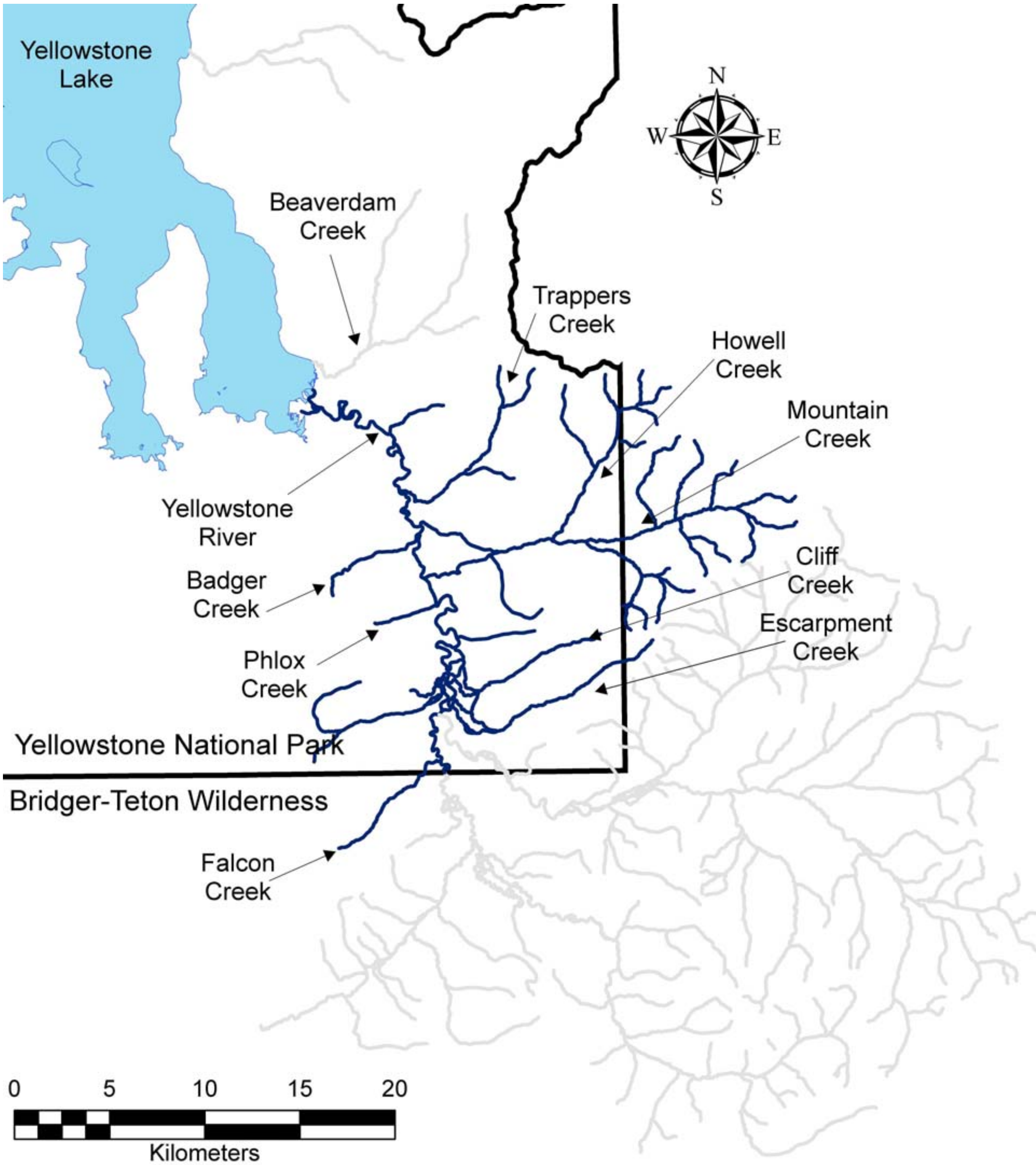

Figure 3. Upper Yellowstone River study area for distribution and abundance portion of the study. Area in blue indicates sample area.

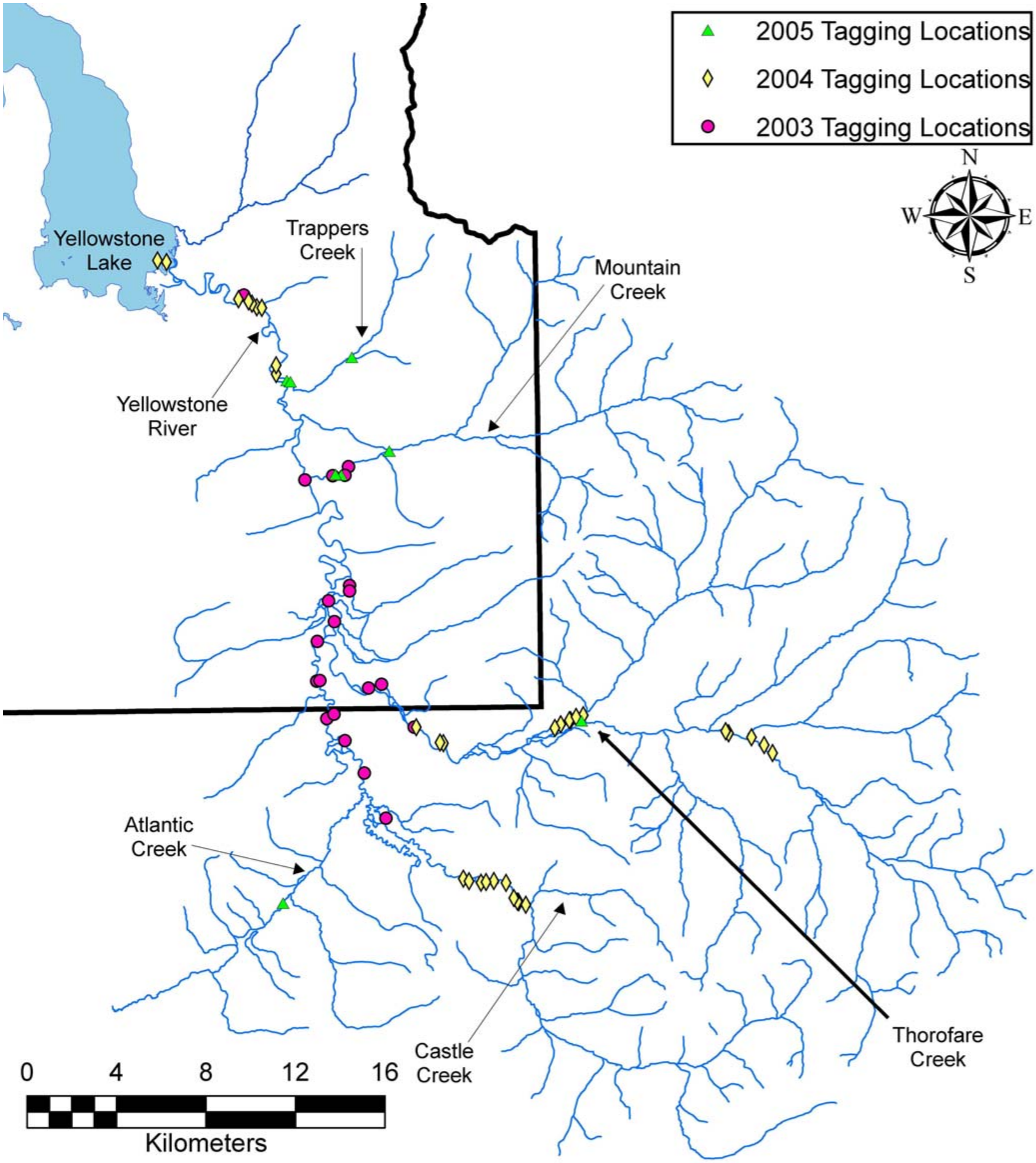

Figure 4. Locations of Yellowstone Cutthroat trout implanted with radio-transmitters in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

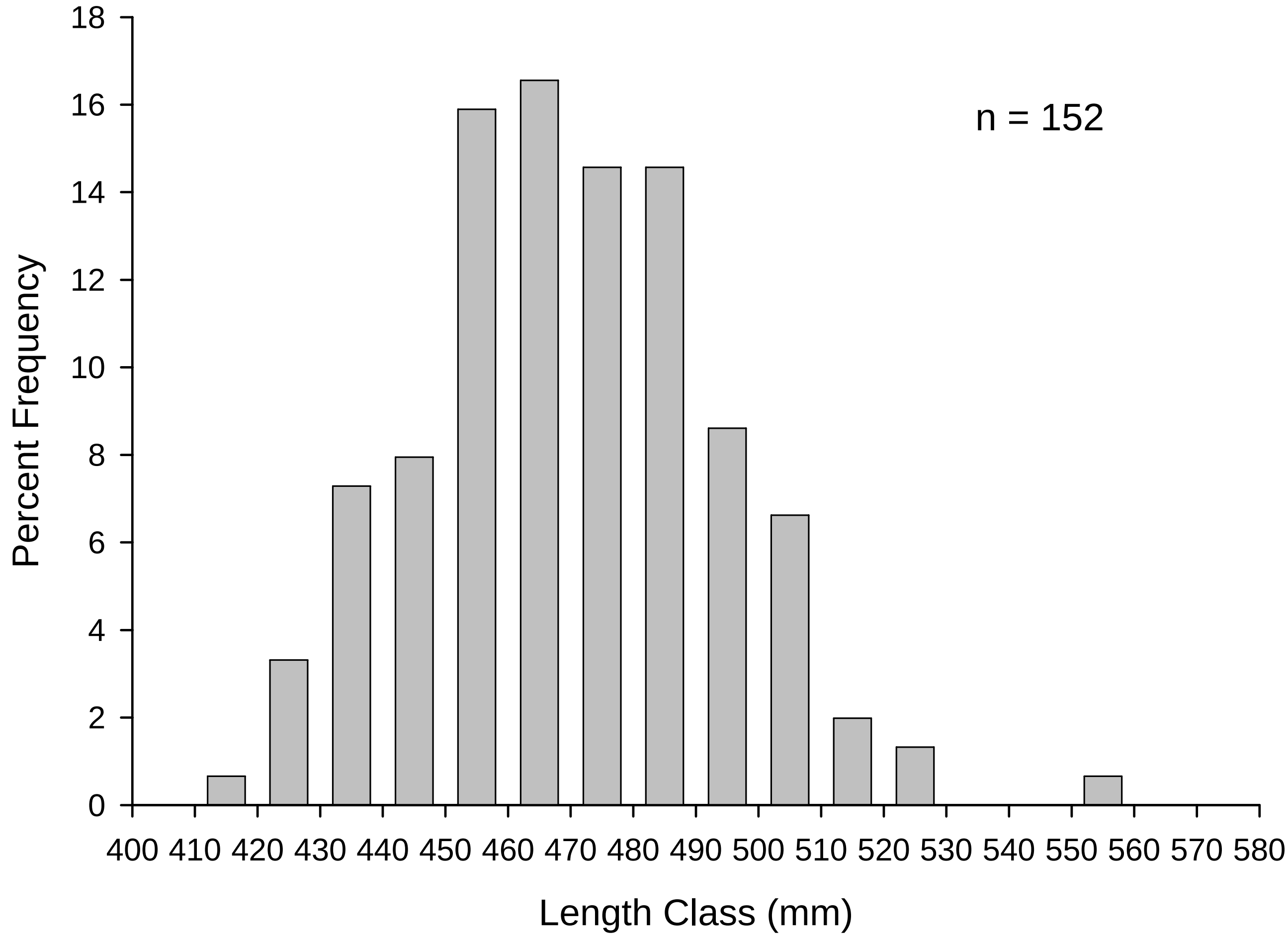

Figure 5. Length frequency of adult Yellowstone cutthroat trout implanted with radio-transmitters in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

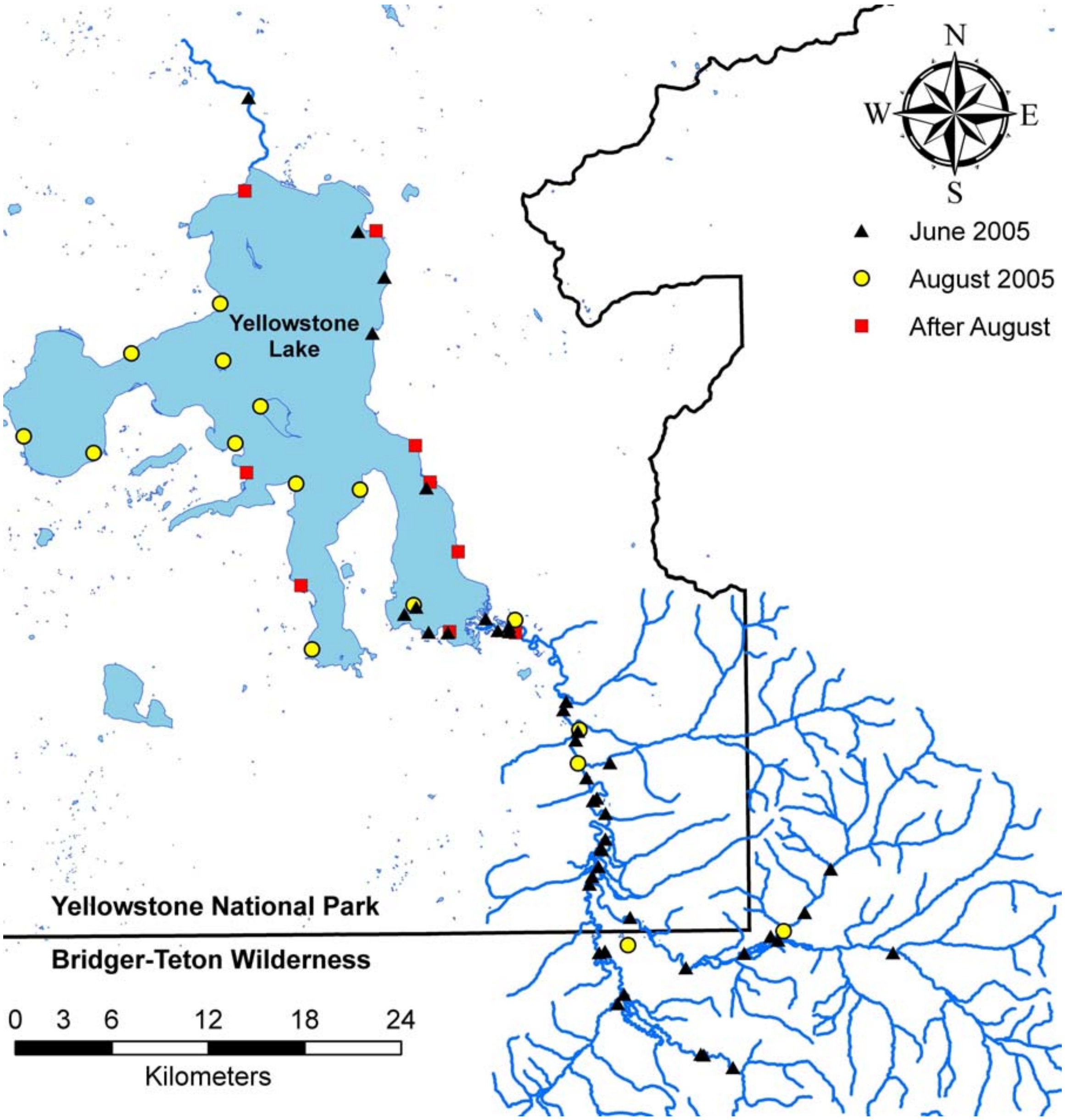

Figure 6. Location of cutthroat trout during the spawning (June 2005) and post-spawning period (August and post-August 2005), in the Yellowstone River and Lake watershed, Wyoming.

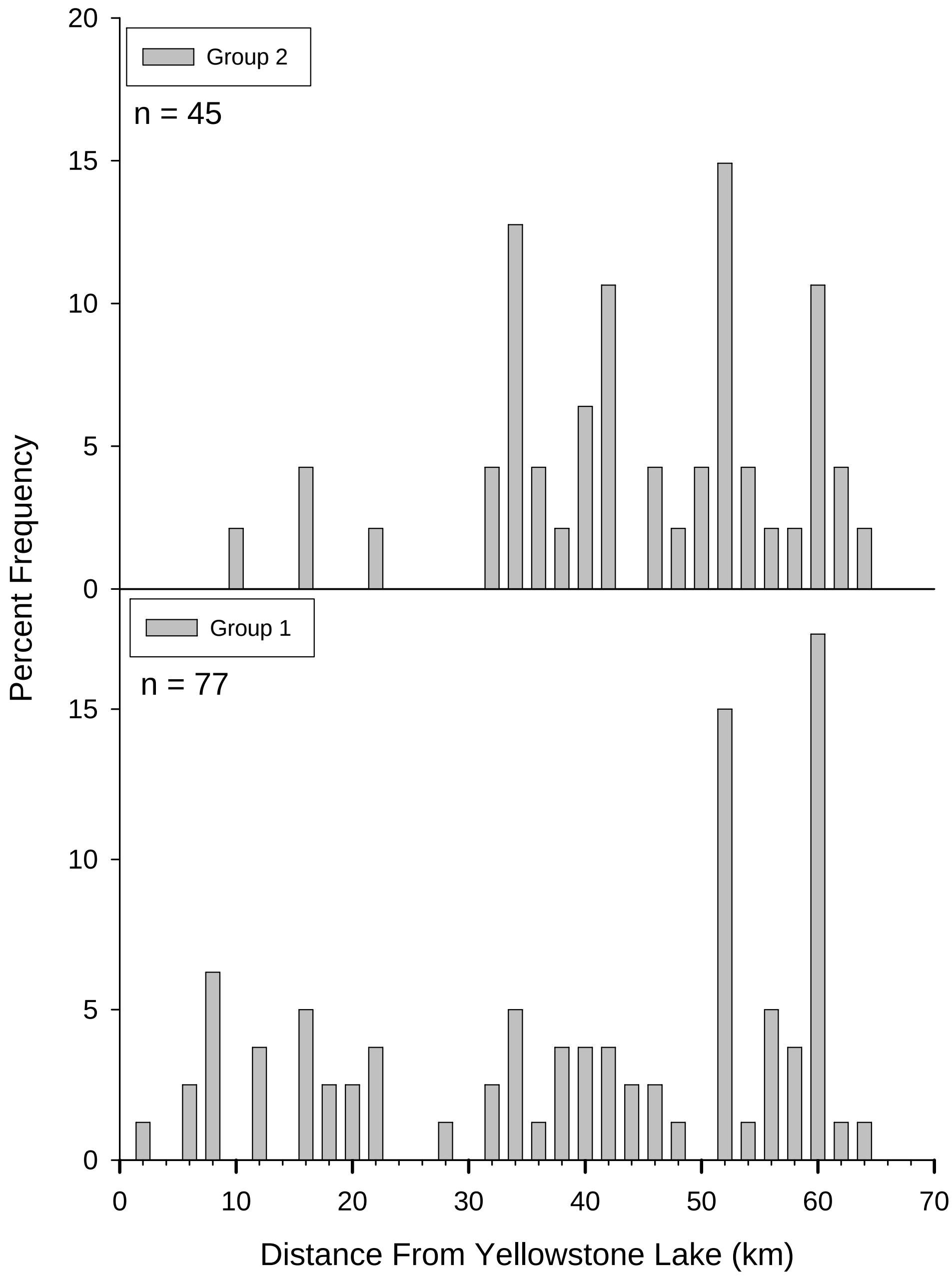

Figure 7. Upstream distance migrated from Yellowstone Lake by cutthroat trout implanted with radio transmitters in the upper Yellowstone River basin, Wyoming, 2003 – 2006. Group 1 represents fish that are known to have entered Yellowstone Lake; Group 2 represents fish that are thought to have entered Yellowstone Lake.

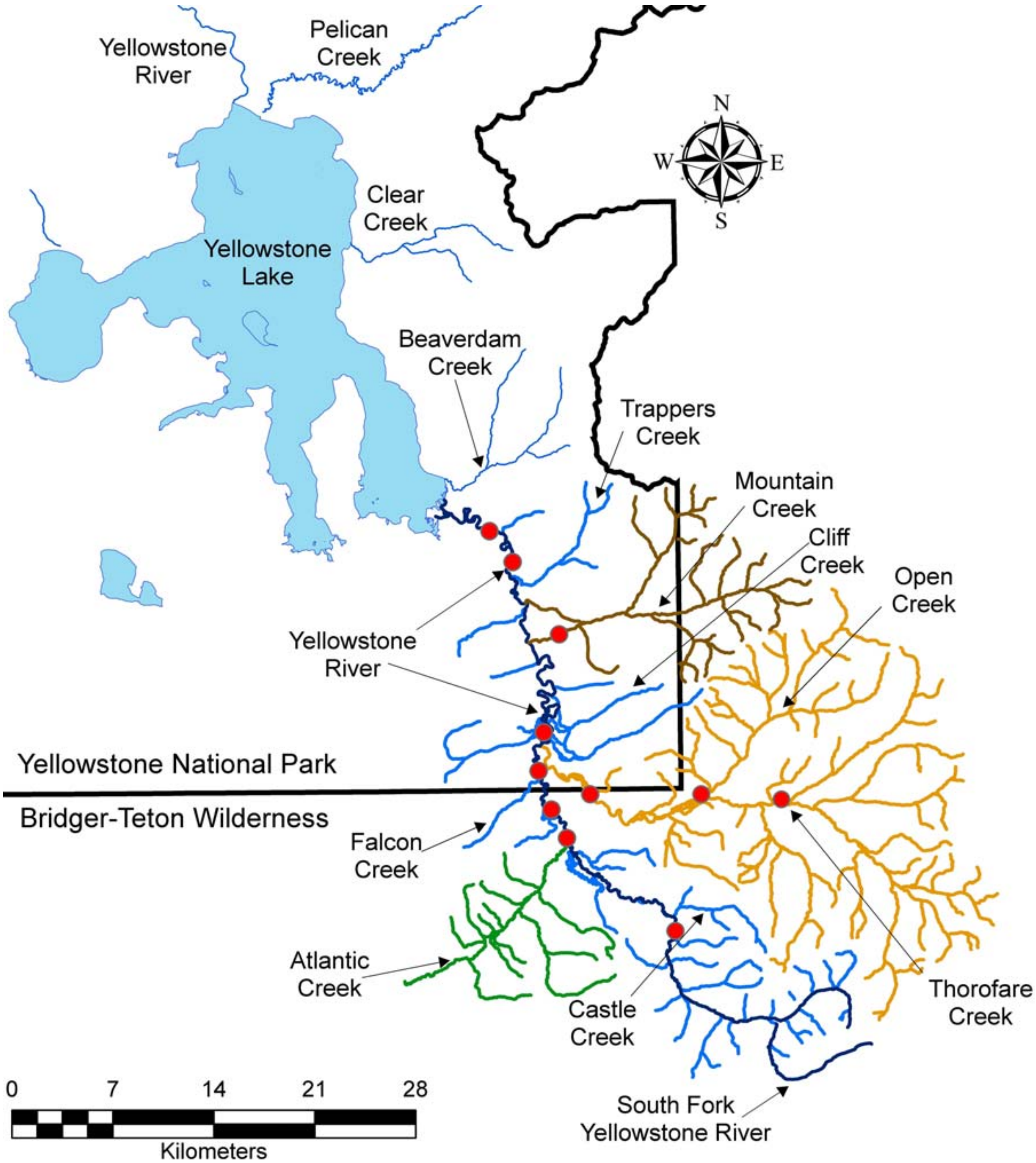

Figure 8. Spawning locations of Yellowstone cutthroat trout identified through radio-tracking of fish in the upper Yellowstone River basin, Wyoming, 2004 – 2006.

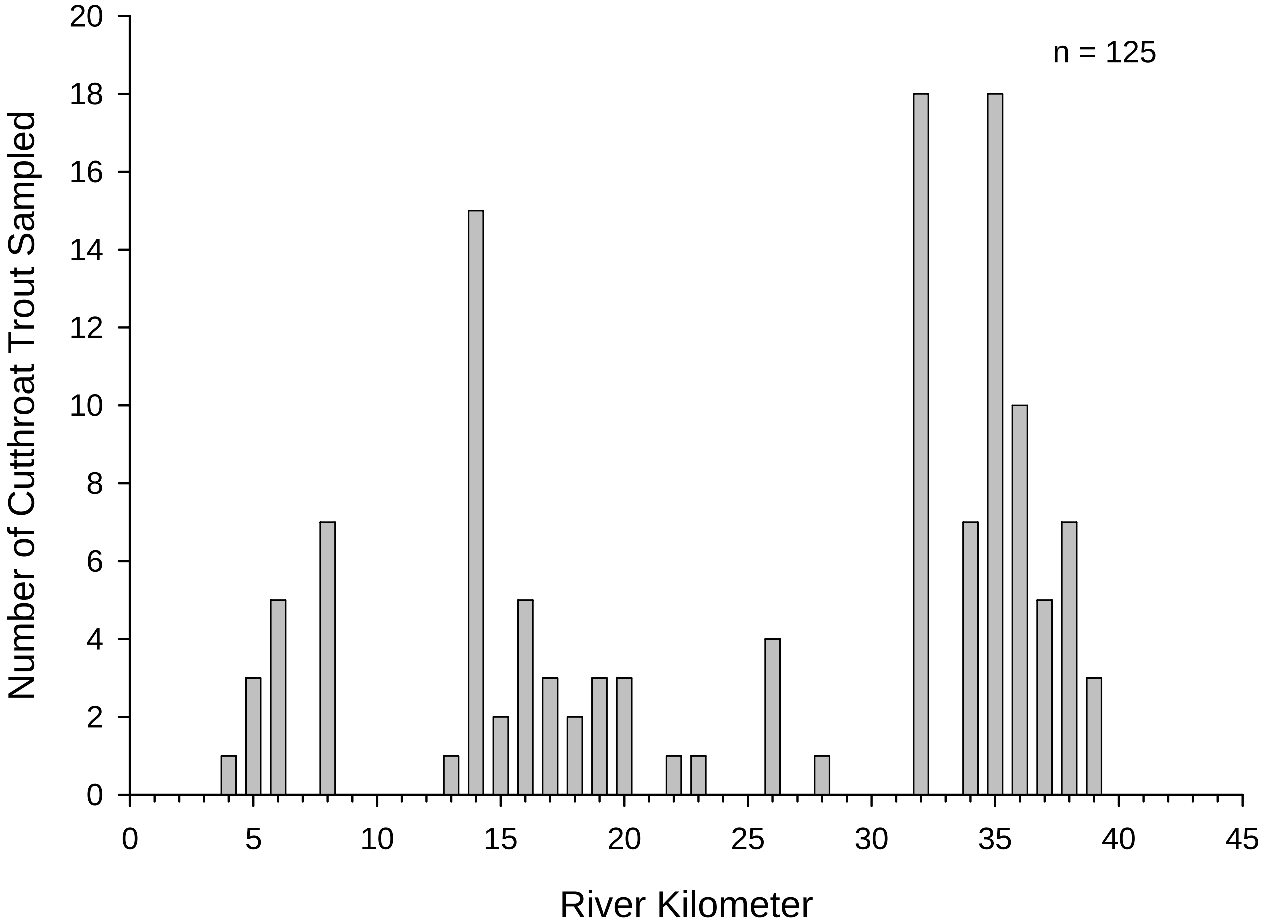

Figure 9. Distribution and number of Yellowstone cutthroat trout observed in the mainstem Yellowstone River during snorkel surveys 2006.

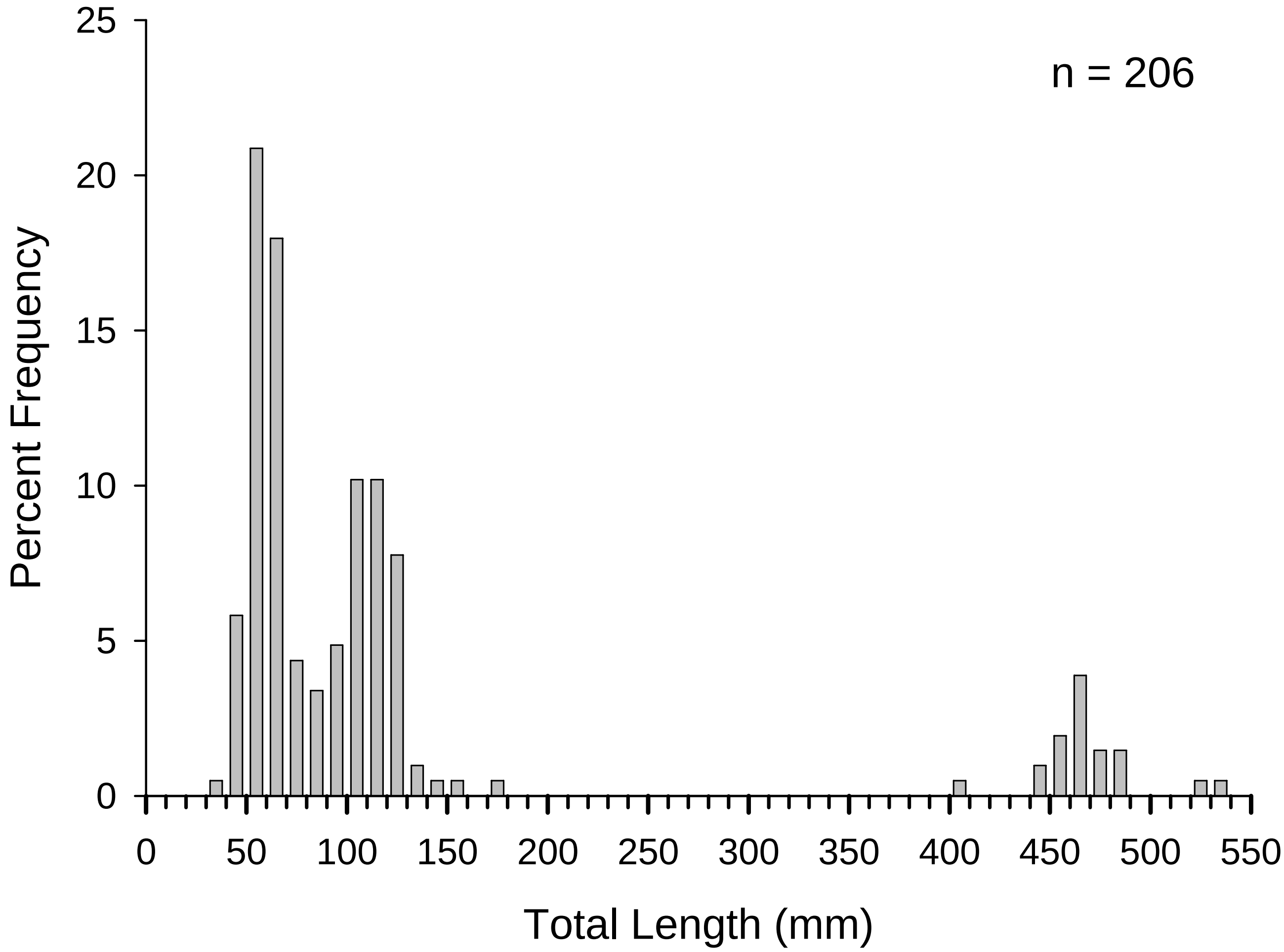

Figure 10. Length frequency of Yellowstone cutthroat trout sampled during mark-and-recapture electrofishing surveys of the mainstem Yellowstone River, September 2006.

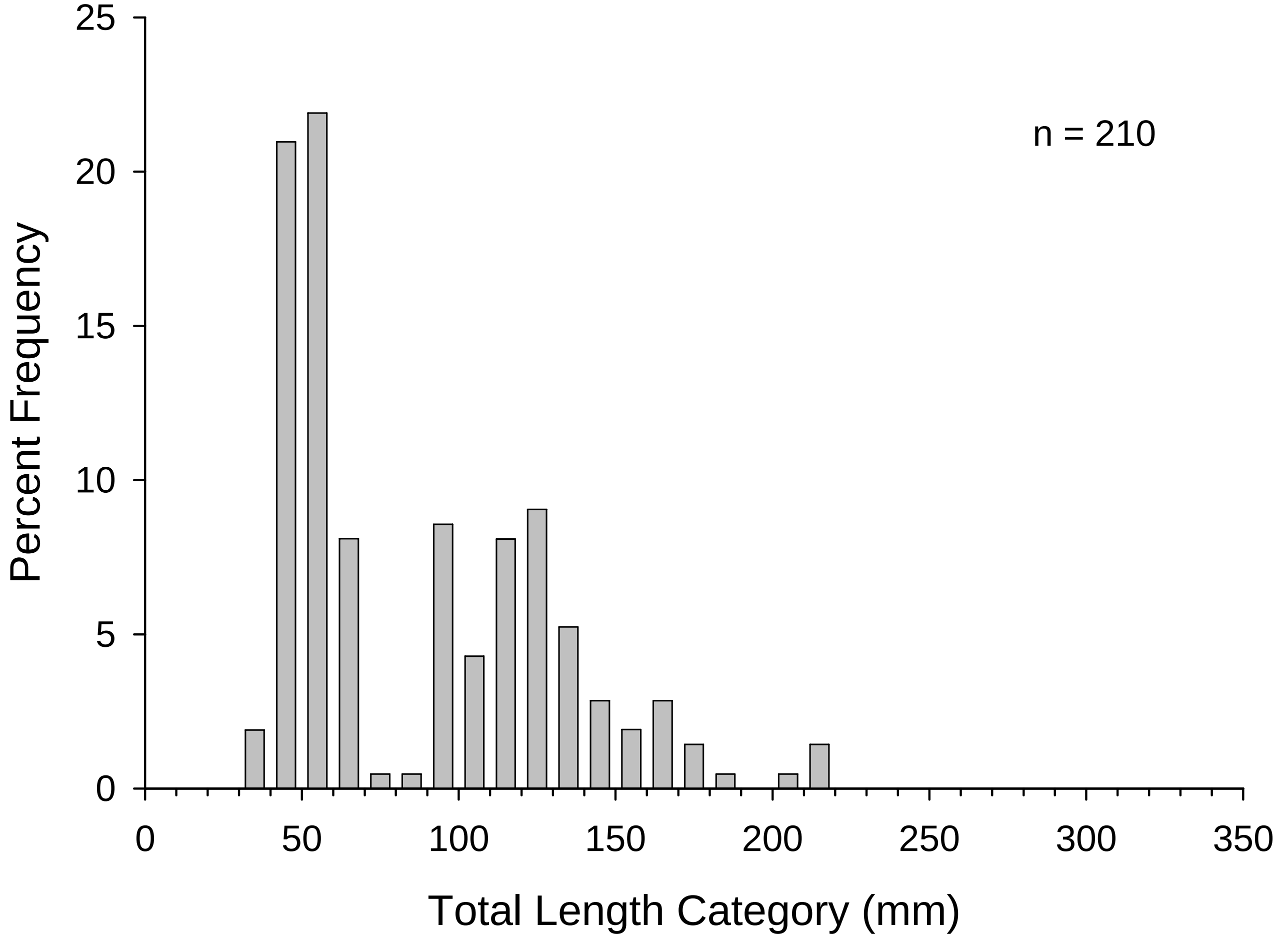

Figure 11. Percent frequency of Yellowstone cutthroat trout sampled in 10-mm size classes, Mountain Creek drainage, Wyoming, 2006.

Table 1. Location, year, number implanted, and capture method for Yellowstone cutthroat trout in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

Location	Year	Number Implanted	Capture Method
Yellowstone Lake	2004	6	Gill-netting
Yellowstone Lake	2004	2	Fyke-nettng
Yellowstone River	2003	40	Angling
Yellowstone River	2004	30	Angling
Trappers Creek	2005	6	Angling
Mountain Creek	2003	6	Angling
Mountain Creek	2005	6	Angling
Thorofare Creek	2003	13	Angling
Thorofare Creek	2004	33	Angling
Thorofare Creek	2005	1	Angling
Trib. of Thorofare	2003	3	Angling
Atlantic Creek	2005	6	Angling

Table 2. Group assignment for fish implanted with radio-transmitters in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

Group	Number	Mortalities Included
1	60	10
2	31	14
3	4	0
4	57	17

Table 3. Julian day of river entry, exit, and spawning and maximum upstream river location for Yellowstone cutthroat trout implanted with radio-transmitters in the upper Yellowstone River basin, Wyoming, 2003 – 2005.

Year	Entry	Exit	Spawn	Maximum Upstream Location (Rkm)
2003				
Group 1	N/A	195 (184 – 229)	183 (175 – 224)	31.5 (7.8 – 47.2)
Group 2	N/A	205 (185 – 226)	185 (176 – 211)	41.5 (35.0 – 57.9)
2004				
Group 1	159 (144 – 186)	194 (165 – 225)	183 (154 – 207)	44.7 (3.2 – 65.1)
Group 2	148 (144 – 163)	195 (159 – 229)	194 (154 – 228)	52.8 (11.7 – 65.9)
2005				
Group 1	167 (147 – 189)	191 (168 – 239)	177 (164 – 196)	43.7 (13.6 – 61.6)
Group 2	164 (147 – 189)	194 (180 – 204)	187 (154 – 203)	46.2 (16.5 – 63.8)

Table 4. Number of Yellowstone cutthroat trout spawning areas identified, presence of ripe fish, and spawning observations in streams of the upper Yellowstone River basin, Wyoming.

Stream	Spawning locations identified	Ripe fish present	Spawning observed
Yellowstone River	7	Yes	Yes
Trappers Creek	0	Yes	No
Mountain Creek	1	Yes	Yes
Cliff Creek	0	Yes	No
Escarpment Creek	0	Yes	No
Thorofare Creek	2	Yes	Yes
Open Creek	0	Yes	No
Atlantic Creek	0	Yes	No

Table 5. Habitat characteristics of the upper Yellowstone River (mainstem), Yellowstone National Park, Wyoming. Surveys were conducted in 41, 500-m reaches over 41 Rkm located within the boundary of Yellowstone National Park in August 2007.

Site Variable	Mean (Range)
Begin Elevation (m) Boundary	2391
End Elevation (m) Mouth	2356
Gradient (m/km)	0.85
Width (m)	40.7 (20.0 – 70.0)
Thalweg Depth (m)	0.40 (0.12 – 7.00)
Riffle (%)	8
Run (%)	72
Glide (%)	19
Pool (%)	1
Bedrock (%)	0
Boulder (%)	0
Cobble (%)	25
Gravel (%)	37
Sand/Silt (%)	38