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SUMMER USE OF SIDE CHANNEL HABITAT BY FISHES IN THE NORTH FORK COEUR D'ALENE RIVER, IDAHO.

Abstract

Large aggregations of westslope cutthroat trout, mountain whitefish, and to a lesser extent rainbow trout were observed moving into cold side channels during the summer months of July and August in the North Fork Coeur d'Alene River. Use of cold side channels varied throughout the day and the season, as well as by size classes of salmonids present. The use of side channel thermal refugia was much greater for salmonids ≥ 300 mm, and movement of salmonids into side channel habitats appeared to be triggered by rising main river water temperatures, and temperature divergences between the main river and the side channels. Larger salmonids were not evenly distributed in the side channels, and channel physical features varied widely. Salmonids ≥ 300 mm used side channels that were both deep (≥ 2m) and cold (≤ 20° C). In addition to suitable temperatures and depths, the presence of adequate flows in the side channels also appeared important for use by larger salmonids. Temperature modeling showed that water temperatures in the side channels were influenced primarily by a channel's location in the floodplain, riparian vegetation abundance, and substrate composition in both the riverside, and opposite side banks. Thermal imaging flights were used to identify cold water springs and areas important for thermal refugia conservation and enhancement. Springs and upwelling hyporheic flows were more common in undeveloped than developed areas in the floodplain. The areas with large amounts of hyporheic upwelling were also associated with declining longitudinal main river water temperatures and increased presence of thermal refugia available for fish. Protection of remaining hyporheic flowpaths and thermal refugia appears to be important for the conservation of summer habitat for westslope cutthroat trout in the North Fork Coeur d'Alene River. Enhancement and construction of side channel habitat may provide a way to increase the availability of thermal refugia that appear spatially limited in the basin. Enhancement efforts should focus on increasing depths (≥2.0 m) adjacent to the main river in side channels identified to provide thermally suitable habitat. Side channel construction should be focused in areas identified to have high concentrations of floodplain springs to ensure interception of existing hyporheic flow paths.

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INTRODUCTION

Temperature has significant impacts on the ecology, behavior, and life history of salmonid fish species. For example, elevated water temperatures have been shown to influence within river movement patterns and habitat use of migrating pacific salmonids (Goniea et al. 2006, High et al. 2006). From a landscape perspective, within river water temperature regimes also influence the distribution patterns of resident salmonid populations (Barton et al. 1985, Isaak and Hubert 2004, Mackenzie-Grieve and Post 2006). In addition to influencing movement and distribution patterns, numerous field and laboratory studies have demonstrated that increasing water temperatures decreases survival of many salmonid species, including bull trout *S. confluentus* (Selong et al. 2001), lahontan cutthroat trout *O. c. henshawi* (Dickerson and Vinyard 1999), Bonneville cutthroat trout *O. c. utah* (Johnstone and Rahel 2003), and westslope cutthroat trout *O. c lewisi* (Bear et al. 2007). Water temperature can also influence aggressive interactions both between species (De Staso and Rahel 1994) and within species (Nielsen et al. 1994, Biro 1998). Furthermore, laboratory studies have documented close associations between foraging activity (Selong et al. 2001, Johnstone and Rahel 2003), metabolic rate (Dickson and Kramer 1971, Dwyer and Kramer 1975), and water temperatures in salmonids. Finally, elevated water temperatures have also lead to higher rates of parasite infestation in some salmonid populations (Cairns et al. 2005).

Although many streams inhabited by native salmonids may exceed critical temperatures, cold water areas in warm stream reaches have significant potential to function as thermal refugia for salmonids during periods of elevated stream temperatures (Power et al. 1999, Ebersole et al. 2003a). Ebersole et al. (2003a) identified cold side channels, alcoves, lateral seeps, and floodplain springbrooks as potential thermal refugia associated with groundwater upwelling. Cold water patches associated with groundwater upwelling show less diel and seasonal temperature variation than surrounding stream waters (Bilby 1984; Poole and Berman 2001) further increasing their attractiveness as thermal refugia. Matthews and Berg (1997) found rainbow trout using deep pools with groundwater seeps as thermal refugia during periods of elevated temperatures in a southern California stream. Young of the year brook trout in lentic systems have also been observed using areas with significant groundwater upwelling as thermal refugia when littoral temperatures exceed 20˚ C (Biro 1998). However, not all cold water refugia are associated with groundwater upwelling, as salmonids have also been observed using cold water tributaries and stratified pools as thermal refugia. Kaya et al. (1977) found large numbers of rainbow and brown trout *S. trutta* moving into a cold tributary during periods of elevated stream temperatures in the summer months. Anadromous chinook salmon *O. tshawytscha* (Goniea et al. 2006) and steelhead *O. mykiss* (High et al. 2006) also use cold tributaries as resting and staging areas when Columbia River temperatures increase during migration. Furthermore, Curry et al. (1997) observed young of the year brook trout spawned in an Ontario lake moving into cold tributaries during the summer to avoid elevated lake temperatures. Large aggregations of trout have also been observed congregating at the mouths of inflowing cold water tributaries during the summer in the Adirondack streams of New York (Baird and Krueger 2003). Lastly, Nielsen et al. (1994) found large numbers of juvenile steelhead using deep thermally stratified pools as thermal refugia in northern California streams.

While side channels have been identified as potential sources of thermal refugia, other ecological functions have been identified for these backwater areas. For example, juvenile coho salmon *O. kisutch* commonly use side channels and other off channel areas as wintering habitat, moving into these backwaters in late fall and back out into the river in the spring

(Bustard and Narver 1975, Peterson 1982, Tschaplinsk and Hartman 1983, Swales and Levings 1984).

In addition to providing overwintering habitat, off channel habitat also provides refugia for salmonids during high flow events (Swales and Levings 1984, Yrjana et al. 2002). Backwater floodplain habitats have also been shown to provide rearing habitat for juvenile coho salmon (Henning et al. 2006) and cutthroat trout (Moore and Gregory 1988). Finally, Morley et al. (2005) found large numbers of juvenile salmonids using both natural and constructed side channels as both summer and winter habitat.

While side channels have demonstrated value for salmonid populations, their functioning as thermal refugia remains relatively un-documented. Additionally, the seasonal importance of side channels has been well documented for juvenile fish, however, the role of side channels in the seasonal ecology of adult salmonids remains relatively unstudied. In the North Fork Coeur d'Alene River in northern Idaho, large numbers of adult westslope cutthroat trout have been observed using side channels as thermal refugia during the warm summer months (DuPont et al. In Press). These findings raised concerns as floodplain development in the North Fork Coeur d'Alene River has reduced the river's ability to shift course and form new side channel habitat. These concerns prompted a study to determine how important side channels were to cutthroat trout as summer cold water refugia, and investigate ways to improve and protect side channel habitat important to cutthroat trout.

OBJECTIVES

1. Evaluate the relative importance of side channel habitat for cutthroat trout and other salmonids during peak water temperatures.

2. Identify factors that influence cutthroat densities in side channels during summer.

3. Identify factors that influence water temperatures in side channels.

4. Identify important floodplain areas for protection, candidate areas for development, and future side channel construction.

STUDY AREA

The North Fork Coeur d'Alene River is located in northern Idaho and extends 123 km from its confluence with Coeur d'Alene River to its headwaters (Figure 1). This river and its tributaries drain belt series geology in a dendritic pattern with non-glaciated alluvial valleys. The watershed encompasses over 232,000 hectares and has a 50 year mean annual flow of approximately 54 m^3/sec, and a 50 year mean peak flow of approximately 512 m^3/sec (USGS site 12413000; Enaville). Elevations in the North Fork Coeur d'Alene River watershed range from 640 m at its confluence with the South Fork Coeur d'Alene River to 2,077 m at its highest peak. About 70% of the watershed occurs between 914 and 1372 m in elevation, which is considered to be sensitive to winter rain-on-snow events. The highest peak flows that have occurred in the North Fork Coeur d'Alene River drainage have been a result of winter rain-on-snow events. Peak flows over 850 m^3/sec occur at a rate of once every 8 years, with the

highest ever recorded peak flow (1,727 m^3/sec) occurring during the winter of 1974. Peak spring flows during 2007 were 575 m^3/sec, and the mean annual flow was 52 m^3/sec.

The North Fork Coeur d'Alene River watershed is predominately (93%) managed by the U.S. Forest Service. The Forest Service has intensively managed these watersheds for timber harvest over the last 100 years (Strong and Webb 1970). Prior to 1930 splash dams and log drives were common in the main North Fork Coeur d'Alene River watershed (Strong and Webb 1970). These activities resulted in a straightened and less complex river channel as log jams, woody debris, large boulders, and sharp channel bends were removed. After 1931, road systems were developed to export logs. Many of these roads were constructed along streams, and the riparian areas are now considered the most altered portion of the entire watershed (IDEQ 2001). The road density in the watershed averages 5 km/km^2, and the North Fork Coeur d'Alene watershed is considered the most densely roaded forested watershed in the entire Columbia River Basin (Quigley et al. 1996). Much of the floodplain in the lower 40 km of North Fork Coeur d'Alene River is privately owned, and has been developed for housing or agriculture. Placer and hard rock mining occurred in the North Fork Coeur d'Alene River, mainly in the Prichard Creek and Beaver Creek watersheds. This hard rock mining resulted in elevated levels of heavy metals in the substrates of both of these drainages. Extensive restoration has taken place since the 1980's with over 1600 kilometers of roads removed in the watershed and 48 kilometers of streams treated.

The North Fork Coeur d'Alene River supports native stocks of westslope cutthroat trout *O. clarkii lewisi*, mountain whitefish *Prosopium williamsoni*, largescale sucker *Catostomus catostomus*, northern pikeminnow *Ptychocheilus oregonensis,* redside shiner *Richardsonius balteatus*, longnose dace *Rhininchthys cataractae*, speckled dace *R. osculus,* torrent sculpin *Cottus rhotheus* , shorthead sculpin *C. confusus* and mottled sculpin *C. bairdi*. Native bull trout, which were once common in some tributaries, have virtually disappeared from this drainage. Introduced rainbow trout, brook trout and Chinook salmon also occur in the watershed. Cutthroat trout are the most abundant trout in the Coeur d'Alene River, and attract hundreds of fisherman each year. Interstate 90 provides easy access to the North Fork Coeur d'Alene River and the river annually receives over 33,000 hours of fishing pressure a year (Fredericks et al. 1997). In 2007, the fishing regulations allowed 2 cutthroat trout (none between 8 and 16 inches) to be harvested daily. Six rainbow trout, 25 mountain whitefish, and 25 brook trout could also be harvested daily. Catch-and-release areas occurred farther upstream and out of our study area.

Our study area extended about 50 km upstream from the mouth of the South Fork Coeur d'Alene River to Shoshone Creek (Figure 1). Within the study area, the North Fork Coeur d'Alene River can be described as a B3 stream type. This stream type is characterized by having a gradient ranging from 2-4% , with predominately cobble substrate and moderately steep valleys, and gentle side slopes (Rosgen 1996). The floodplain in this section of river typically exceeded 200 m in width. Side channels occur throughout the study area where the main river has shifted paths over time.

Within the study area, we identified 63 different side channels through use of satellite imagery and on the ground surveys. We selected 21 of these side channels for this study (Figure 2). These side channels were selected based on connectivity with the main river (none were selected that were not connected during mid-June), length (none under 100 m in length were selected), and depth (none with maximum depths < 1 m were selected). Within each of these side channels, we selected one to three transects to conduct fish and habitat surveys and temperature assessments. These transects were selected based on areas we thought cutthroat

trout could occupy and we could effectively snorkel. In total, we selected 27 different transects to conduct our analysis (Figure 2). Transects ranged from 45 m to 300 m in length, and all ended at shallow (< 0.2 m) constrictions. We believed this would prevent most fish from leaving the transect during our surveys. Upon surveying transect 14-1, it became evident that the abundance of wood that occurred in the channel made snorkel surveys ineffective and unreliable. For this reason we dropped transect 14-1 from our study, which brought the total number of side channels we surveyed to 20 and the total number of transects to 26. For comparative purposes, we also snorkeled nine different transects in the main river (Figure 3). These nine transects were annual trend sites that have been snorkeled since 1973, and they were selected based on what was believed to be good cutthroat trout habitat (Bowler 1974). Thermographs were also placed in the main river at six locations that were spaced out at about 8 km intervals (Figure 3).

METHODS

FIELD WORK

We used thermographs (HOBO and TidbiT data loggers by Onset) to collect water temperatures in 27 side channel transect locations and six main river locations on an hourly basis. USFS aided in the selection of side channels to study. The thermographs were calibrated in an ice bath to test for accuracy. Only those thermographs that were accurate to within 0.2°C were used for this study. All Hobo data loggers were placed in water tight plastic canisters. These canisters were then bolted into 75 mm diameter sections (125 mm long) of steel pipe to keep them submerged on the bottom. The Tidbit data loggers were wired directly inside a 50 mm diameter copper pipe. All thermographs were then placed in the deepest water at each transect and remained in place for at least the duration of the study (June to September of 2007). The collection of temperature data was a cooperative effort with the USFS.

To inventory the habitat at each of the side channels selected for our study, we started at the mouth of each side channel and then proceeded upstream systematically at 50 m intervals until we reached the end of the side channel. If the side channel was less than 200 m in length we collected data every 25 m. At each cross sectional transect, we collected data to characterize the canopy cover, type of riparian vegetation, habitat type, substrate in the channel bottom and both banks, maximum depth, water temperature, and wetted width (Appendix A). Canopy cover was determined using a densiometer (Platts et al. 1987), maximum depth was measured with a measuring rod, temperature was measured with a hand held thermometer, stream width was measured with a laser range finder, and all other variables were estimated visually. Through use of ArcGIS and satellite imagery we also determined whether tributaries entered each side channel, the location of the side channel within the floodplain, the maximum distance between the side channel and the main river, and the relative density of vegetation between the side channel and the main river.

We used snorkeling surveys to assess the fishery in each of the 26 side channel transects and 9 main river transects. Our intent when snorkeling was to be reasonably certain that all of the fish in the transects were visible to the divers, and few or no fish were overlooked. Two divers were used in transects located in wider reaches or in more turbid water where one diver could not easily see fish across the transect. Divers began at the downstream end of each

side channel transect and snorkeled upstream, however, depths and current required the river snorkel transects to be snorkeled downstream. When snorkeling in pairs, we tried to remain even with each other and the snorkeler counted only those fish that passed. This prevented double counting of fish that often spook out in front of one snorkeler and then swim past the other. Where woody debris or boulders were common, the snorkeler would often have to swim around them to ensure all fish were counted. We periodically duplicated counts using different divers to check for accuracy. If there were noticeable differences in fish counts or estimates of fish length between snorkelers, discussions as to why this occurred were made and then the transect was re-snorkeled.

Estimates of fish abundance were limited to age 1 and older fish (>75 mm), as summer counts for young of the year (YOY) fishes are typically unreliable. Most YOY cutthroat trout will be smaller than 80 mm during surveys in July and August, and occupy the shallow stream margins where snorkeling is less effective (Thurow 1994). All observed fish were recorded by species in 75 mm length groups. Prior to snorkeling, each observer practiced estimating the lengths of plastic pipes to ensure accurate estimates of fish lengths were made. Throughout the snorkel surveys we periodically held these practice sessions to maintain our accuracy and precision.

After completing fish counts, we measured the length and width of each transect with a laser rangefinder to determine the surface area (m^2) surveyed. At least four width measurements were taken to get an average width of the transect surveyed. Characteristics of the transects were also recorded at each site following snorkeling. Transect characteristics collected included: habitat type (percent pool, riffle, run, or glide), maximum depth, amount and type of available cover (estimated % of surface area), substrate composition, aquatic vegetation (estimated % of surface area), water temperature, flow, and visibility (Appendix B). We visually estimated habitat composition, aquatic vegetation, cover, and substrate composition. We measured maximum depth with a calibrated meter, water temperature with a handheld thermometer, and flow using a Marsh-McBirney flow meter. Because the flow meter proved ineffective at lower water velocities, we summarized the flow data into five categories of relative flow. Visibility was measured by having a snorkeler move away from shore to the point they could not see it any more. At this point, the distance between the snorkeler and shore was measured using a laser range finder.

We conducted snorkel surveys and habitat assessments for each of the side channel transects four times throughout the summer starting on June 25, 2007. These surveys were repeated about every two weeks and ended on August 9, 2007 (Table 1). The main river was snorkeled once on July 31 and August 1, 2007.

We assessed fish use in the shallow reaches of the 20 side channels through electrofishing. We selected transects to electrofish using a stratified random sample by ranking all the side channels from coldest to warmest and then dividing them evenly into three even groups (cold, moderate or warm). These side channels were then divided into 100 m transects of which we randomly chose five from each group for electrofishing. If we chose a transect that we believed had maximum depths > 1 m, another transect was randomly selected. While electrofishing, we attempted to net all fishes observed, and all fish captured were identified to species and measured for total length. The length, average width (at least four width measurements), and bottom temperature of the area sampled were also measured for each transect. Because temperatures in each side channel were not uniform throughout, the actual temperature of the transect we sampled often did not reflect the temperature grouping it was originally assigned to. For this reason, when we summarized the electrofishing data it was

grouped together to reflect the relative abundance of fishes that occurred in shallow sections of all side channels.

DATA ANALYSIS

We used the snorkel data to evaluate whether densities of salmonids (cutthroat trout, rainbow trout, and mountain whitefish) differed between the side channels and the main river. Because the main river was snorkeled on July 31 and August 1, we used only the snorkel data from the side channels collected during the fourth (last) round of sampling (August 1 to 9) for this comparison. Data from 5 of the 26 side channel transects were not used because they lost connectivity to the main river before salmonids had a chance move into them. Cutthroat trout density data from 21 side channel transects and nine main river transects were averaged and tested for differences using a nonparametric W ilcoxon Rank Sum Test (Higgins 2004), with an alpha level of 0.10 to denote significance. The alpha level of 0.10 is often used to determine significance when evaluating fish and wildlife populations for management purposes (Peterman 1990, Johnson 1999, Anderson et al. 2000).

Temperature data from 23 side channel locations and 6 main river locations were summarized using the maximum weekly maximum temperature (MWMT) and maximum average weekly temperature (MAWT) metrics (Dunham et al. 2005). We tested for differences in the mean MWMT between the side channels and main river using a Wilcoxon Rank Sum Test (Higgins 2004), with an alpha level of 0.10 used to denote significance. Thermographs from four of the side channel sites were lost during the study and consequently, were not included in our analysis.

To assess the timing of movement of salmonids ≥ 300 mm into the side channels, we calculated their mean densities during each of the four time periods. We used density data from only those transects that each of the salmonid species we evaluated were found to use. For cutthroat trout and rainbow trout we evaluated data from eight transects and for mountain whitefish six transects. Differences in fish densities between the time intervals were tested using a Kruskal-Wallis Test (Higgins 2004), with an alpha level of 0.10 used to denote significance. When the Kruskal-Wallis Test showed that a significant difference ($p \leq 0.10$) in density occurred between the time intervals, we used Tukey's Rank-Based HSD Tests (Higgins 2004) to identify pair-wise differences in fish densities between the time intervals. Density differences between time intervals were used to asses when adult salmonids began moving into side channel habitat.

The side channels selected for the study varied considerably in length, from 108 m up to 925 m. Since side channel lengths varied considerably, we selected more than one snorkel transect in five side channels at locations we thought could potentially support larger cutthroat trout. A total of six additional transects were selected in all. To determine if salmonids ≥ 300 mm moved up the side channels into these six transects as the main river temperatures warmed, we calculated their mean densities during each of the four time periods. Differences in fish densities between time intervals were tested using a Kruskal-Wallis Test with an alpha level of 0.10 used to denote significance. When the Kruskal-Wallis Test showed that a significant difference ($p \leq 0.10$) in density occurred between the time intervals, we used Tukey's Rank-Based HSD Tests to identify pair-wise differences in fish densities. Density differences between time intervals were used to assess whether salmonids ≥ 300 mm moved up the longer side channels during the summer.

We assessed whether salmonids ≥ 300 mm moved into or out of side channels throughout the day in relation to water temperatures. To accomplish this, we snorkeled four different side channel transects (2-1, 2-2, 4-1, and 8-1) that were known to support salmonids ≥ 300 mm during four time periods on August 1, 2007. These time periods were spaced throughout the day so that the first one occurred in the morning about when the coolest water temperatures occurred, and the last one occurred in the afternoon about when the warmest water temperatures occurred. To evaluate whether the abundance of salmonids ≥ 300 mm differed between the four time periods, we compared the numbers of each salmonid that was observed in each transect to the maximum number of each salmonid that was observed in that transect during the day. This would essentially tell us what percentage of the maximum of each salmonid species used the transect during each time period. These percentages were then averaged for all four transects for each time period (mean use). To evaluate whether salmonid use differed between the four time periods, we conducted an analysis of variance (ANOVA) on the mean use value for each salmonid during each time period. We used a p-value ≤ 0.10 to denote when a significant difference in use occurred between time periods. When an ANOVA showed that a significant difference ($p \leq 0.10$) in use occurred between time periods, we used Fisher's Least-Significance-Difference Test to evaluate which time periods differed significantly. Fisher's Least-Significance-Difference Test was chosen for this analysis as this test tends to maximize the power, which increases the ability to show statistically significant differences with low sample sizes (Milliken and Johnson 1992).

Habitat variables collected at side channel snorkel transects, thermograph data, and data collected from habitat inventories of each side channel were used to evaluate habitat characteristics that could explain the densities of salmonids ≥ 300 mm that were observed in the side channels. Because each of the snorkel events over the four sample periods were not independent, we calculated average salmonid densities for each transect for snorkel periods 2-4. We did not include data from the first snorkel period as salmonids had not moved into the side channels at this date. We also averaged the habitat characteristics collected at each transect for snorkel periods 2-4. To evaluate the influence of habitat attributes on densities of salmonids ≥ 300 mm in the side channels we used Yohai's MM-Estimation Robust Regression Analysis (Yohai 1987). Nonparametric modeling methods were necessary because of extreme non-normality and skewness in the fish density distributions. Additionally, outliers in the fish density data made the Yohai's MM-Estimation Robust Regression Analysis more appropriate than standard least squares multiple regression, as MM-Estimation protects from overly influential points in both the x and y space (Yohai 1987). The outlying points were not thrown out prior to analysis because these represented side channels with adult salmonid densities that were considerably higher than those observed at other side channels. Thus, we felt it was important to include these points in our analysis because they represented what appeared to be the best side channel habitat in the study area. Finally, variables were added to the model using stepwise regression methods (Ott and Longnecker 2001). Variables were first added in a forward step-wise direction, then checked by starting over and going in the backward step-wise direction. Both directions of adding variables to the stepwise regression model yielded identical results, and thus were used as the final models. Only variables that showed a significant relationship ($p \geq 0.10$) for the specified salmonids species were included in the model.

After developing linear models for predicting densities of cutthroat trout ≥ 300 mm based on habitat attributes, we looked at each attribute in more detail to see how they influenced fish distribution. For example, if maximum depths showed a significant relationship with cutthroat trout density, what depths did cutthroat trout prefer? This type of information would be useful when determining how to construct a side channel that cutthroat could use as cold water

refugia. To accomplish this we created frequency histograms that showed how the significant habitat variables were distributed in the 26 side channel transects we surveyed. We then overlaid this histogram with another that showed how cutthroat trout were distributed in these side channels in relation to each habitat variable. We put an emphasis on those transects with higher densities of cutthroat trout ≥ 300 mm than what occurred in the main river. Because cutthroat trout are the species that will drive any future side channel construction, we also examined how the significant habitat variables for cutthroat trout related to rainbow trout and mountain whitefish densities.

An information-theoretic modeling approach (Burnham and Anderson 2002) was used to evaluate the influence of side channel morphology and riparian habitat features on water temperatures in the side channels. Prior to modeling we reduced the number of independent variables (collected during the side channel habitat inventory) used with best subset regression analysis (Ott and Longnecker 2001) and limited the number of independent variables to five to avoid over-fitting the model. In the best subset regression analysis, the R^2 value was used as criterion for "best", and the subset of variables with the highest R^2 value represented the best set of a given number of variables. Once a subset of five variables was identified for inclusion in the modeling, Akaike's Information Criterion (AIC) (Akaike 1973) was used to select the best model using those five independent variables. After AIC model selection, least squares multiple regression was used to estimate the regression coefficients in the linear model.

We modeled the effects of side channel features on temperatures within the side channel using both the maximum average weekly temperature and maximum weekly maximum temperature metrics. Both metrics were used in modeling because different temperature metrics can be influenced by different features, and both average and maximum temperatures are biologically relevant (Johnson 2004). Since the side channel temperatures were regulated by upwelling groundwater, this modeling essentially evaluated the side channel features influencing hyporheic flow into the side channels, which is a crucial factor for stream temperature buffering (Poole and Berman 2001).

AIRBORN THERMAL SENSING SURVEY

To help evaluate how water temperatures were influenced by landscape scale characteristics, the U.S. Forest Service (funded through EPA) contracted watershed Science Inc. to conduct an airborn thermal sensing survey. This survey gave us a snapshot in time of the water temperatures in the main river, adjoining tributaries, springs, and side channels that occurred within the floodplain of the study area. The airborn thermal sensing survey occurred on August 9, 2007, 13:48 to 14:51. When compared to thermograph data collected in the main river, the thermal sensing data was within 0.5°C in all cases. As part of their contract, Watershed Sciences, Inc. submitted a report of their airborn thermal sensing study (Watershed Sciences Inc. 2007). The methods used to conduct this survey and display the data are presented in their report.

One of the products the airborn thermal sensing study produced was a longitudinal temperature profile within the floodplain of the North Fork Coeur d'Alene River, Idaho, from the South Fork Coeur d'Alene River to Shoshone Creek. This profile showed the median water temperatures in the main channel, contributing streams, and surrounding springs. We overlaid the river km locations from this profile and the locations of the springs onto a floodplain map we developed for the study area. This floodplain map was created using ArcGIS, 1:24,000 U.S.

Geological Survey topographic map, and satellite imagery. This floodplain map was produced to show where the historic floodplain occurred, and areas where development (roads, homes, farming, trailer parks, dikes) had restricted the rivers ability to migrate. Through use of this map in conjunction with the airborn thermal sensing data, we were able to assess where springs were prevalent and where the river cooled or warmed in relation to development. This data allowed us to identify floodplain areas important to protect because they could allow new side channel development in the future, they contributed to cooling of the main river, or because they were areas where future side channel construction would likely be successful in creating cold water refugia.

RESULTS

SIDE CHANNEL SPECIES USE AND COMPARISON TO THE MAIN RIVER

We snorkeled 26 different transects in 20 different side channels to help evaluate their importance to salmonids between June 25 and August 9, 2007. Through these surveys, we observed 9,918 fishes representing 10 different species. Northern pikeminnow (41%) and mountain whitefish (34%) were the most abundant species observed (Table 2). Cutthroat trout were the fourth most abundant species (6% of total) observed and the most abundant trout species (Table 2). Rainbow trout and brook trout were also observed, but each represented less than 3% of the species recorded. For comparative purposes, we snorkeled nine transects in the main North Fork Coeur d'Alene River on July 31 and August 1, 2007. We observed 8,624 fishes representing seven different species. Northern pikeminnow (50%) and mountain whitefish (34%) were the most abundant species observed (Table 3). Cutthroat trout were the fourth most abundant species (6% of total) observed, and the most abundant trout species (Table 3). Three percent of the fish were rainbow trout, and no brook trout were observed in the main river.

The sizes of cutthroat trout, rainbow trout, and mountain whitefish observed while snorkeling side channels ranged from about 75 mm to 550 mm in length (Figures 4-5). About 64% of the cutthroat trout, 43% of the rainbow trout, and 74% of the mountain whitefish were ≥ 300 mm in length (Figures 4-5, Table 4). In the main river 20% of the cutthroat trout, 17% of the rainbow trout and 26% of the mountain whitefish were ≥ 300 mm in length (Figures 4-5, Table 4). About 12% of the brook trout observed were ≥ 300 mm in length in the side channels, whereas none were observed in the river (Figure 5, Table 4).

We also backpack electrofished 16 different 100 m transects in the side channels from July 25 to August 13, 2007 to evaluate species use in habitat less than 1 m deep. We sampled 1,284 fishes representing 15 different species (Table 5). Northern pikeminnow (17%), speckled dace (15%), and brook trout (15%) were the most abundant species sampled (Table 5). Cutthroat trout, rainbow trout and mountain whitefish all represented less than 1% of the species sampled. The largest cutthroat trout, rainbow trout, and mountain whitefish sampled were 138 mm, 189 mm, and 76 mm respectively.

To assess whether the densities of salmonids differed between the side channels and main North Fork Coeur d'Alene River, we compared the mean density between the last snorkel round (August 1 to August 9) in the side channels with the mean density in the main river (July 31 to August 1). The mean density of cutthroat trout, rainbow trout, and mountain whitefish (all

< 300 mm) were significantly higher (Wilcoxon Rank Sum; P = 0.003, 0.004, 0.001) in the main river than in the side channels (Figures 6-7). However, the mean densities of cutthroat trout and mountain whitefish ≥ 300 mm were significantly higher (Wilcoxon Rank Sum, P = 0.0152, P = .0004) in the side channels than in the main river (Figures 6-7). The mean density of rainbow trout ≥ 300 mm was significantly lower (Wilcoxon Rank Sum; P = 0.08) in the side channels than the main river (Figure 6).

TIMING OF SIDE CHANNEL USE BY SALMONIDS

The daily maximum water temperature in the main river (averaged across six sites) increased about 12°C from when we first started snorkel surveys (June 25, 2007) to when the highest average maximum temperature of 23°C was recorded on July 23, 2007 (Figure 8). The daily maximum temperatures in the side channels (averaged across 26 sites) were approximately 3-7°C cooler than those observed in the main river during the four periods when we conducted our snorkel surveys (Table 1, Figure 8). A Wilcoxon Rank Sum Test showed that the mean maximum weekly maximum temperature for the side channels was significantly cooler (P = 0.0004) than what was observed in the main river.

Because larger salmonids (≥ 300 mm) displayed the greatest use of side channel habitat, all analysis in this section focused on these larger fish. Cutthroat trout were consistently observed in eight different side channels transects (not including upstream transects). Based on density estimates in these eight side channels transects, cutthroat trout ≥ 300 mm moved into side channels around the second week of July (July 9 to 17) when daily maximum water temperatures began exceeding approximately 21°C (Figures 8-9) in the main river. Mean cutthroat trout densities increased over eight fold between the first (June 25 to July 3) and second (July 9 to 17) sample periods. Cutthroat trout densities remained fairly steady from the second to fourth (last) sample periods. From the second to fourth sample period (July 9 to August 9), mean cutthroat trout densities were on average 3.6 times higher in the eight side channel transects than what was observed in the main river. Significant differences (Kruskal-Wallis, P = 0.017) in densities of cutthroat trout occurred between the four sample periods, with pair-wise comparisons (Tukey's Rank Based HSD Procedure) showing that cutthroat trout densities were significantly lower during the first sample period (June 25 to July 3) than the last three.

Rainbow trout were consistently observed in eight different side channel transects (not including upstream transects). The mean densities of rainbow trout ≥ 300 mm in the eight side channel transects were similar to what was observed in the main river through the first two sample periods (June 25 to July 17) (Figure 9). During the third sample (July 23 to 31), when water temperatures reached their peak (23°C), rainbow trout densities increased over three fold in the eight side channel transects (Figures 8-9). When compared to the main river, mean rainbow trout densities in the eight side channel transects were over four times higher during the third sampling period. Rainbow trout densities declined by about half from the third to forth sample period (Figure 9). The maximum daily water temperature in the main river declined from 22.4 °C to 20.6 °C during this same period (Table 1, Figure 8). Kruskal-Wallis Tests (P = 0.131) failed to show a significant difference in rainbow trout densities between the four sample periods despite over a fourfold difference between the second and third sample periods. The relatively small sample sizes (8 transects/group) combined with high variability likely reduced our statistical power to detect differences that may have existed between the time intervals.

Mountain whitefish were consistently observed in six different side channel transects. The mean density of mountain whitefish ≥ 300 mm in these transects increased about 16 fold from the first to the third sampled periods (Figure 10). During this same period the mean maximum daily water temperature in the main river increased from 17.9°C to 22.4°C (Table 1, Figure 8). The mean mountain whitefish density during the third sample period was over 6 times higher than was observed in the main river (Figure 10). The mean mountain whitefish density declined from the third to the fourth sample period, but was still over four times higher than what was observed in the main river. Kruskal-Wallis testing (P = 0.195) failed to show a significant difference in mountain whitefish densities between the four sample periods despite approximately a 16 fold difference between the first and third sample periods. Once again this was likely due to small sample sizes and high variability leading to low statistical power.

Movement of cutthroat trout, rainbow trout, and mountain whitefish into or out of side channels throughout the day was evaluated on August 1, 2007. To evaluate this movement snorkeling occurred over four time periods, in four different side channel transects known to be used by salmonids (Table 6, Figure 11). The average water temperature in the main river on this day was near its lowest (<17°C) when we started snorkeling and rose steadily to near its maximum (> 21°C) when we conducted our last snorkel round (Figure 11). Approximately 70% of the maximum number of cutthroat trout (≥ 300 mm) that were observed in the four side channels transects were observed during the first time period (Figure 12). This essentially means that 70% of the cutthroat trout that used these side channels on August 1, 2007 were found in the channels during the first snorkel period (Figure 12). Cutthroat trout use did not change appreciably until the third time period when about 96% of the fish were observed in the side channels (Figure 12). Water temperatures in the main river increased on average from 18.8°C to 20.1°C during this time period (Table 6, Figure 11). Cutthroat trout use dropped to 84% of the total during the last time period when water temperatures in the main river reached their maximum. Analysis of Variance (ANOVA) testing (P = 0.455) failed to show that cutthroat trout use changed throughout the day in these side channels.

Rainbow trout and mountain whitefish (≥ 300 mm) showed similar patterns of use throughout the day in the four side channel transects. Fewer than 40% of the fish were observed during the first time period, around 45% of the fish were observed during the second time period, and over 90% were observed during third period (Figure 12). Rainbow trout use dropped to around 80% of the total during the last time period. ANOVA testing found that use of rainbow trout and mountain whitefish in side channels differed significantly (rainbow trout, P = 0.029; mountain whitefish, P = 0.003) over the four time periods. Pair-wise comparisons using Fisher's Least-Significance-Difference Tests showed that densities of rainbow trout and mountain whitefish tended to be significantly lower during the first two time periods than the second two (Table 7). The water temperature in the main river increased on average from 18.8°C to 20.1°C during the period when rainbow trout and mountain whitefish showed large movements into the side channels.

MOVEMENT UP SIDE CHANNELS

We evaluated whether salmonids moved up side channels by examining fish densities over four sampling periods (Table 1, Figure 8) in the transects that were upstream of the main river. There were six different side channels transects that met this description (Table 2). Densities of cutthroat trout, rainbow trout, and mountain whitefish (≥ 300 mm) in these upstream side channel transects were considerably lower than what was observed in the main river

regardless of which sample period we evaluated (Figures 13-14). Densities of all these fish tended to increase after the first sample period, but none of these changes were significant (cutthroat trout, P = 0.889; rainbow trout, P = 0.663; mountain whitefish, P = 0.865) based on Kruskal-Wallis testing.

Fish densities in one of the six transects (2-2) we evaluated showed that salmonids ≥ 300 mm will move short distances up side channels past constrictions with suitable depth. Side channel transect 2-2 was 46 m from the river and to reach it the fish had to move past a constriction that was about 1 m deep. Over time this constriction became progressively more shallow. By August 1, the water depth at this constriction had decreased to about 0.5 m, and few salmonids (over 12 fold decline) moved past it even though cool water temperatures (< 14°C) and ample depth (max depth of 3 m) occurred up-channel. Transect 15-1 was 143 m long and fish were commonly observed at its upstream boundary. However, transect 15-2, which was 170 m upstream had depths > 2 m, and cold water temperatures (< 10°C), did not have an increase in salmonids density (≥ 300 mm) over time. The riffle between these two transects had relative flows that were considered high, and water depths were typically around 0.2 m.

SALMONID DENSITY MODELING

To evaluate the influence of various habitat attributes on densities of salmonids ≥ 300 mm in the side channels, we used Yohai's MM-Estimation Robust Regression Analysis (Yohai 1987). We used data characterizing 27 different habitat variables in this analysis (Table 15). Out of these 27 variables, two showed a significant relationship in explaining the density of cutthroat trout ≥ 300 mm in the side channels we assessed (Table 8). These two variables were the maximum depth to temperature ratio and visibility. Combined, these two variables explained approximately 48% of the variation in cutthroat trout density we observed in the side channels. For rainbow trout and mountain whitefish, maximum depth was the most significant variable influencing their densities, and temperature did not show a significant relationship (Table 8). Additionally, rainbow trout densities were significantly related to percent bedrock substrates and overhead canopy coverage, while mountain whitefish densities were significantly related to visibility, the amount of small woody debris in-channel, and the transect's distance to the main river (Table 8).

In an effort to assess what maximum depths, water temperatures, and flows were important to cutthroat trout ≥ 300 mm, we looked at how these attributes occurred in the side channels and how cutthroat trout were distributed in relation to them. We elected to look at flows versus visibility, which had a significant relationship with cutthroat trout density, for three reasons: 1) flows were moderately correlated to visibility ($\rho = 0.43$), 2) relative flow velocity was moderately correlated with densities of cutthroat trout ≥ 300 mm ($\rho = 0.40$), and 3) it was easier to understand how to create a side channel with flow versus one that has clearer water. The maximum depth in side channel transects we assessed ranged from 0.8 m to 6.0 m (Table 9). Cutthroat trout (≥ 300 mm) were observed at least once in side channels with maximum depths throughout this range (Figure 15). Seven of the side channel transects we assessed had cutthroat trout densities greater than what was observed in the main river (0.17 fish/100 m^2). Six of these transects (86%) had maximum depths > 2 m (Figure 15). The MWMT in side channel transects we assessed ranged from 10.5 to 25.0 °C (Table 9). Cutthroat trout (≥ 300 mm) were located at least once in side channels throughout this temperature range (Figure 16). All of the side channel transects that had cutthroat trout densities greater than what was

observed in the main river had a MWMT < 20°C (Figure 16). When we evaluated how flow influenced cutthroat trout use, we found that no cutthroat trout (≥ 300 mm) were ever observed in side channel transects with zero flow. Side channel transects with cutthroat trout densities greater than what was observed in the main river all had relative flows greater than 1 unit (Figure 17).

When we evaluated how maximum depth, temperature, and flows influenced rainbow trout and mountain whitefish (≥300 mm) distribution in side channels we found similar patterns as observed with cutthroat trout. The only differences were that rainbow trout were found in water that was more shallow and warmer than water used by cutthroat trout (Figures 18-20). Additionally, mountain whitefish appeared to prefer maximum depths > 2.5 m (Figures 21-23).

TEMPERATURE MODELING

We modeled the relationship between side channel morphology, riparian habitat features, and water temperatures in side channels using an information-theoretic approach (Burnham and Anderson 2002). We used data characterizing 27 different habitat variables in this analysis. Best subset regression analysis reduced the number of variables used in modeling to five for each temperature metric. The variables used in modeling MAWT were valley location, percent fines in the bottom substrate, percent gravels in the bottom substrate, percent boulder in the river-side bank, and light riparian vegetation levels (Table 10). Using these five variables, we used AIC model selection methods to identify the most parsimonious model. The best model included all five variables and explained approximately 81% of the variation in MAWT observed in the 20 side channels we assessed. The variables used in modeling MWMT were percent fines in the riverside bank, percent boulder, bedrock, and cobble in the opposite side bank, and average distance between the river and the side channel (Table 10). Using AIC model selection methods the best model contained all 5 variables, and explained approximately 75% of the variation in MWMT observed in the side channels.

AIRBORN THERMAL SENSING

The results presented in the following paragraph are from the final contract report from Watershed Sciences Inc. (2007).

The airborn thermal sensing flight took place on August 9, 2007, from 13:48 to 14:51. When compared to thermograph data collected in the main river, the thermal sensing data was within 0.5°C in all cases. The median channel temperatures for the North Fork Coeur d'Alene River were plotted from the confluence of the South Fork Coeur d'Alene River upstream about 50 river km to Shoshone Creek (Figure 24). Water temperatures ranged between 16.2-21.1 °C and generally decreased in a downstream direction (Figure 24). There were 26 surface inflows documented (streams, side channels and sloughs) into the North Fork Coeur d'Alene River with 14 contributing water that was cooler than the main river (Figure 24, Table 12). In addition, 35 spring inputs were documented during the analysis (Figure 24, Table 13). A spring was classified as any distinct discharge that was not associated with a tributary or other obvious surface inflow. All 35 springs had cooler water temperatures than the main river.

Through ArcGIS, we developed a map of the floodplain for the 50 km reach of our study area (Figure 25). The total historic floodplain area in this reach was calculated to be 1,428 hectares. The floodplain ranged from about 50 m to 1,200 m in width. The narrowest floodplain widths tended to occur in the upper 11 km of our study area. As of 2007, development reduced the area where the river could shift course by 36%, and the widest floodplain width to about 700 m (Figure 25). Road development has resulted in the largest decline in floodplain area, followed by temporary structures such as trailer parks and private recreation areas (Table 14). Flooding can still occur throughout many of the areas considered to be lost floodplain; however, under their current management the river will not be allowed to shift course through them.

Through use of this floodplain map and the airborn thermal sensing data, we found that springs were most prevalent in floodplain areas where the river could shift course (Figure 25). Declining main river temperatures were prevalent in areas associated with an abundance of springs, whereas river temperatures tended to increase in areas where springs were not detected (Figures 24-25). River cooling also occurred where sudden floodplain constrictions (3 fold decrease in width within 100 m length of river) were located (river km 20 and 31). There were several areas (river km 6.5, 23, and 38) where the floodplain widths decreased by about 50% in a 100 m reach, but they were not associated with a noticeable decline in river temperature (Figures 24-25).

DISCUSSION

PATTERNS OF SIDE CHANNEL USE

Side channels were found to provide important cold water refugia to cutthroat trout in the lower North Fork Coeur d'Alene River. However, this was only true for larger fish, especially those over 300 mm in length. Movement of westslope cutthroat trout ≥ 300 mm into side channel habitats in mid July coincided with both increases in main river water temperatures, and the temperature divergence between the main river and the side channels. While average daily maximum temperatures in the main river exceeded 22˚ C, average maximum side channel temperatures stayed consistently around 15˚ C. During the mid-summer period of elevated river temperatures, cutthroat trout densities in the side channels that were used as thermal refugia increased eight fold. The pattern of fish movement into the side channels while the temperatures diverged between the main river and the channels suggests these areas were being used as thermal refugia by cutthroat trout. Similarly, Baird and Krueger (2003) observed large aggregations of brook and rainbow trout move into cold water refugia formed by upwelling groundwater and tributary confluences during the summer when main river water temperatures exceeded 20˚ C. Breau et al. (2007) observed large aggregations of juvenile Atlantic salmon in New Brunswick congregating in cold water refugia in response to elevated summer river temperatures exceeding 24˚C. Furthermore, use of cold water tributaries as thermal refugia by migrating adult summer steelhead (High et al. 2006) and Chinook salmon (Goniea et al. 2006) has been linked with increases in main stem Columbia River water temperatures. Gowan and Fausch (2007) suggested that trout will use movement to monitor habitats as they change temporally and adjust their locations according to changing conditions. Bear et al. (2007) found that both westslope cutthroat trout and rainbow trout growth declines significantly at temperatures above 20˚ C, with optimal growth temperatures around 13˚ C for both species. Reduced growth at elevated temperatures should provide strong incentive for cutthroat trout to seek thermal refugia. This further supports our conclusion that fish movement into the side

channels during this study was primarily driven by rising main river temperatures, coupled with more stable and colder side channel temperatures. In contrast, Schrank et al. (2003) found no evidence that Bonneville cutthroat trout moved into cold water refugia during summer despite river temperatures reaching 27˚ C. However, this observation was based only on a sample of six fish, and they did not quantify availability of cold water refugia in their study area.

Movement of mountain whitefish and rainbow trout ≥ 300 mm into side channels used as thermal refugia occurred in late July and coincided with the peak in main river water temperatures. Rainbow trout abundance tripled in the side channels during the third sampling period, when the average daily maximum water temperature in the main river was 22.4˚ C. Similarly, during the third sampling period mountain whitefish densities in side channel thermal refugia were 16 times higher than during the first sampling period. The observed peak of rainbow trout use of thermal refugia during periods of maximum river temperatures has been observed by multiple studies (Kaya et al. 1977, Mathews and Berg 1994, Ebersole et al. 2001, Sutton et al. 2007). Furthermore, studies in Adirondack streams found rainbow trout used available thermal refugia less than native brook trout during periods of elevated summer stream temperatures (Baird and Krueger 2003). This pattern of movement where rainbow trout and mountain whitefish densities peaked later in the summer and during higher main river temperatures suggests these species may be less dependent on cold water refugia in this river system. While the significance of reduced dependence of rainbow trout on thermal refugia in the North Fork Coeur d'Alene was not fully assessed, it may have strong implications as other studies have found rainbow trout can displace cutthroat trout in low elevation reaches (Griffith 1988), and temperatures can influence the success of salmonid invasions (Fausch 2007). Thus existing thermal refugia in the lower reaches of the North Fork Coeur d'Alene River may be preventing displacement of cutthroat trout by rainbow trout in these areas.

Differences in the patterns and magnitude of side channel use may have been due to differences in temperature preferences, preferred habitat features, or competitive interactions between the three species. Cutthroat trout used side channels in large numbers throughout the summer. In contrast, mountain whitefish and rainbow trout use of side channel thermal refugia occurred over a shorter period, with smaller aggregations of rainbow trout observed. Bear et al. (2007) found survival of juvenile westslope cutthroat trout decreased at temperatures above 20˚ C, while survival of juvenile rainbow trout did not decrease until temperatures exceeded 24˚ C. Additionally, westslope cutthroat trout survival was significantly lower than rainbow trout survival at temperatures above 20˚ C, and rainbow trout exhibited significantly higher resistance to acute temperature exposure over 20˚ C (Bear et al. 2007). Literature on temperature preference for mountain whitefish is limited, however, Ihnat and Bulkley (1984) reported acute temperature preference varies seasonally, and the maximum temperature preference of 17.7˚ C occurred during the pre-spawning period. These studies suggest that the differences in the use of side channels as thermal refugia by salmonids in our study may have been related to differences in temperature preference between the three species. If rainbow trout prefer slightly higher temperatures than other salmonids, we would expect to find rainbow trout less dependent on thermal refugia than the other species. In contrast, other studies indicate that the side channel use by rainbow trout we observed may not be related to temperature preferences. For example, numerous studies have found rainbow trout use of thermal refugia to be highly variable, even during periods of extreme river temperatures (Mathews et al. 1994, Baigun et al. 2000, Ebersole et al. 2001), indicating factors other than temperature may have strong influences on thermal refugia use. Although many potential thermal refugia may be available, there suitability for use by large numbers of fish may be highly variable due to physical and chemical characteristics (Ebersole et al. 2003a). Finally, Magnuson et al. (1979) suggested that competition and availability of other resources can influence the use of thermal resources by fishes. Although

we did not attempt to quantify competitive interactions in this study, the large aggregations observed would suggest competition for space, food, or other resources may have occurred.

Strong size structured differences in side channel habitat use by westslope cutthroat trout were also observed in this study. Almost 64% of cutthroat trout observed in the side channels were ≥ 300 mm. In contrast, 20% of cutthroat trout in the main river were ≥ 300 mm. Similarly, Breau et al. (2007) observed the oldest age classes of juvenile salmon occupied the coldest regions of thermal refugia used during periods of elevated stream temperature. Ebersole et al. (2001) documented that the largest rainbow trout occupied the coldest portions of thermal refugia used in northeast Oregon streams. The differences in side channel habitat use by different size classes of salmonids may be due to differences in thermal tolerances. Bear et al. (2007) found smaller westslope cutthroat trout and rainbow trout had significantly higher survival at temperatures above 20˚ C than larger fish. Furthermore, Meeuwig et al. (2004) found the effects of different thermal regimes on lahontan cutthroat trout varied with the initial mass of the fish, with the effects of altered thermal regimes being more pronounced in larger fish. The dominance of westslope cutthroat trout ≥ 300 mm in side channel habitat use may also be the result of intra-specific competition. Magnuson et al. (1979) suggested that intra-specific competition for thermal resources is similar to competition for food, and often results in the dominant individuals competitively excluding other individuals from the preferred temperature range. Size related differences in habitat use are common in other salmonids (Mäki-Petäys et al. 2004, Al-Chokhachy and Budy 2007) and are often most pronounced in the summer (Baltz et al. 1991). In reality, temperature tolerance and intra-specific competition may not be completely independent events when associated with size structured habitat shifts, as increased tolerance to temperature extremes may be an evolutionary adaptation to being competitively excluded from optimal temperature ranges. Regardless of the mechanism causing the size structured use of thermal refugia, the presence of larger fish in these habitats indicates their importance to cutthroat trout on the study area.

Size related differences in side channel habitat use in the North Fork Coeur d'Alene River were also observed for mountain whitefish and rainbow trout. Almost 74% of mountain whitefish observed in the side channels were ≥ 300 mm, whereas only 26% of mountain whitefish in the main river were ≥ 300 mm. There was also a larger percentage of rainbow trout ≥ 300 mm in the side channels than the main river, although the difference was less distinct. Although the use of side channel thermal refugia by larger mountain whitefish suggests side channels may be preferred during periods of extreme river temperatures, the overall timing of side channel thermal refugia use by mountain whitefish and rainbow trout suggests these areas are not as important for these species as they are for cutthroat trout

In addition to varying by fish size throughout the summer, use of side channel habitats as thermal refugia also appeared to vary throughout the day. Although some degree of diel changes in density were recorded for all species, diel fluctuations in densities were most pronounced for rainbow trout and mountain whitefish. As temperatures increased in the main river throughout the day, so did the densities of mountain whitefish and rainbow trout in the side channels. Densities of cutthroat trout in the side channels increased slightly throughout the day, although, these increases were not significant. Similar to our observations, other studies have documented peak use of thermal refugia by rainbow trout during the peak in daily temperatures (Ebersole et al. 2001, Sutton et al. 2007). Since trout can use movement to monitor changing habitat conditions over time (Gowan and Fausch 2002), the diel movements we observed may have been due to increasing river temperatures. However, movement of fish can also be used to maximize foraging opportunities (Gowan and Fausch 2002), and the movement out of side channels we observed may have been to maximize foraging opportunities in the main river. The

high densities of fish observed in side channel thermal refugia during this study would indicate that food availability was likely limited, thus movement may have been foraging related. If food availability in the side channels were limited due to the high densities of fish observed, this would infer a competitive advantage to fish able to move out of the channels and into the main river to feed. Although our data are limited to only one day, they suggest that cutthroat trout make less movement into and out of the side channels than rainbow trout. Once again this suggests that cutthroat trout are more dependent on existing side channel thermal refugia than rainbow trout in this river system.

Differences in the densities of fish ≥ 300 mm between the side channels and the main river indicate the relative importance of side channel habitat for salmonids in our study. Densities of westslope cutthroat trout and mountain whitefish in the observed side channels were significantly larger than the densities observed in the main stem Coeur d'Alene River. Although the average densities of rainbow trout observed in the side channels were significantly lower than the main river, aggregations of fish were still observed in some channels. The observed side channels in this study varied considerably in their physical features, and thus were not all used equally. Aggregations of salmonids in thermal refugia larger than those found elsewhere in the same river have been reported in numerous other studies (Kaya et al. 1977, Brown and Mackay 1995, Baird and Krueger 2003, Ebersole et al. 2001, Sutton et al. 2007, Breau et al 2007). The larger aggregations of cutthroat trout in available cold water refugia suggests that these habitats are limited spatially (Brown and MacKay 1995, Power et al. 1999), and may be critically important for this species due to the potential for cumulative sub-lethal effects of high temperatures (Meeuwig et al. 2004). Furthermore, density may not always reflect habitat quality; however, we did observe the dominant larger fish in these areas, suggesting a density reflected quality in our observations (Van Horne1983).

Electrofishing shallow reaches (≤ 1 m) of the side channel habitats showed that these areas are not used extensively by cutthroat trout, rainbow trout, or mountain whitefish of any size in the lower reaches of the North Fork Coeur d'Alene River. In contrast, other studies have found side channels provided important habitat for juvenile salmonids (Swales and Levings 1984, Giannico and Hinch 2003, Morley et al. 2005). In the North Fork Coeur d'Alene River, juvenile salmonids often use tributary streams as rearing habitat (DuPont et al. *in press*); thus, side channels are not likely as important for juvenile rearing habitat. However, multiple size classes of non-native brook trout were found to use cold side channels. Interestingly, brook trout are not observed in the main stem North Fork Coeur d'Alene river (DuPont, unpublished data), suggesting the existence of brook trout in this system is closely linked to side channel habitats. Brook trout are fall spawners, and the occurrence and prevalence of winter floods can limit their invasions into cutthroat trout habitat (Dunham et al. 2002). In the North Fork Coeur d'Alene River winter rain-on-snow floods and high bedload movements are common. Furthermore, the use of off-channel habitat such as side channels as refugia from high flow events by salmonids is well documented (Swales and Levings 1984, Yrjana et al. 2002). Thus, it is likely that side channel areas provide protection from high flow events for developing brook trout eggs, allowing their persistence in these off channel areas. In addition to providing habitat for non-native brook trout, the shallow backwater areas of cold side channels also provide habitat for multiple species of native and non-native fish not normally observed in the main river.

The ontogenic differences in habitat use, diel and seasonal movement patterns, and the significantly larger densities of cutthroat trout ≥ 300 mm in the side channels than the main river suggests the importance of these seasonal habitats for this species in the North Fork Coeur d'Alene River. The reduced use of thermal refugia by rainbow trout in the lower reaches of the study area suggests these habitats are not as critical for this species. This finding has strong

implications for conservation of westslope cutthroat trout in the lower reaches of the North Fork Coeur d'Alene River, as other studies have documented rainbow trout displacing cutthroat trout in low elevation reaches in the western United States (Griffith 1988, Paul and Post 2001). Our findings indicate that displacement of cutthroat trout by rainbow trout in lower elevation reaches may be facilitated by a reduced dependence on colder water in these areas. Furthermore, low elevation reaches commonly have human disturbances that destroy and limit availability off channel habitats that may serve as thermal refugia for native species. This was the case on our study area, where 36% of the floodplain has been lost to human development. Further losses in the floodplain could feasibly facilitate displacement of cutthroat trout by rainbow trout in the lower reaches of the North Fork Coeur d'Alene River.

This study is unique in documenting the importance of side channel habitat as thermal refugia during the summer by larger salmonids. Other studies have documented the use of side channels as rearing habitat for juvenile salmonids (Swales and Levings 1984, Giannico and Hinch 2003). Other studies have also documented the use of thermal refugia by adult fish (Nielsen et al. 1994, Baigun et al. 2000, Goniea et al. 2006, High et al. 2006), and indicated the potential of side channels to function as thermal refugia (Ebersole et al. 2003a), however no previous studies that we are aware of have documented the use of side channels as thermal refugia by large numbers of adult salmonids. These findings demonstrate the potential for side channels to provide important seasonal habitats for adult trout, and have implications for conservation of active floodplains, hyporheic flow paths, off-channel habitats, and thermal refugia that may be beneficial in similar river systems.

FACTORS INFLUENCING DENSITIES OF SALMONIDS ≥ 300 MM IN THE SIDE CHANNELS

Densities of adult westslope cutthroat trout in side channel habitats were influenced by the ratio of maximum depth to bottom temperature and water visibility within the side channels. The interaction between depth and temperature had the strongest influence on cutthroat trout densities in the side channels, with channels that were both deeper and colder containing the highest densities of fish. Specifically, adult cutthroat trout used side channels that were ≥ 2 m deep, with temperatures that stayed ≤ 20˚ C. Similarly, Baird and Krueger (2003) found use of tributary confluences as thermal refugia by brook and rainbow trout was influenced by confluence depth, with fish selecting deeper confluence areas. Breau et al. (2007) also found use of cold water refugia by juvenile Atlantic salmon was influenced by water temperature and depth. In this study, salmon were not always associated with the coldest habitats but rather the areas that were both cold and deep (Breau et al. 2007). Selection for deeper areas also appears common with other adult salmonids (Mäki-Petäys et al. 2004, Al-Chokhachy and Budy 2007) and may be related to reduced predation pressure from terrestrial vertebrates (Harvey and Stewart 1991). Although the ratio of maximum depth to temperature influenced cutthroat trout densities in side channels, a large amount of variation remained unexplained (r^2 = 0.476). Similarly, Isaak and Hubert (2004) found a considerable amount of variation remained unexplained when they modeled the effects of temperature on cutthroat trout densities. The significance of water visibility in the cutthroat density model suggests the possibility of observer bias in our observations. We do not believe this is the case, however, since multiple observers were used when visibility was reduced. It is more likely that visibility is an indicator of water flow in the side channels, as those channels with reduced visibility were usually in channels with no observed flow. Although relative flow was not significant in the model, it was correlated with visibility. Additionally, the presence of flow in the side channel appeared important for use by cutthroat trout, as no fish were observed in side channels without flow. The significance of

visibility and not the relative amount of flow suggests that the presence of flow was more important than the amount of flow.

Densities of adult rainbow trout in side channels were influenced by side channel maximum depth, the proportion of bedrock substrate, and overhead canopy coverage. Side channel maximum depth had the strongest influence on adult rainbow trout densities in the side channels, with increased densities associated with increased depths. Specifically, most adult rainbow trout used side channels that were ≥ 2 m deep. Similarly, Ebersole et al. (2001) found mean rainbow trout densities in thermal refugia were positively correlated with increasing mean depths. Baird and Krueger (2003) found rainbow and brook trout use of thermal refugia associated with deeper areas. Furthermore, Harvey et al. (2005) found rainbow trout densities were positively influenced by habitat depth. Densities of rainbow trout in our study were negatively associated with increased canopy coverage, which contrasts with other studies (Baigun 2003, Ebersole et al. 2003b). Canopy coverage in this study, however, was not related to side channel maximum weekly maximum temperatures (linear regression, $P = 0.9255$), as temperatures were regulated by upwelling groundwater. Adult rainbow trout densities were also related to proportion of bedrock substrate in our study. Other studies evaluating the use of pool habitat by adult summer steelhead have found pool use is related to substrate composition (Baigun 2003) and substrate embededness (Nakamoto 1994). Finally, a large amount of variation in rainbow trout density remained unexplained by the model ($r^2 = 0.334$) which suggests there were likely other factors influencing rainbow trout densities that were not accounted for.

Adult mountain whitefish densities in the side channel transects were influenced by maximum depth, water visibility, the quantity of small woody debris, and the distance of the transect from the main river. Similar to cutthroat and rainbow trout, maximum depth was an important characteristic of side channels that were used as thermal refugia by whitefish. As side channel depth increased, so did the densities of mountain whitefish in the side channels, once again similar to salmonids in other studies (Brown and Mackay 1995, Ebersole et al. 2001, Baird and Krueger 2003, Breau et al. 2007). Specifically, adult mountain whitefish used side channels that were ≥ 2.5 m deep. As with cutthroat trout, it is likely that water visibility was an indicator of the presence of surface flow, as no whitefish were observed in channels without some degree of flow. Additionally, increasing the amount of small woody debris in the side channels led to increased densities of mountain whitefish. The importance of small woody debris for salmonids has been well documented (Roni and Quinn 2001, Zika and Peter 2002, Giannico and Hinch 2003), as it provides in-stream cover used by multiple age classes. Lastly, the distance of a transect up the side channel from the main river was inversely related to mountain whitefish densities in the side channels. This supports our observation that fish using side channels as thermal refugia did not appear to move up the longer side channels, but stayed in the cold deep reaches close to the mouth. It is also important to note that a large amount of variability remained unexplained in this model ($r^2 = 0.375$), indicating the presence of other factors influencing side channel use by mountain whitefish.

Surprisingly, temperature alone was not significant in any of the adult salmonid density models. This is likely related to the fact that nearly all of the side channels were colder than the main river, and thus had potential to function as thermal refugia. That temperature influenced side channel use is apparent in the fact that no side channels with maximum temperatures ≥ 20˚ C contained large aggregations of salmonids ≥ 300 mm in this study. Despite most of the channels being colder than the main river, they varied widely in their physical characteristics, and subsequently their suitability for use by fish was highly variable. The absence of temperature as a significant factor in the density modeling thus likely reflects the fact that nearly

all of the channels were suitable thermally, but use of the available thermally suitable habitat was dictated by physical habitat characteristics. This is similar to other studies that concluded temperature was the driving force behind thermal refugia occupancy, but specific use of thermal refugia was dictated by other habitat features (Baigun et al. 2000, Sutton et al. 2007). Additionally, Picard et al. (2003) found models predicting presence or absence of brook trout based solely on temperature indices were much more effective at predicting absence than presence. This was because thermally unsuitable habitat will not likely be used; however, presence in thermally suitable habitat is often influenced by other factors (Picard et al. 2003). Furthermore, the use of thermal refugia can depend on the ambient river temperatures at the reach level (Ebersole et al. 2001). While we monitored river temperatures over a broad spatial scale on our study area, we did not monitor river temperatures at a spatial resolution fine enough to detect differences in side channel densities based on main river temperatures adjacent to each specific side channel reach. Additionally, all of the density models left a considerable amount of variation unexplained (Table 8), which is likely at least partially due to the relatively small sample sizes for modeling (n = 21), combined with the high natural variability in the use of these habitats. Lastly, we did not monitor dissolved oxygen levels in the side channels, and this factor can significantly influence the suitability of thermal refugia for use by fish (Ebersole et al. 2003a). In summary, large aggregations of westslope cutthroat trout were limited to side channels > 2 m deep, with temperatures < 20° C, and some degree of flow present.

TEMPERATURE MODELING

Our results suggest the factors showing a significant relationship with MAWT in the side channels were a channel's location in the floodplain and the levels of riparian vegetation surrounding side channels. Specifically, a side channel being located against the floodplain valley wall led to significantly colder MAWT. Similarly, Ebersole et al. (2003a) found groundwater upwelling frequently occurred where steam channels came into contact with valley walls. Additionally, light riparian vegetation levels showed a positive significant relationship with MAWT in the side channels. Both Ebersole et al. (2003a) and Johnson (2004) found experimental shading can lower stream temperatures; however, Ebersole et al. (2003a) found no correlation between canopy coverage and longitudinal temperature in cold water patches. Our results also showed no relationship between canopy coverage and water temperature (P = 0.9255), which was likely due to the large amounts of groundwater regulating in-channel temperatures. Lastly, lower MAWT was associated with increases in bolder substrate in the riverside bank, as well as fine and gravel substrate in channel. Coarse substrates often have increased hydraulic conductivity (Kasahara and Hill 2006), which can lead to increased hyporheic exchange (Morrice et al. 1997). Therefore boulder substrates in the riverside bank likely facilitated subsurface flow from the main river and into the side channels. Fine substrates in channel can reduce hyporheic exchange (Kasahara and Hill 2008), therefore fine substrates in colder channels likely just facilitated retention of groundwater coming in through the bank substrates (i.e. prevented groundwater from leaving out the bottom of the channel) and probably did not increase rates of hyporheic exchange in channel. Additionally, the deposition of fines and gravels in the side channel habitats is likely facilitated with high flow events in this river system. Therefore, the smaller substrates in cold channels may have been a function of decreased flow velocities during high flow events, allowing these substrates to settle.

Maximum weekly maximum temperatures in the side channels were most strongly influenced by substrate composition in the side channel bank opposite the river. Specifically, increased bedrock substrate in the opposite bank led to decreased MWMT. Increased cobble

and boulder substrates in the opposite bank, and fines in the riverside bank, led to increased MWMT. The porosity of these substrates likely influenced the rate and retention of hyporheic exchange in the side channels (Kasahara and Hill 2006). Finally, increases in the average distance between the main river and the side channels led to significantly decreased temperatures. Larger distances indicate water flowing subsurface from the main river is underground longer, which would likely decrease the temperature of the water.

Taken together the results from modeling, the effects of physical features on the different temperature metrics within the side channels can be used to hypothesize a model of groundwater flow into the side channels. While the models for each temperature metric were slightly different, they both included parameters indicating that a channels location in the floodplain, as well as in-channel substrates may influence water temperatures. Additionally, the MAWT model (r^2 = .8111) explained more variation that the MWMT model (r^2 = .7551). The most significant variable influencing temperatures in the side channels was the side channel's location in the floodplain. Similar to Ebersole et al. (2003a), we found groundwater upwelling was common in channels against floodplain valley walls. It is likely that water flowing subsurface may be forced to the surface when it comes into contact with the impermeable bedrock walls. W e commonly observed subsurface flow entering the side channels laterally from the riverside banks. This suggests that much of the subsurface water entering the side channels was flowing from the main river and through the bar separating the river from the side channels before entering the channel. Increasing the distance between the river and the side channel led to decreased water temperatures in the side channels. Increasing the distance the subsurface water flows from the river to the side channel would mean increasing the amount of time the water spends subsurface, which may decrease the water temperatures. Additionally, the riverside bank being composed of boulder substrates led to decreased temperatures, while the bank being composed of fine substrates led to increased temperatures. This indicates that as the water flows subsurface from the river and into the side channel, the porous bolder substrates in the bank may allow more subsurface flow to enter the channel, while less permeable fine substrates reduce the flow (Kasahara and Hill 2006). Furthermore, the substrate composition in the bank opposite of the riverside was also significantly related to water temperatures in the side channels. Increasing amounts of porous cobble and bolder in the opposite bank led to increased water temperatures, while increasing bedrock composition in the opposite bank led to decreasing water temperatures. This indicates that the impermeable bedrock in the opposite bank may prevent groundwater from going subsurface out the opposite side of the channel, while porous substrate in the opposite side bank may facilitate more subsurface movement (Kasahara and Hill 2006). Thus, we hypothesize that the channel's location in the floodplain is the dominant factor shaping the amount of upwelling groundwater, and the role of substrate in shaping side channel water temperatures lies in regulating the inflow and retention of groundwater within the channels.

AIRBORN THERMAL SENSING

The airborn thermal sensing report provided by Watershed Sciences Inc. for the North Fork Coeur d'Alene river shows an observed downstream cooling trend in the river. This is opposite of the downstream warming trends that typically occur, and suggests the presence of strong temperature buffers in this system (Poole and Berman 2001). The temperature buffers in this system exist in the form of springs formed by hyporheic flow entering the river from subsurface (Watershed Sciences Inc. 2007). In addition to a general downstream cooling trend, a cooling effect was also observed near several constrictions of bounded alluvial valley

segments. This result is similar to results found in other studies documenting hyporheic upwelling commonly occurring at the downstream end of bounded alluvial valley segments (Baxter and Hauer 2000, Pepin and Hauer 2002).

Springs formed by upwelling hyporheic flow in the North Fork Coeur d'Alene river system most commonly occur in areas with an intact floodplain (Figure 25). Much of the floodplain in the lower reaches of this system is privately owned, and development has caused significant loss of intact floodplain in these areas. The most common cause of floodplain loss is road construction, which permanently limits natural movement of the river. Limiting the natural floodplain dynamics leads to destruction of existing off channel habitats, and may prevent new side channel formation. Additionally, the largest cooling trends in the main river were associated with areas of intact floodplain. In contrast, warming main river trends were associated with developed areas, which have implications for floodplain conservation. As previously mentioned we believe the available thermal refugia in the lower reaches of the river are critical for cutthroat. This fact, coupled with the current state of habitat loss in the lower reaches, suggests the critical importance of protecting these areas from further development and habitat loss. Examples of such areas can be found (but are not limited to) near river kilometers 4, 10, 11, 27, 28, 31, 32 (Figure 25).

We suspect the downstream cooling effect observed in this system may differ from those in other northern Idaho river systems. In other rivers such as the St. Joe, North Fork Clearwater, and Lochsa resident fish have been found to move long distances upstream to reach cooler waters during summer. These rivers are more canyon like and lack the floodplain and alluvial valley habitat that are necessary to form hyporheic flow. In the North Fork Coeur d'Alene River trout migrate long distances to upstream spawning grounds; however, summer movements occur over short distances and are more localized (DuPont et al. *in press*).

IMPLICATIONS FOR SIDE CHANNEL CONSERVATION AND ENHANCEMENT

This study has documented the importance of side channel habitats as cold water refugia for larger salmonids in the North Fork Coeur d'Alene River during periods of elevated temperatures. Similar studies have documented the importance of other types of thermal refugia for salmonids of various life history stages during periods of thermal stress both in the summer (Mathews and Berg 1997, Baird and Krueger 2003, Breau et al. 2007, Sutton et al. 2007) and winter (Brown and Mackay 1995). The large aggregations of fish observed using thermal refugia in both this and other studies (Brown and Mackay 1995, Baird and Krueger 2003, Breau et al. 2007, Sutton et al. 2007) suggests that these habitats are spatially limited (Brown and Mackay 1995, Power et al. 1999). Cumulative small scale losses of such thermal refugia can turn good trout habitat into poor habitat (Power et al. 1999, Poole and Berman 2001), thus conservation of these habitats is of critical importance. Conservation of thermally stable off channel habitats for use as thermal refugia by westslope cutthroat trout during the summer may also provide benefits during other seasons (Brown and Mackay 1995). Furthermore, the importance of thermal refugia to cutthroat trout will likely increase over time, as global climate change poses a serious threat to trout habitat in the western United States (Keleher and Rahel 1996, Rahel et al. 1996, Jager et al. 1999).

The first logical step in conservation or enhancement of side channel thermal refugia is protecting the important habitats already identified. Our study indicates that conserving existing cold side channels in the lower reaches of the North Fork Coeur d'Alene system is important

due to the large degree of habitat loss that has already occurred. This would include side channels 2, 3, 4, 6, 7, 10, and 15 but not be limited to these areas as additional springs have been identified (Figure 25). Cutthroat trout populations are healthy in these lower reaches (DuPont, unpublished data); however, changes in thermal regimes can facilitate spread of invasive salmonids (Fausch 2007). Therefore, protecting existing side channel thermal refugia should aid in maintaining local cutthroat trout populations. Much of the floodplain in these areas is privately owned, therefore, conserving suitable habitats will require strong cooperation with private landowners. The upper reaches of the study area are mostly under the jurisdiction of the U.S. Forest Service, and therefore may be easier to conserve. Nonetheless, coordinated efforts should be made to conserve the cold side channels already identified on federal lands, as well as the cold springs identified through thermal imaging. Additional efforts should be made to protect floodplain connectivity at the downstream end of bounded alluvial valley segments (river km 20 and 31), as this and other studies have indicated these areas commonly have large amounts of upwelling hyporheic groundwater (Baxter and Hauer 2000, Pepin and Hauer 2002). Proactive conservation of cold off channel habitats will also be more cost effective in the long term, as methods to protect existing habitats are often less expensive, more effective, and easier to implement than restoration efforts (Kauffman et al. 1997). Finally, these hyporheic flow paths are not static systems, and large variations in these processes have been reported by other authors (Ebersole et al. 2003b, Wright et al. 2005). Therefore, protection of intact floodplain will facilitate natural hydrologic processes and allow the river channel to shift and form new off-channel habitat.

Enhancement of existing side channel habitats may provide an effective way to increase the suitability of unused thermal refugia to adult salmonids. Restoration efforts that focus on restoring ecological processes will likely be more effective than a single species or group of species approach (Kaufmann et al. 1997). However, this is not always possible, and in these situations, stream enhancement for a specific group of species can still be a viable option (Kaufmann et al. 1997). Ebersole et al. (2003a) suggested that not all cold water patches are suitable thermal refugia for fish due to varying levels of dissolved oxygen concentrations. We did not measure dissolved oxygen levels in our study; however, the larger aggregations of fish suggested that dissolved oxygen levels were adequate in side channels that were used as thermal refugia. Low dissolved oxygen could, however, have attributed to the lack of use of some of the channels by salmonids in our study. Additionally, Ebersole et al. (2001) found that many cold water patches were too small or shallow to be used by large numbers of fish. Our results agree with these studies, as adequate depth had a strong influence on side channel use by adult salmonids. Based on the results of our study perhaps the single most effective enhancement approach available is reconnecting existing cold water side channels that loose connection with the main river during low flows, and ensuring adequate depths are maintained by physically manipulating the mouths of these channels. There were many observed side channels in our study that remained colder than the main river and provided adequate flows but were not used by large numbers of fish because they lacked suitable depth. Examples of side channels that would be good candidates for enhancement include numbers 3, 7, 10, 17, 18, 19, and 20 (Figure 2, Table 9). Efforts to maintain depth of 2.0 m or more in these or other cold areas will likely provide the largest benefit to adult cutthroat in our study area. Adequate depths need to be maintained directly up channel from the main river, as fish did not appear to move up-channel past depths < 1.0 m, even when suitable habitat was available upstream. Lastly, efforts to maintain or restore adequate levels of riparian vegetation will also likely benefit side channel habitats, as was found to influence thermal characteristics of cold water areas.

In areas where suitable side channel habitat has been lost due to floodplain development or river constriction, constructing new side channels to be used as thermal refugia

may prove effective. If side channel construction is a desired option, we recommend locating channels in areas identified to have significant groundwater upwelling, as this has proved effective in other studies (Morley et al. 2005). This would provide a cold water source and reduce the likelihood of producing a channel that will not be cold enough to be used as thermal refugia. Similarly, Morley et al. (2005) reported artificial side channels constructed over known groundwater upwelling sites maintained groundwater flow and had cooler summer temperatures and warmer winter temperatures than natural side channels. Concentrated springs identified through thermal imaging that may provide adequate amounts of groundwater upwelling for side channel construction include the areas near river kilometers 4, 10, 25, 27, 31, 32, 33, 36, 38, 40, 46, 47, and 50 (Figure 25). Since our study found side channel temperatures were influenced mainly by side channel location, riparian vegetation levels, and substrate composition in the riverside bank, these factors should also be considered. Ideally a constructed side channel would be located in an area with significant groundwater upwelling alongside the valley wall. To provide the most benefit to salmonids in the North Fork Coeur d'Alene River system, channels should be constructed so that adequate depths (≥ 2.0 m) are maintained immediately upstream of the river in the side channel, and river depths adjacent to the mouth of the side channel remain ≥ 1 m. If financially feasible, side channels should be of adequate length and constructed so that they contain pool-riffle sequences within the channel. This would promote subsurface flow, as hyporheic flow within channel commonly down wells at the head of riffles and up wells at the tail of riffles (Pool and Berman 2001, Kasahara and Hill 2006), and longer side channels may increase the likelihood of intercepting hyporheic flow. Using coarser substrates in-channel creates higher hydraulic conductivity, which can increase hyporheic flow (Kasahara and Hill 2006, Kasahara and Hill 2008). Furthermore, increasing the in channel hydraulic gradient can increase hyporheic exchange in constructed riffles (Kasahara and Hill 2006) and may have a stronger influence on hyporheic exchange than the size of the substrate used in the channel (Kasahara and Hill 2008). In addition to promoting channel complexity through construction of pool-riffle sequences, placing large wood in the channel may be beneficial, as large wood in-channel can help maintain pool depth (Johnson et al. 2005), and channel spanning log structures are often associated with in channel hyporheic flow (Baxter and Hauer 2000).

If side channel habitat is constructed or enhanced, periodic maintenance will likely be required to ensure these dynamic channels maintain desired characteristics. Since depth is important for the use of side channel habitats as thermal refugia by adult salmonids, efforts need to ensure adequate depths are maintained over time. Studies have shown that both full and partial spanning in-stream structures used in restoration can maintain depth over time in small streams (Crispin et al. 1993, Schmetterling and Pierce 1999), and may be effective in maintaining depth within side channels. In contrast, Morley et al. (2005) used no in-channel structures in their constructed side channels, and found no noticeable change in depths over a ten year period. In addition to maintaining depth, maintenance of hyporheic flow over time is necessary. Hyporheic flows may be reduced over time (Kasahara and Hill 2006), which can be facilitated by fine sediments settling over porous substrates (Kasahara and Hill 2008). In this study, however, we commonly observed considerable groundwater upwelling in side channels that had small layers of fine sediment overlaying more porous substrates, suggesting fine substrates were not significantly reducing rates of hyporheic exchange in the observed side channels. One final maintenance concern involves the ability of flooding to cause significant changes in channel morphology, as well as both surface and subsurface flow paths (Wondzell and Swanson 1999). Although flooding helps create side channels, it also has the potential to destroy or alter the physical and subsurface flow characteristics desired in side channels over time (Wondzell and Swanson 1999). Previous side channel construction projects have dealt with this reality by constructing large dikes between the river and the side channel to prevent

future flooding from altering the suitability of constructed side channels for target fish species (Sheng et al. 1990). Thus, any future side channel construction efforts in the North Fork Coeur d'Alene floodplain should consider the possible influences of high flow events on constructed channels.

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Table 1. The average daily maximum temperature (DMT) during four sampling periods in the side channels and in the main North Fork Coeur d'Alene River, Idaho.

Sample period	Dates	Average DMT	
		River	Side channel
1	June 25 to July 3, 2007	17.9	12.5
2	July 9 to July 17, 2007	22.0	14.5
3	July 23 to July 31, 2007	22.4	15.4
4	August 1 to August 9, 2007	20.6	15.1

Table 2 The number of fish observed while snorkeling side channel transects on the North Fork Coeur d'Alene River, Idaho, during four sampling periods from June 25 to August 9, 2007. Transects numbers that end in a "1" started at the mouth of the side channel whereas those that ended in a "2" or "3" occurred upstream from the mouth.

Transect	WCT	RBT	BRK	MWF	TRS	LSS	NPM	RSS	LND	PMK	Total
1-1							1,082	701		2	1,785
2-1	15	4		871		44	1,115	200			2,249
2-2	14	9		100			190				313
3-1	2		17	2			10			40	71
3-2			5	8							13
4-1	32	48		769			111				960
5-1		1		1					5		7
6-1	61	68		109		1	1				240
7-1				63							63
7-2	12	27	31	117							187
7-3	2	5	5								12
8-1	19	27	1	37		40	160	300			584
9-1				7			304				311
10-1							75				75
10-2		1	9	21							31
11-1	6	2			1						9
12-1				4		40	950				994
13-1	19	19	4	9							51
15-1	399	24	14	1,240							1,677
15-2	28	4	72								104
16-1	6	7	1			2	30				46
17-1			5			1					6
18-1			26								26
19-1		2	13			59	20				94
20-1	1		2			1					4
21-1	3	1		2							6
Total	619	249	205	3,360	1	188	4,048	1,201	5	42	9,918
Percent	6.2	2.5	2.1	33.9	0.0	1.9	40.8	12.1	0.1	0.4	100.0

WCT = westslope cutthroat trout, RBT = rainbow trout, BRK = brook trout, MWF = mountain whitefish, TRS = Torrent sculpin, LSS = largescale sucker, NPM = Northern pikeminnow, RSS = redside shiner, LND = longnose dace, PMK = pumpkinseed.

Table 3. The number of fish observed while snorkeling transects in the main North Fork Coeur d'Alene River, Idaho, on July 31 and August 1, 2007.

Transect	WCT	RBT	MWF	CHS	LSS	NPM	LND	**Total**
NF1	29	22	550		80	1250		1,931
NF2	16	11	220		10	20		277
NF3	31	22	560		40	610		1,263
NF4	42	27	600		300	1200		2,169
NF5	72	49	275		160	1200		1,756
NF6	43	36	200			55		334
NF7	141	39	350	1	50		1	582
NF8	64	12	180					256
NF9	39	7	10					56
Total	477	225	2,945	1	640	4,335	1	8,624
Percent	5.5	2.6	34.1	0.0	7.4	50.3	0.0	100.0

WCT = westslope cutthroat trout, RBT = rainbow trout, MWF = mountain whitefish, CHS = Chinook salmon; LSS = largescale sucker, NPM = Northern pikeminnow, LND = longnose dace.

Table 4. The percent of salmonids ≥ 300 mm in length observed while snorkeling side channels and the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

	Percent ≥ 300 mm	
Species	Side channel	Main river
Cutthroat trout	62.4	19.7
Rainbow trout	43.1	17.3
Mountain whitefish	74.4	25.9
Brook trout	11.6	NA

Table 5. The number of fish sampled through electrofishing transects approximately 100 m in length in side channels located along the North Fork Coeur d'Alene River, Idaho, from July 25 to August 13, 2007. The transect number has been recorded as two numbers spaced by a ".". The first number indicates what side channel the sampling occurred in and the second number indicates how many meters (times 100) upstream from the mouth the sampling occurred.

Transect	Temp	Time	WCT	RBT	BRK	MWF	TRS	SHS	LSS	LNS	NPM	RSS	LND	SPD	TEN	PMK	BBH	Total
3.2	12.5	9:55			3		2	1	17		42	30	1	29		25		150
3.4	10.0	11:00			52			1								22		75
5.3	18.0	12:00							5		87	33		11	1	15	3	155
6.2	10.0	13:46	1		4		2		4	6	76	1			1	1		96
7.6	18.5	14:50	2	1	8		11	3					13	4				42
7.9	20.0	15:41		1	16		5	11			2		16	1				52
11.1	17.5	10:05	1	3			56	27					5					92
11.2	17.0	9:58			4		13	7	4				3					31
13.2	14.0	10:48			1	3			8		7			10				29
15.1	12.0	13:16			22		7		1	2			3	9				44
15.5	12.0	16:00	1	2	39		6	2			3							53
17.3	15.5	14:00							6	56				62	6			130
17.4	14.0	15:00							5	49				72				126
18.3	10.0	11:50	2		24		1	2										29
18.4	9.0	12:03	1		21		23	20		1	1							67
19.0	22.0	10:10							24	17			72					113
Total	NA	NA	8	7	194	3	126	74	74	131	218	64	113	198	8	63	3	1,284
Percent	NA	NA	0.6	0.5	15.1	0.2	9.8	5.8	5.8	10.2	17.0	5.0	8.8	15.4	0.6	4.9	0.2	100.0

WCT = westslope cutthroat trout, RBT = rainbow trout, BRK = brook trout, MWF = mountain whitefish, TRS = torrent sculpin, SHS = shorthead sculpin, LSS = largescale sucker, LNS = longnose sucker, NPM = Northern pikeminnow, RSS = redside shiner, LND = longnose dace, SPD = speckled dace, TEN = tench, PMK = pumpkinseed, BBH = brown bullhead.

Table 6. Average temperatures observed in the four snorkeled side channels and the main North Fork Coeur d'Alene River, Idaho, during four time periods on August 1, 2007.

		Average temperature (°C)	
Time period	Time	River	Side channels
1	8:30 to 9:50	17.0	15.0
2	10:50 to 12:30	18.8	15.8
3	13:25 to 14:50	20.1	16.5
4	15:30 to 16:45	21.1	17.0

Table 7. Pair-wise comparisons (Letter group) of the average percent of maximum cutthroat trout, rainbow trout, and mountain whitefish observed in four side channels across four time periods using Fishers Least-Significance-Difference tests with a p-value of 0.10 denoting significant differences.

		Average Percent of Maximum			Pairwise Comparison		
Time Period	Time	Cutthroat	Rainbow	Whitefish	Cutthroat	Rainbow	Whitefish
1	8:30 to 9:50	69	25	39	A	A	A
2	10:50 to 12:30	66	47	44	A	AB	A
3	13:25 to 14:50	96	90	98	A	C	B
4	15:30 to 16:45	84	79	98	A	BC	B

Table 8. Results of Yohai's MM-Estimation Robust Regression Analysis that shows the linear model of attributes that significantly (< 0.10) influenced densities of cutthroat trout, rainbow trout, and mountain whitefish ≥ 300 mm in length in side channels along the North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

Species	**Linear Model**	**R^2**
Cutthroat Trout	Y = -0.1172 + 1.4617(md/bt) + 0.0088(v)	0.476
Rainbow Trout	Y = -0.0036 + 0.0215(md) + 0.0165(bed) - 0.0011(cc)	0.334
Mountain Whitefish	Y = -1.0748 + 0.4501(md) + 0.0472(v) + 0.0133(sw) - 0.0008(d)	0.375

md = maximum depth, bt = instantaneous bottom temperature, v = visibility, bed = percent bedrock substrate, cc = canopy cover, sw = quantity of small woody debris, d = distance from the main river.

Table 9. Habitat attributes of side channel transects along the North Fork Coeur d'Alene River, Idaho, that were found to have a significant relationship with cutthroat trout, rainbow trout or mountain whitefish (≥ 300 mm) densities during the summer of 2007.

Side channel	Density (fish ≥ 300 mm/100 m^2)			Maximum depth (m)	MWMT	Relative flow	Visibility (m)	% small wood	% bedrock	Canopy cover	Distance from river
	Cutthroat	Rainbow	Whitefish								
1-1	0.00	0.00	0.00	1.7	20.1	0	5.1	6.0	0.7	23.4	0
2-1	0.23	0.05	12.76	4.0	17.3	2	11.6	1.7	0.0	12.0	0
2-2	0.19	0.13	0.74	2.9	14.0	2	10.4	0.7	3.3	4.4	39
3-1	0.04	0.00	0.07	1.4	15.4	1	10.1	3.3	0.0	34.9	0
3-2	0.00	0.00	0.00	6.0	10.5	1	6.0	5.0	6.7	13.8	270
4-1	0.60	0.50	13.35	2.9	18.5	3	12.8	7.3	0.0	19.5	0
5-1	0.00	0.00	0.00	0.8	21.1	0	13.4	0.7	0.0	9.8	0
6-1	0.21	0.23	0.71	2.1	19.7	5	12.1	5.3	0.0	14.3	0
7-1	0.00	0.00	0.00	0.9	19.5	5	10.6	0.3	0.0	12.8	0
7-2	0.02	0.02	0.00	1.5	17.7	4	11.5	1.3	0.0	5.7	433
7-3	0.00	0.00	0.00	1.6	17.5	3	14.6	6.7	0.0	8.0	710
8-1	0.12	0.17	0.52	2.1	20.0	2	12.1	2.7	0.0	1.7	0
9-1	0.00	0.00	0.00	1.4	19.1	0	6.4	6.7	0.0	17.0	55
10-1	0.00	0.00	0.00	1.3	19.5	1	10.6	11.7	0.0	6.8	0
10-2	0.00	0.00	0.07	1.9	15.6	1	6.4	6.7	0.0	21.8	27
11-1	0.07	0.00	0.00	0.8	19.3	3	16.4	0.7	0.0	21.4	0
12-1	0.00	0.00	0.00	1.7	18.2	0	2.5	8.7	0.0	36.2	0
13-1	0.98	0.35	0.07	1.3	12.6	4	7.9	13.3	0.0	1.5	0
15-1	2.71	0.21	8.58	2.8	12.9	5	7.6	0.7	11.7	29.3	0
15-2	0.30	0.04	0.00	2.3	10.1	4	7.3	1.0	0.0	12.3	310
16-1	0.02	0.00	0.00	1.5	22.0	4	8.8	0.3	0.0	7.9	0
17-1	0.00	0.00	0.00	1.0	14.9	2	6.3	16.7	0.0	15.4	0
18-1	0.00	0.00	0.00	1.9	15.8	3	7.3	3.3	0.0	22.2	100
19-1	0.00	0.00	0.00	1.0	18.8	1	13.4	2.7	0.0	13.3	100
20-1	0.00	0.00	0.00	1.0	14.5	2	10.9	15.0	0.0	14.4	0
21-1	0.00	0.00	0.00	1.3	25.0	5	10.3	3.7	0.0	14.9	0

Table 10. Information-theoretic (AIC) modeling of factors influencing maximum average weekly temperature (MAWT) and maximum weekly maximum temperature (MWMT) in side channels along the North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

MAWT

Variables in Model	AIC	Δ AIC	R^2
lrv fine grav boldbr vw	21.6013	-	0.8111
lrv grav boldbr vw	27.1044	5.5031	0.7134
lrv fine boldbr vw	30.7874	9.1861	0.6484
lrv boldbr vw	31.1824	9.5811	0.5983
fine grav boldbr vw	31.8467	10.2454	0.6271

MWMT

Variables in Model	AIC	Δ AIC	R^2
dist finebr boldbo bedbo cobbo	40.7598	-	0.7551
dist finebr boldbo cobbo	44.2710	3.5112	0.6972
dist boldbo cobbo bedbo	47.5913	6.8315	0.656
dist cobbo bedbo	48.6296	7.8698	0.6133
dist finebr cobbo bedbo	49.5213	8.7615	0.6295

lrv = light riparian vegetation, fine = in-channel fine substrate, grav = in-channel gravel substrate, boldbr = boulder substrate in the riverside bank, vw = channel location against valley wall, dist = distance between side channel and main river, finebr = fine substrate in the riverside bank, boldbo = boulder substrate in the opposite side bank, bedbo = bedrock substrate in the opposite side bank, cobbo = cobble substrate in the opposite side bank.

Table 11. Multiple regression models of factors influencing maximum average weekly temperature (MAWT) and maximum weekly maximum temperature (MWMT) in side channels along the North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

Metric	Linear Model	R^2
MAWT	Y = 30.5245 - 4.4474(vw) - 0.5269(boldbr) - 0.4130(grav) - 0.1171(fine) + 3.4443(lrv)	0.8111
MWMT	Y = 9.3107 - 0.3141(bedbo) - 0.0264(dist) + 0.3271(cobbo) + 0.0875(boldbo) +0.0774(finebr)	0.7551

lrv = light riparian vegetation, fine = in-channel fine substrate, grav = in-channel gravel substrate, boldbr = boulder substrate in the riverside bank, vw = channel location against valley wall, dist = distance between side channel and main river, finebr = fine substrate in the riverside bank, boldbo = boulder substrate in the opposite side bank, bedbo = bedrock substrate in the opposite side bank, cobbo = cobble substrate in the opposite side bank.

Table 12. Water temperatures of tributaries and other surface inflows as determined through airborn thermal sensing on August 9, 2007 in comparison to the main North Fork Coeur d'Alene River, Idaho, with left (L) or right (R) bank designation when looking downstream (as reported in Watershed Sciences Inc. 2007).

Tributaries	River Kilometer	Tributary Temp (ºC)	Main Stem Temp (ºC)	Difference
SF Coeur d'Alene (L)	0.07	17.4	16.5	0.9
Prado Creek (R)	3.71	19.6	18.1	1.5
side slough (R)	4.57	21.1	18.1	3.0
old channel/slough (R)	5.75	22.1	17.8	4.3
NF Coeur d'Alene (R)	7.42	18.6	18.2	0.4
Lightner Draw (R)	7.69	17.4	18.5	-1.1
Studer Creek (R)	8.22	18.4	18.1	0.3
unnamed-cold (R)	10.66	14.6	17.5	-2.9
Cougar Gulch (R)	13.30	14.3	18.4	-4.1
Steamboat Creek (R)	17.22	17.6	17.9	-0.3
Coal Creek-very small (L)	20.85	11.0	17.7	-6.7
Graham Creek (L)	23.66	13.8	17.4	-3.6
Cinnabar Creek (L)	26.11	10.9	17.1	-6.2
cold side channel (L)	26.36	16.3	17.4	-1.1
side channel (R)	26.58	20.8	17.4	3.4
Brown Creek (R)	28.61	16.9	18.6	-1.7
side channel/shadow (L)	31.75	11.9	19.1	-7.2
Hopkins Creek (R)	32.06	16.0	18.9	-2.9
Hopkins Creek/spring (R)	32.29	10.6	18.7	-8.1
Cedar Creek (L)	33.30	11.6	19.3	-7.7
Beaver Creek (L)	35.89	15.3	19.6	-4.3
Prichard Creek (L)	39.95	15.7	20.4	-4.7
Clee Creek (L)	46.30	18.4	18.5	-0.1
Lost Creek (L)	47.71	14.8	20.3	-5.5
Shoshone Creek (L)	50.20	19.4	20.4	-1.0

Table 13. Water temperatures of springs as determined through airborn thermal sensing on August 9, 2007 in comparison to the main North Fork Coeur d'Alene River, Idaho, with left (L) or right (R) bank designation when looking downstream. (as reported in Watershed Sciences Inc. 2007).

Springs	River Kilometer	Spring Temp (ºC)	Main Stem Temp (ºC)	Difference
spring (R)	3.58	11.8	18.1	-6.3
spring (L)	6.72	11.4	17.9	-6.5
spring (L)	23.35	9.2	17.4	-8.2
spring (L)	25.23	6.9	17.2	-10.3
spring (L)	25.27	9.4	17.4	-8.0
spring (R)	25.34	10.0	17.1	-7.1
spring (L)	30.82	15.1	18.8	-3.7
spring (R)	30.89	11.5	18.5	-7.0
spring/shadow (L)	31.59	15.1	19.4	-4.3
small spring (L)	32.15	15.8	18.9	-3.1
spring (L)	32.37	15.5	18.8	-3.3
Spring on Hopkins (R)	32.52	10.0	19.1	-9.1
spring/very small (L)	32.71	16.1	19.5	-3.4
spring/shadow (L)	34.01	16.1	19.6	-3.5
spring/shadow (R)	35.04	12.4	19.2	-6.8
spring (R)	37.61	16.3	19.4	-3.1
spring (L)	38.16	10.0	19.4	-9.4
spring (L)	38.24	10.4	19.2	-8.8
spring (L)	38.35	12.1	19.4	-7.3
spring (L)	39.62	16.5	19.6	-3.1
spring (R)	39.80	16.1	20.0	-3.9
spring - side channel (R)	42.58	14.6	19.4	-4.8
spring (R)	46.48	14.0	18.7	-4.7
spring (R)	46.63	15.2	18.6	-3.4
spring (R)	46.93	15.8	18.9	-3.1
spring (R)	48.48	10.3	20.3	-10.0
spring (R)	48.79	17.3	20.1	-2.8
spring (R)	49.37	12.3	20.4	-8.1
spring (R)	49.59	14.7	20.6	-5.9
spring (L)	50.08	15.8	20.8	-5.0

Table 14. The amount and causes of floodplain loss in comparison to the historic floodplain area (1,428 hectares) along the lower 50 km of the North Fork Coeur d'Alene River, Idaho.

Reasons for flooplain loss	Hectares lost	Percent lost
Roads	225	16%
Temporary structures	138	10%
Permanent structures	111	8%
Dikes	38	3%
Total	513	36%

Table 15. Variables used in step-wise robust regression to evaluate the factors influencing densities of cutthroat trout, rainbow trout, and mountain whitefish ≥ 300 mm in length in side channels along the North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

Transect	Time	BT	Vis	%Pool	%Run	%Glide	%Riffle	MD	%Aq Veg	%TC	%LW	%SW	%LS	%UC	%OH	% OC	%FS	%GS	%CS	%BLD	%BED	GWF	CC	DFM	SMD	RD	RF
1-1	1107	17.25	5.7	100	0	0	0	1.705	58.75	42.75	2.75	4.75	0	1.5	15	16.25	79.25	5.5	14.5	0.25	0.5	-0.09	23.4	0	1.7	0.202	0
2-1	1138.75	15.75	11.9	100	0	0	0	4.115	31.25	21.5	0.5	1.75	17	0	0	3	30	25	27.5	16.25	1.25	-0.13	12.0	0	4	0.202	2
2-2	1177.25	13.625	10.1	100	0	0	0	2.895	1.75	28	0	0.5	16.25	0	0	11.25	2.5	32.5	46.25	15	3.75	-0.10	4.4	41	2	0.202	2
3-1	1049.75	15.25	10.8	95	5	0	0	1.3575	77.5	49	1	3	0	2.5	12.5	30	30	37.5	32.5	0	0	0.01	34.9	0	1.2	0.202	1
4-1	1208	16.5	13.2	96.25	0	0	3.75	2.925	1.75	35.25	1.75	5.5	23.75	1.25	3	0	38.75	13.75	22.5	25	0	0.01	19.5	0	2.9	0.202	3
5-1	1223	16	13.9	10	0	90	0	0.85	2	7.25	0	0.5	0	0	0.5	6.25	12.5	40	45	2.5	0	0.00	9.8	0	0.72	0.202	0
6-1	1119.25	16	13.0	52.5	43.75	0	3.75	2.3	0.75	35.25	0.75	4	25	1.25	4.25	0	10	26.25	38.75	25	0	-0.02	14.3	0	2.5	0.103	5
7-1	1343.75	16	12.2	10	3.75	86.25	0	0.915	47.5	27.5	0	0.25	0.5	2.25	3.25	21.25	17.25	30	52.5	0.25	0	0.44	12.8	0	0.35	0.045	5
7-2	1478	16.25	13.4	58.25	6.25	33.75	1.75	1.505	23.75	27.5	0	1	18.75	0	1.5	6.25	10	26.25	37.5	26.25	0	0.23	5.7	433	0.3	0.045	4
8-1	1403.5	17.5	12.8	82.5	0	17.5	0	2.075	2	42.5	13.75	2.5	20	0	0	6.25	36.25	13.75	25	25	0	-0.01	1.7	0	1.8	0.045	2
9-1	1208	15.5	7.0	75	0	25	0	1.46	2.25	22.5	7.5	5.5	0	3.75	5.75	0	80.75	7.75	11.25	0.25	0	0.02	17.0	55	0.2	0.045	0
10-1	1206.75	15.75	10.9	98.75	1.25	0	0	1.385	6.25	29	0	9	16.25	0	0	3.75	13.75	40	28.75	17.5	0	0.00	6.8	0	1.4	0.045	1
11-1	1459.25	17	16.2	13.75	26.25	58.75	1.25	0.8	5.5	15	0	0.75	9.25	0.25	1.75	3	0.75	22	54.75	22.5	0	0.04	21.4	0	0.8	0.069	3
12-1	1405.25	16.75	5.3	100	0	0	0	1.67	5.5	43.25	0	7.75	13.25	1.75	20	0.5	71	4	7.5	17.5	0	0.01	36.2	0	1.3	0.069	0
13-1	1337.25	16	8.7	55	30	0	15	1.27	25	44.25	12.5	12.5	14.25	0	0	5	37.5	26.25	20	16.25	0	-0.25	1.5	0	0.7	0.108	4
15-1	1315.5	13.125	8.2	96.25	0	3.75	0	2.925	45	45.75	7.5	0.75	22.5	0	0	15	36.25	11.25	12.5	28.75	11.25	0.34	29.3	0	1.7	0.108	5
15-2	1162	8.75	9.2	96.25	2.5	0	1.25	2.245	15	27.75	0.5	1	23.75	0	0	2.5	37.5	12.5	25	23.75	1.25	0.31	12.3	310	0.08	0.108	4
16-1	1205.25	19.125	9.3	62.5	33.75	2.5	1.25	1.435	0.25	28.25	1	0.25	26.25	0	0.75	0	8.75	20	47.5	23.75	0	0.04	7.9	0	1.2	0.108	4
17-1	1439.25	15	6.8	100	0	0	0	0.97	81.25	53	20	12.5	20	0	0	0.5	75	0.75	3	21.25	0	0.01	15.4	0	0.8	0.384	2
20-1	1072	13.5	10.5	98.75	0	0	1.25	0.965	91.25	66.75	0	12.5	9.25	0	0	45	88.75	0	0	11.25	0	-0.02	14.4	0	0.8	0.419	2
21-1	1103.5	18.125	11.0	43.75	32.5	0	23.75	1.3875	1.5	27.25	0.25	3.25	13.75	7.5	2.5	0	16.25	23.75	42.5	17.5	0	0.04	14.9	0	1.8	0.100	5

Bt = bottom temperature, vis = visibility, %pool = percent pool habitat, %run = percent run habitat, %glide = percent glide habitat, %riffle = percent riffle habitat, md = max depth, %aq veg = percent aquatic vegetation, %tc = percent total cover, %lw = percent large woody cover, %sw = percent small woody cover, %ls = percent large substrate cover, %uc = percent undercut bank cover, %oh = percent overhead cover, %fs = percent fine substrate, % gs = percent gravel substrate, % cs = percent cobble substrate, %bld = percent boulder substrate, %bed = percent bedrock substrate, gwf = estimated groundwater flow, cc = canopy coverage, dfm = distance from mouth, smd = smallest max depth, rd = density of fish in closest main river transect, rf = relative flow.

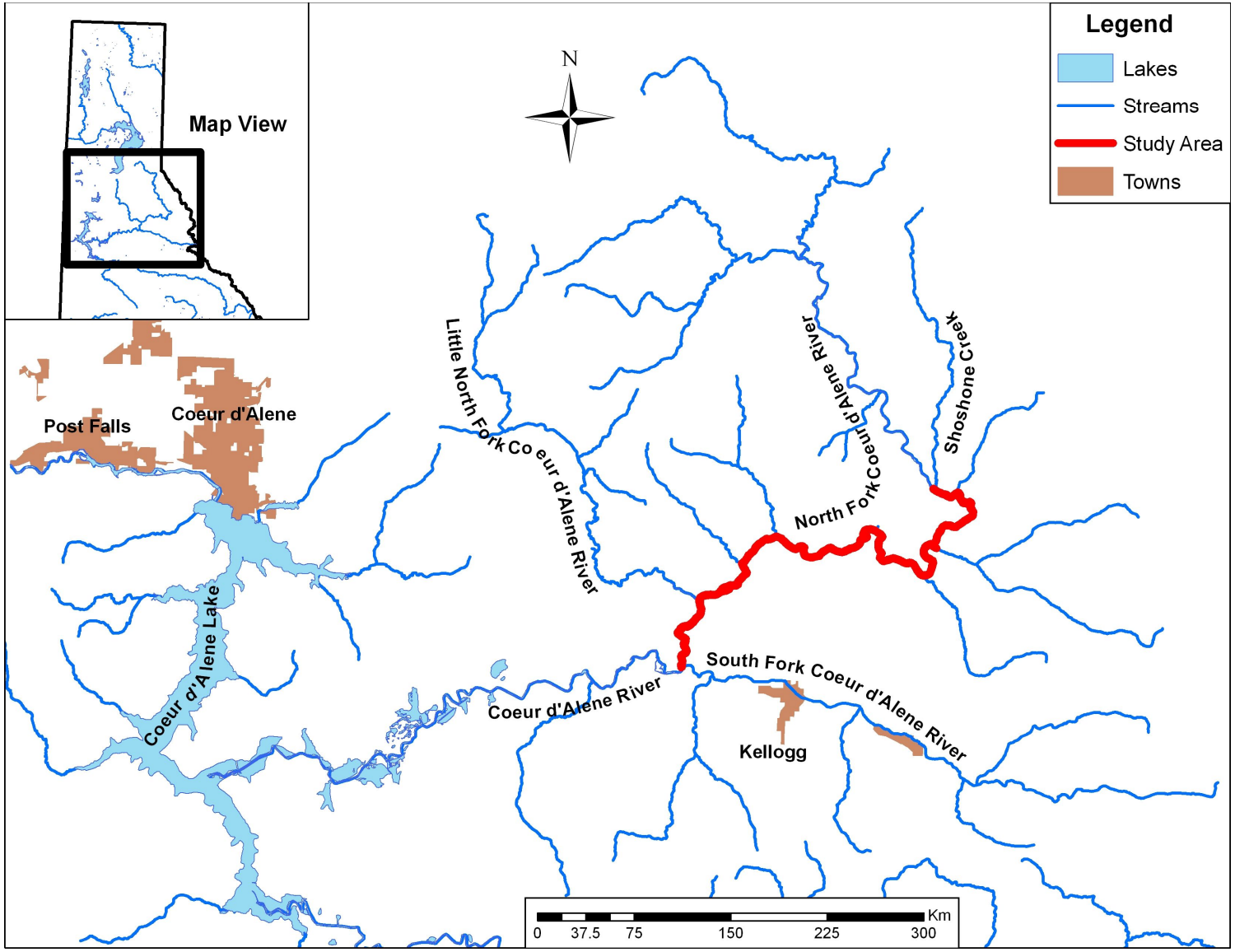


Figure 1. The location of the 50 km study reach on the North Fork Coeur d'Alene River, Idaho.

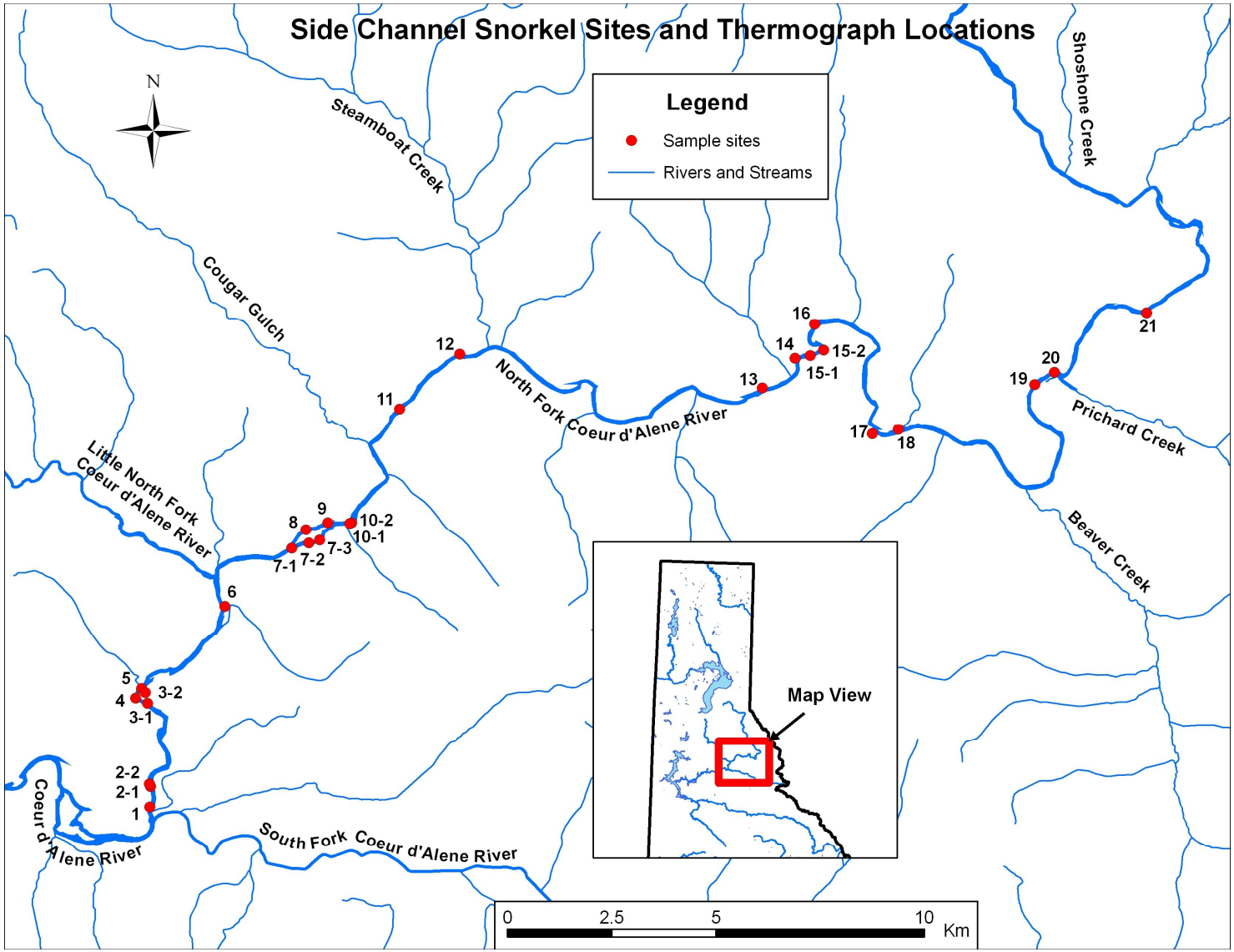


Figure 2. Locations of side channel transects along the North Fork Coeur d'Alene River, Idaho, that were selected for fisheries and habitat assessments during the summer of 2007.

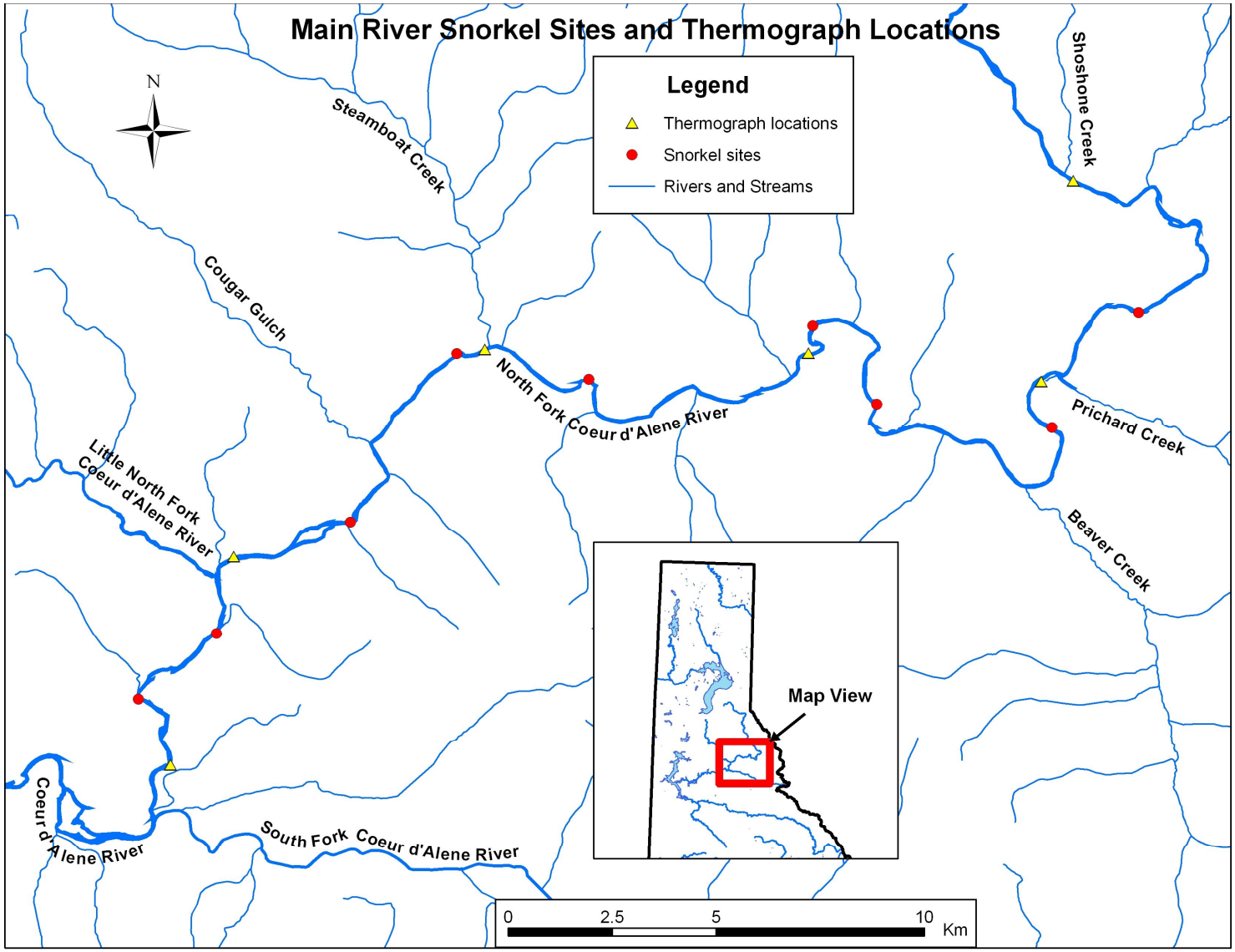
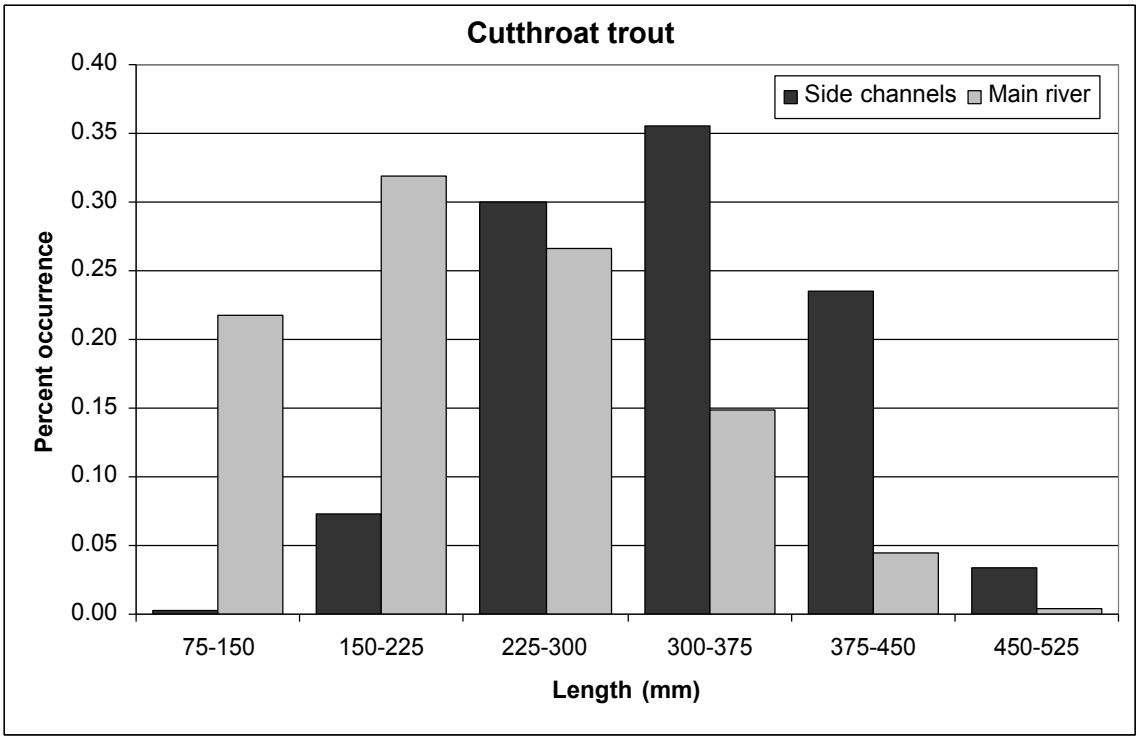


Figure 3. Locations of snorkel sites and thermographs in the North Fork Coeur d'Alene River, Idaho, during 2007.



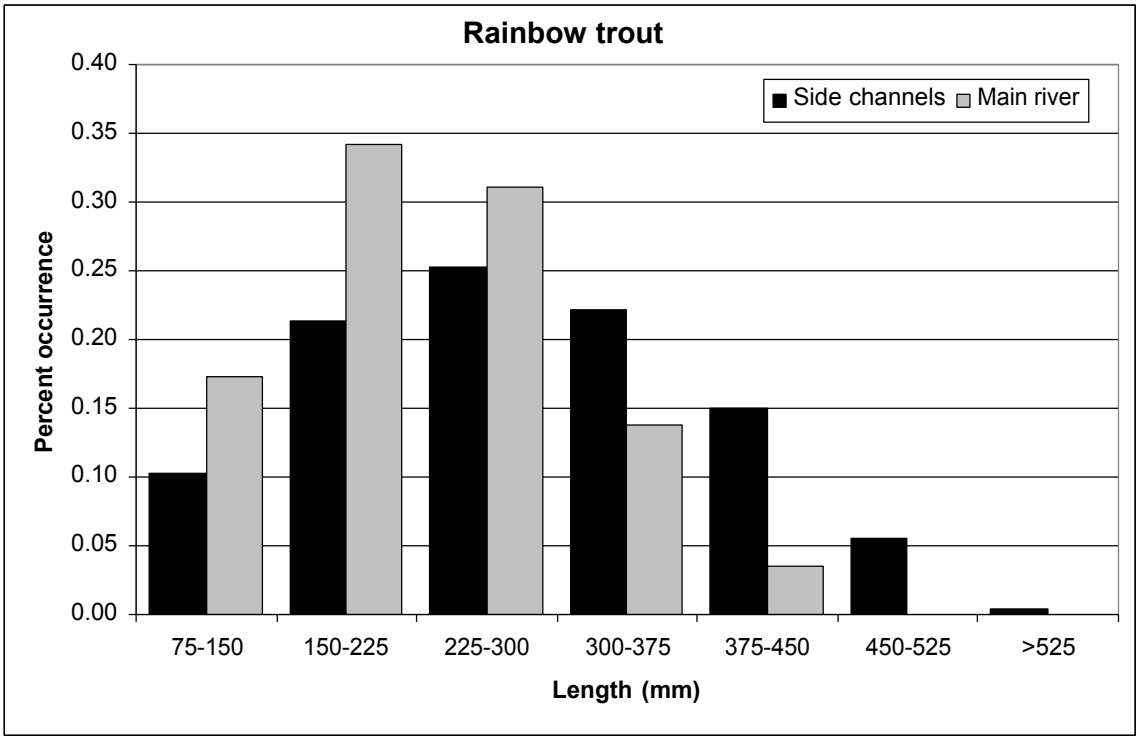
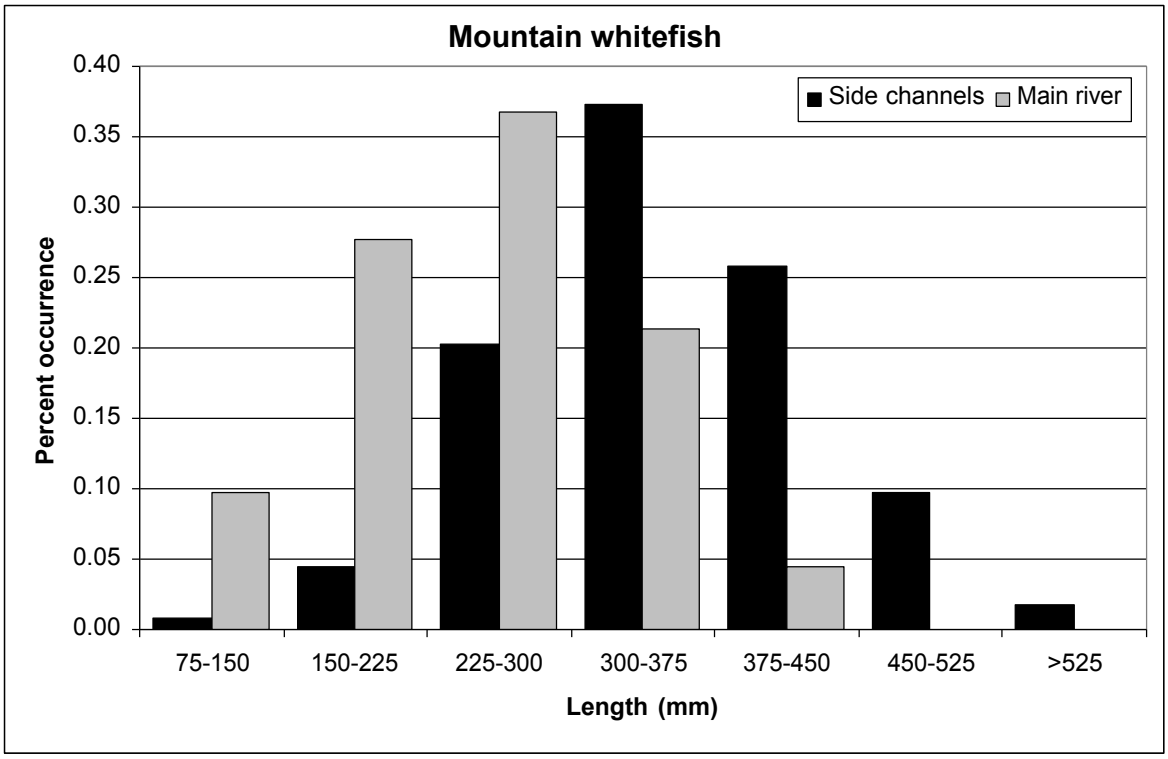


Figure 4. Length frequency histograms showing the sizes of cutthroat trout and rainbow trout observed while snorkeling side channels and the main North Fork Coeur d'Alene River, Idaho, during 2007.



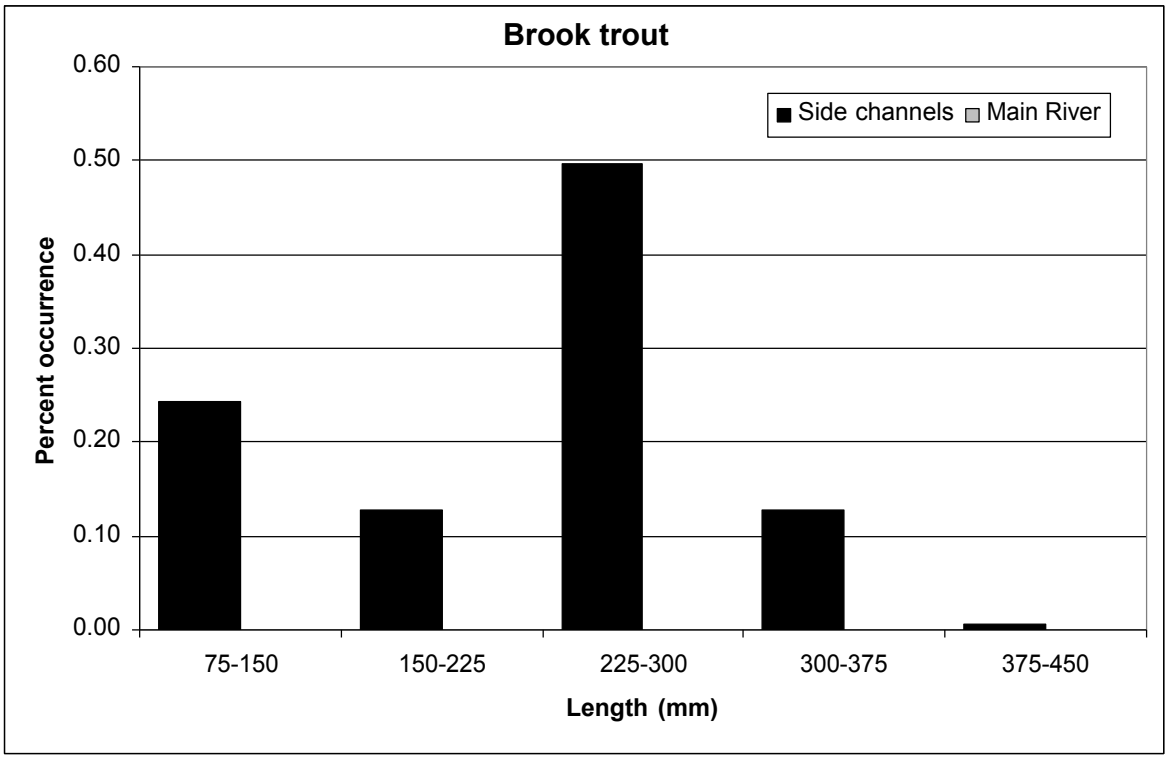
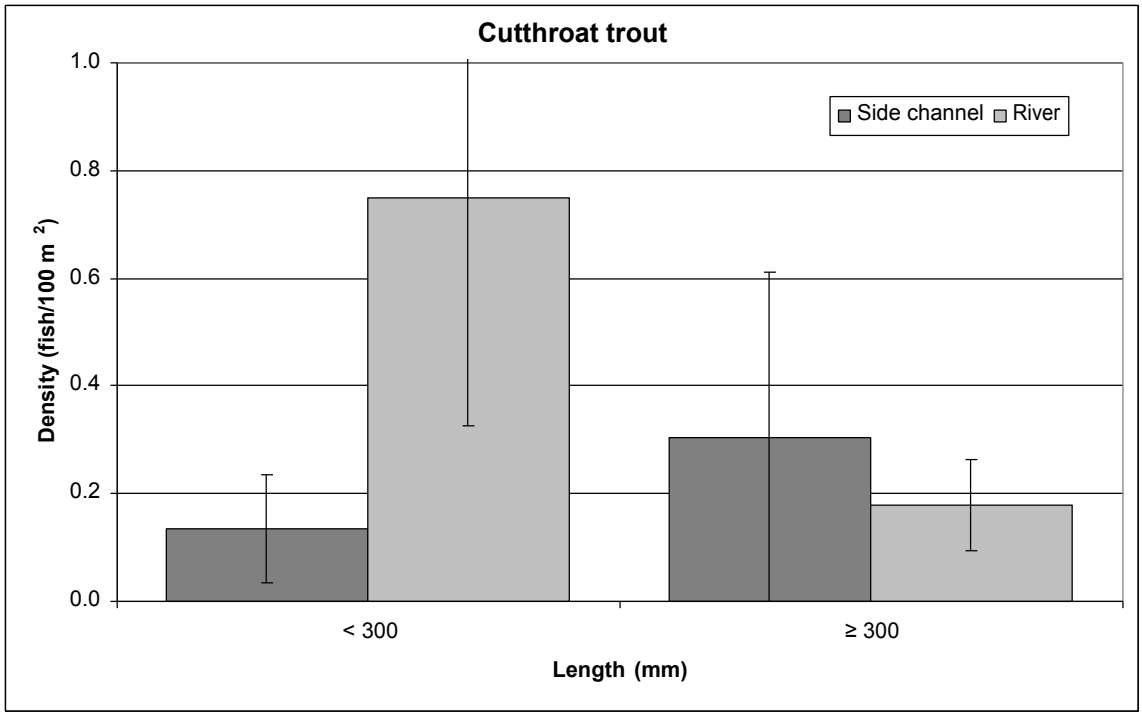


Figure 5. Length frequency histograms showing the sizes of mountain whitefish and brook trout observed while snorkeling side channels and the main North Fork Coeur d'Alene River, Idaho, during 2007.



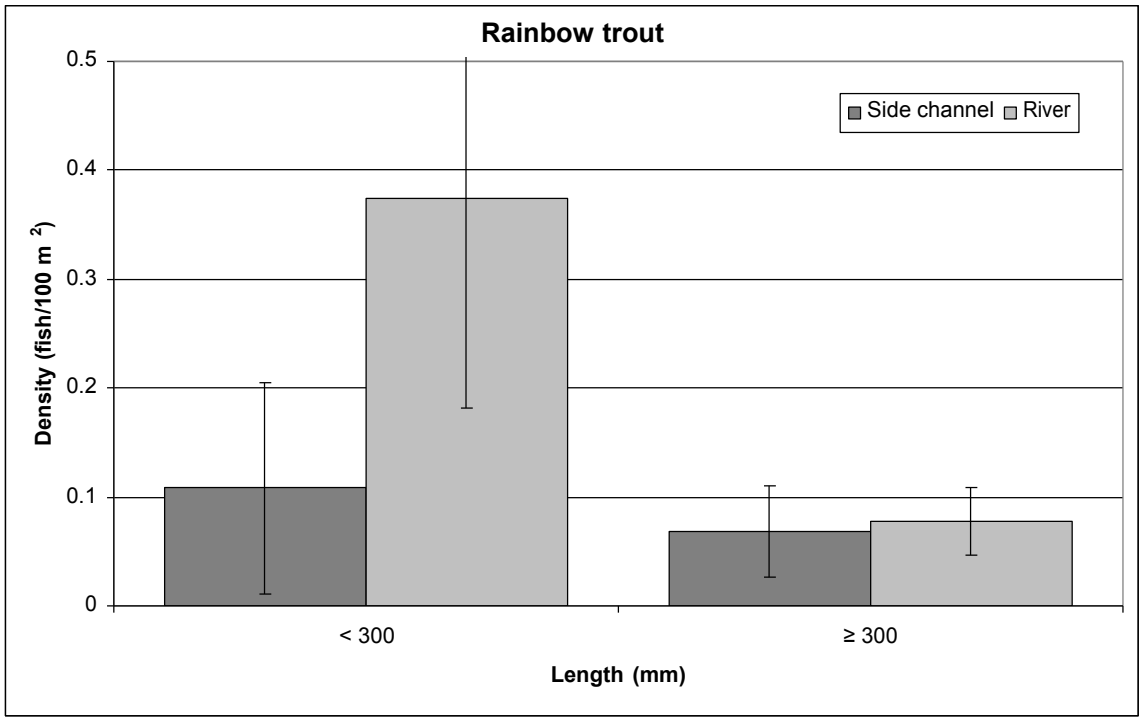


Figure 6. The average density of two size classes (< 300 mm and ≥ 300 mm) of cutthroat trout and rainbow trout observed through snorkeling 23 side channel transects and 9 transects in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007. The bars are 90% confidence intervals.

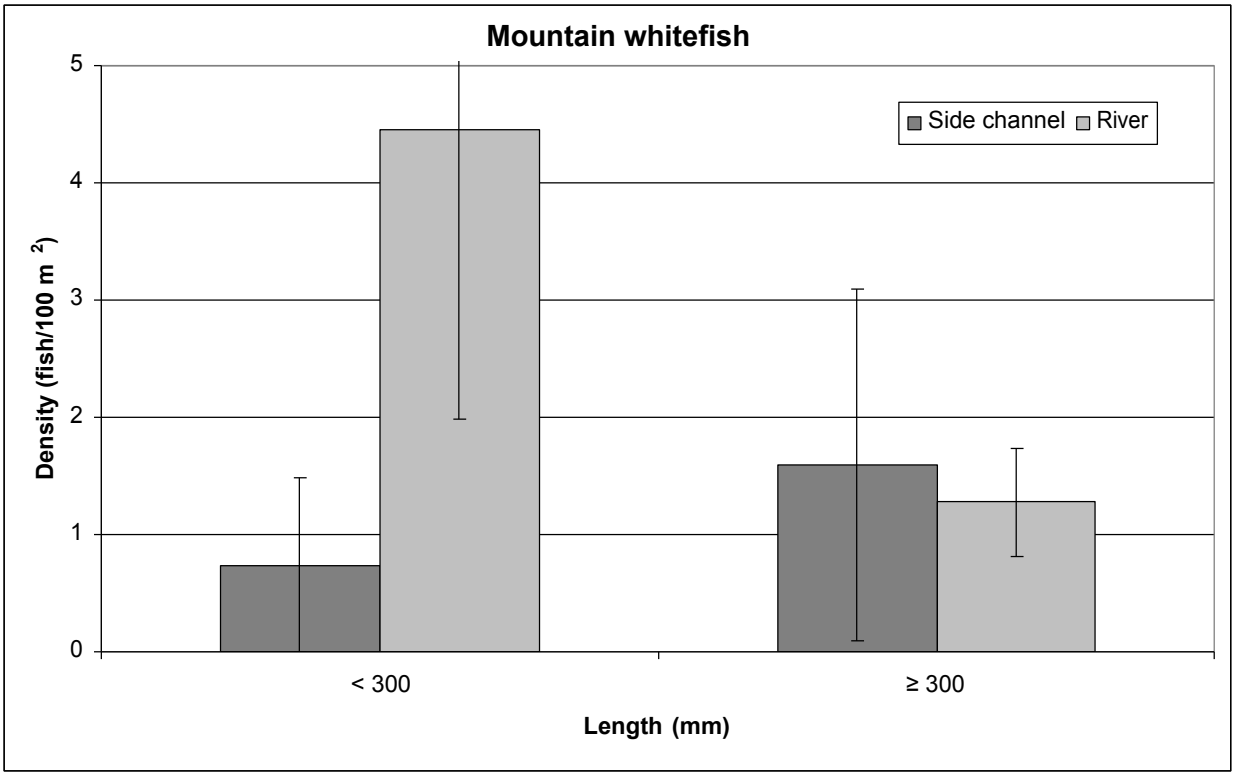


Figure 7. The average density of two size classes (< 300 mm and ≥ 300 mm) of mountain whitefish observed through snorkeling 23 side channel transects and 9 transects in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007. The bars are 90% confidence intervals.

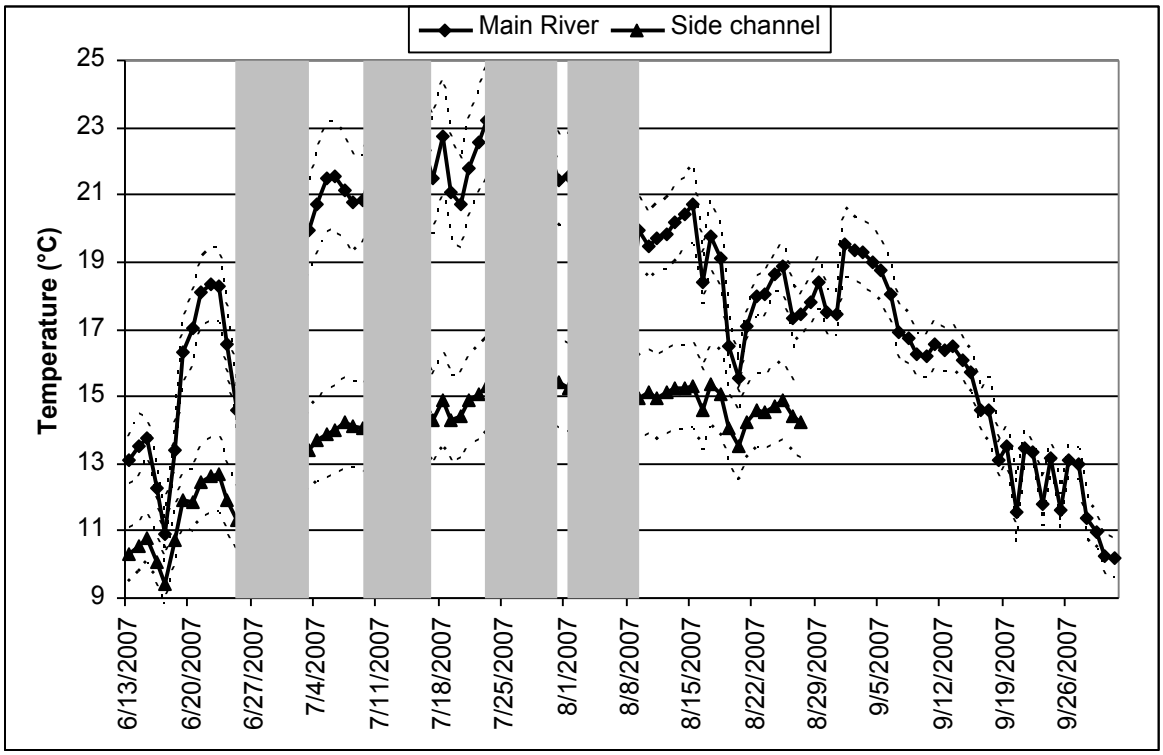


Figure 8. The average daily maximum water temperature from six main river sites and 20 different side channels on the lower North Fork Coeur d'Alene River, Idaho, during 2007. The dashed lines indicate 90% confidence intervals, and the gray bars are the time periods when the side channels were snorkeled.

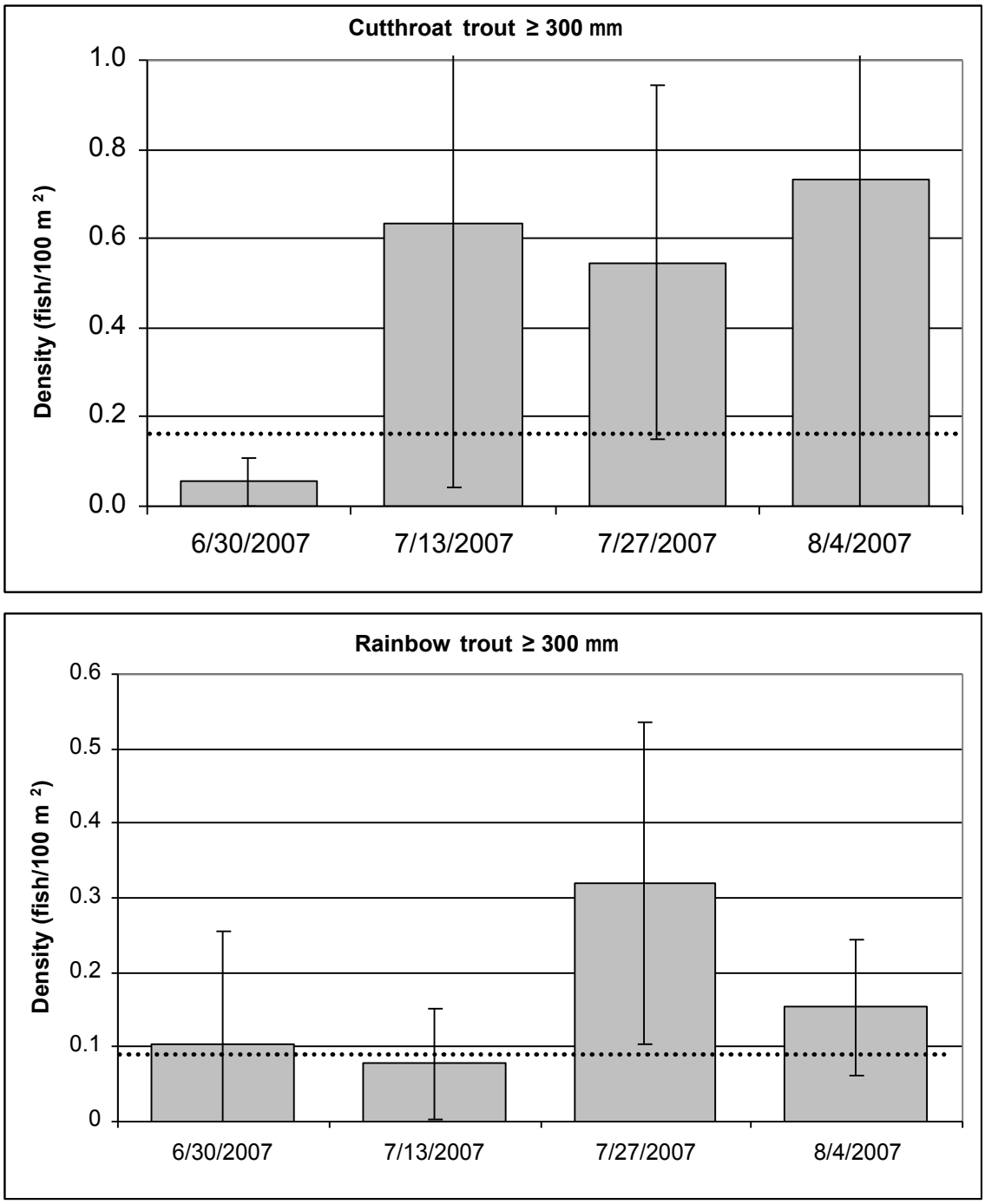


Figure 9. Densities of cutthroat trout and rainbow trout ≥ 300 mm observed during four snorkeling time periods in side channels used as thermal refugia along the North Fork Coeur d'Alene River, Idaho. The dotted lines indicate the average density of cutthroat trout or rainbow trout ≥ 300 mm that were observed in the main river during August, 2007. The bars are 90% confidence intervals.

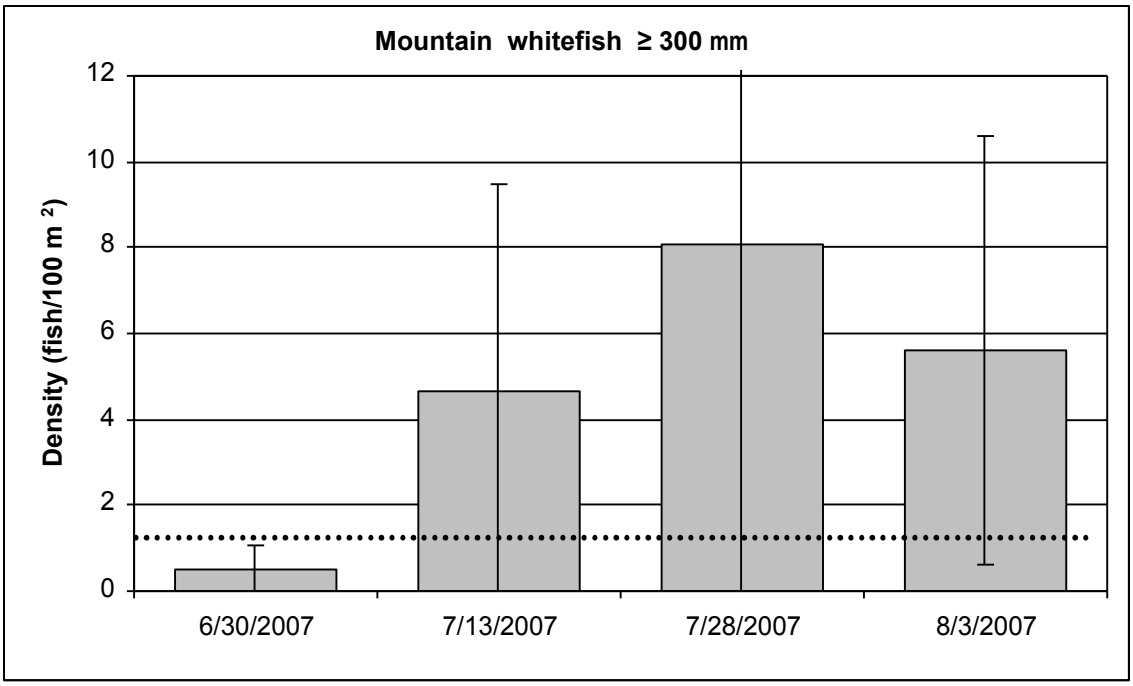


Figure 10. Densities of mountain whitefish ≥ 300 mm observed during four snorkeling time periods in side channels used as thermal refugia along the North Fork Coeur d'Alene River, Idaho. The dotted lines indicate the average density of mountain whitefish ≥ 300 mm that were observed in the main river during August, 2007. The bars are 90% confidence intervals.

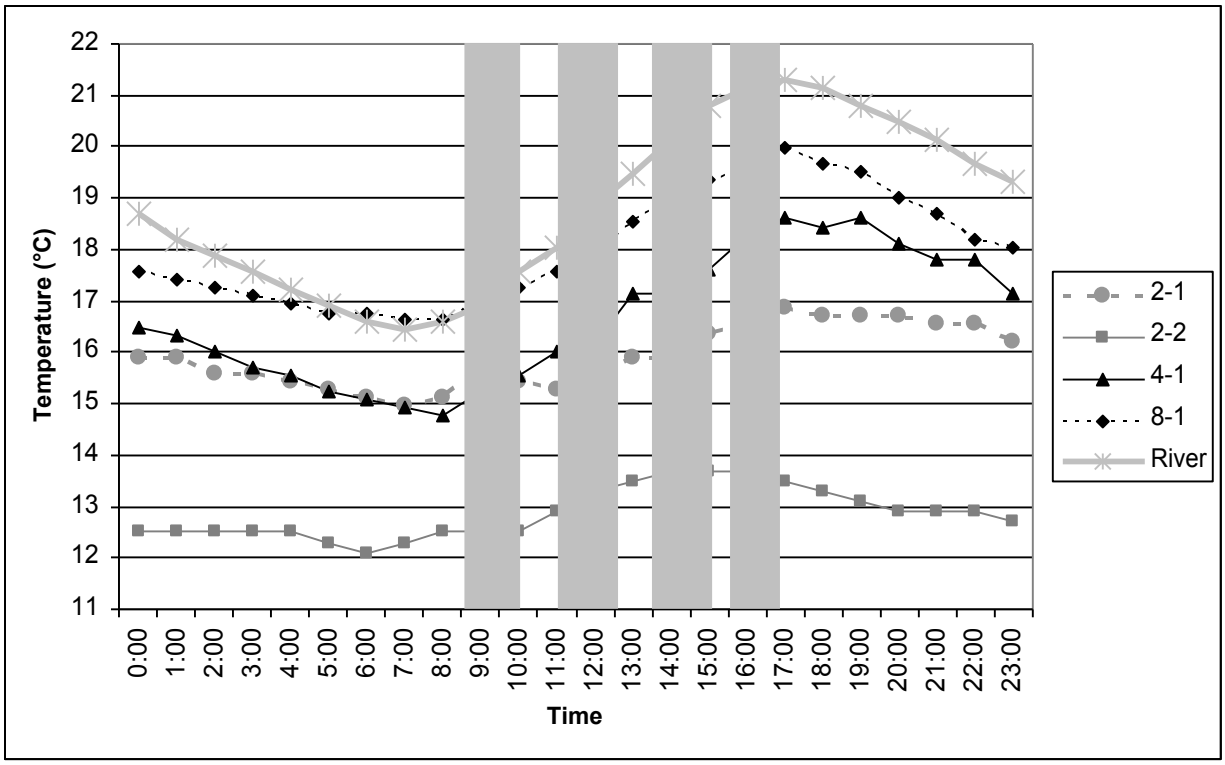


Figure 11. Hourly water temperature in four different side channels and the main North Fork Coeur d'Alene River, Idaho, on August 1, 2007. The grey bars indicate the four different time periods when the side channels were snorkeled.

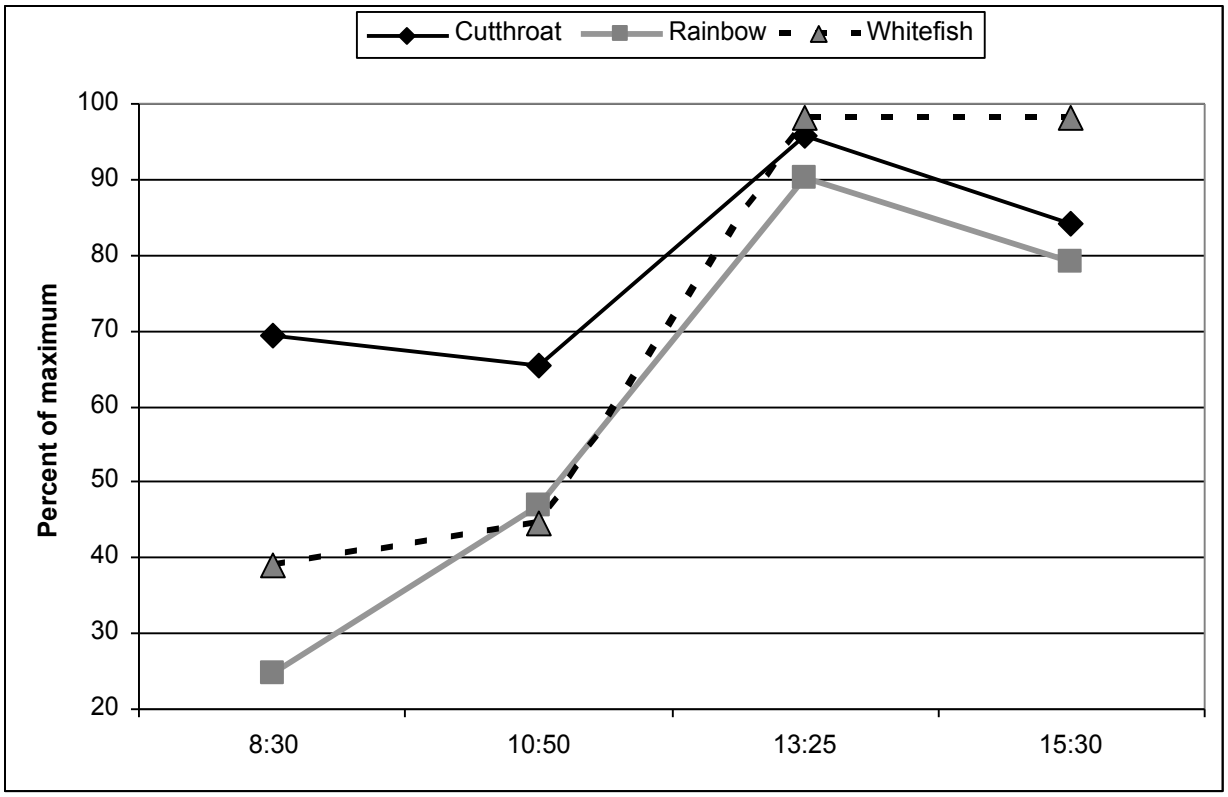


Figure 12. The average percentage of the maximum number of cutthroat trout, rainbow trout, and mountain whitefish that the were observed in four different side channels along the North Fork Coeur d'Alene River, Idaho, during four different time periods on August 1, 2007.

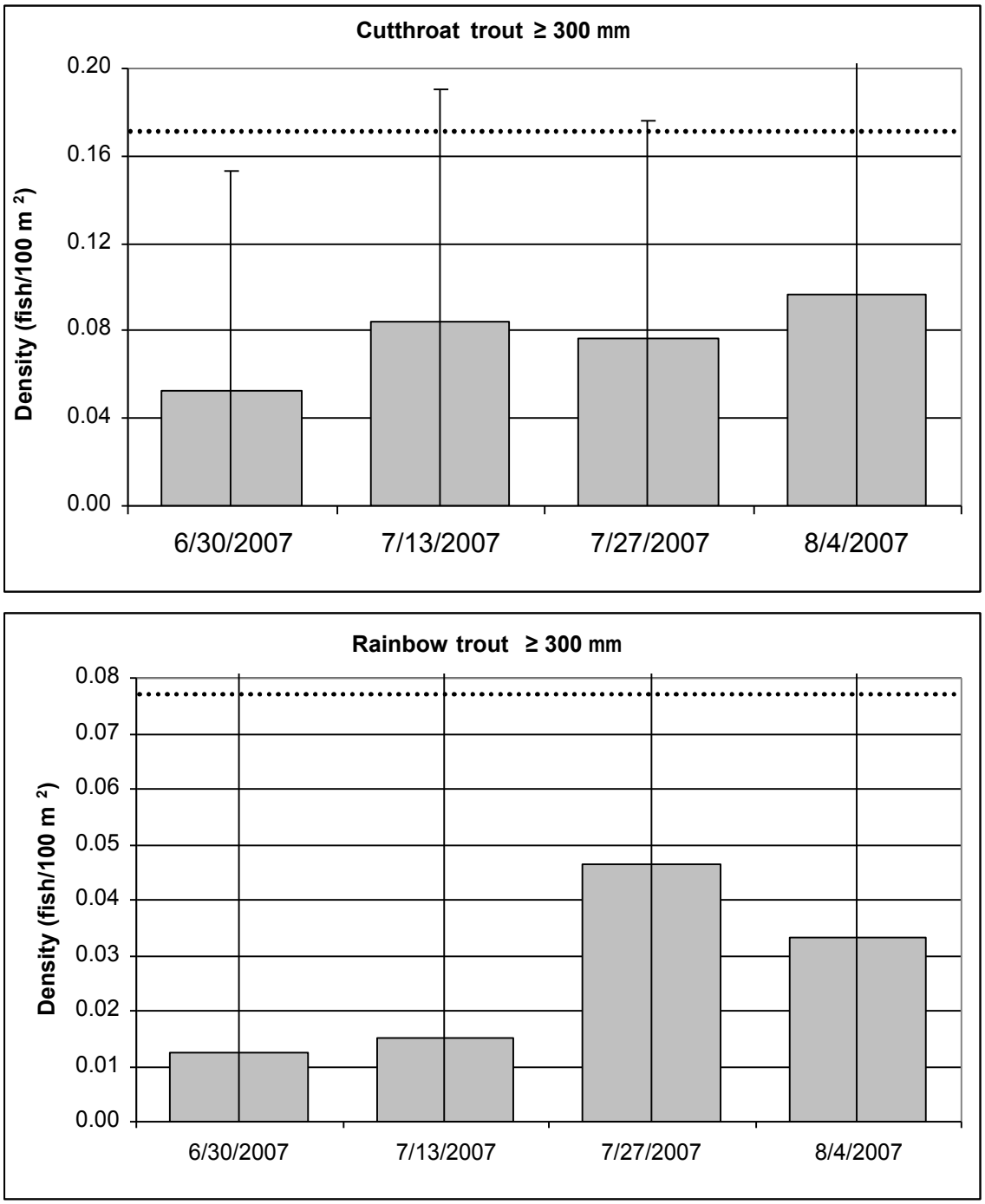


Figure 13. Densities of cutthroat trout and rainbow trout ≥ 300 mm in side channel reaches at least 60 m upstream from the main North Fork Coeur d'Alene River, Idaho during four snorkeling time periods. The dotted lines indicate the average density of cutthroat trout or rainbow trout ≥ 300 mm that were observed in the main river during August, 2007. The bars are 90% confidence intervals.

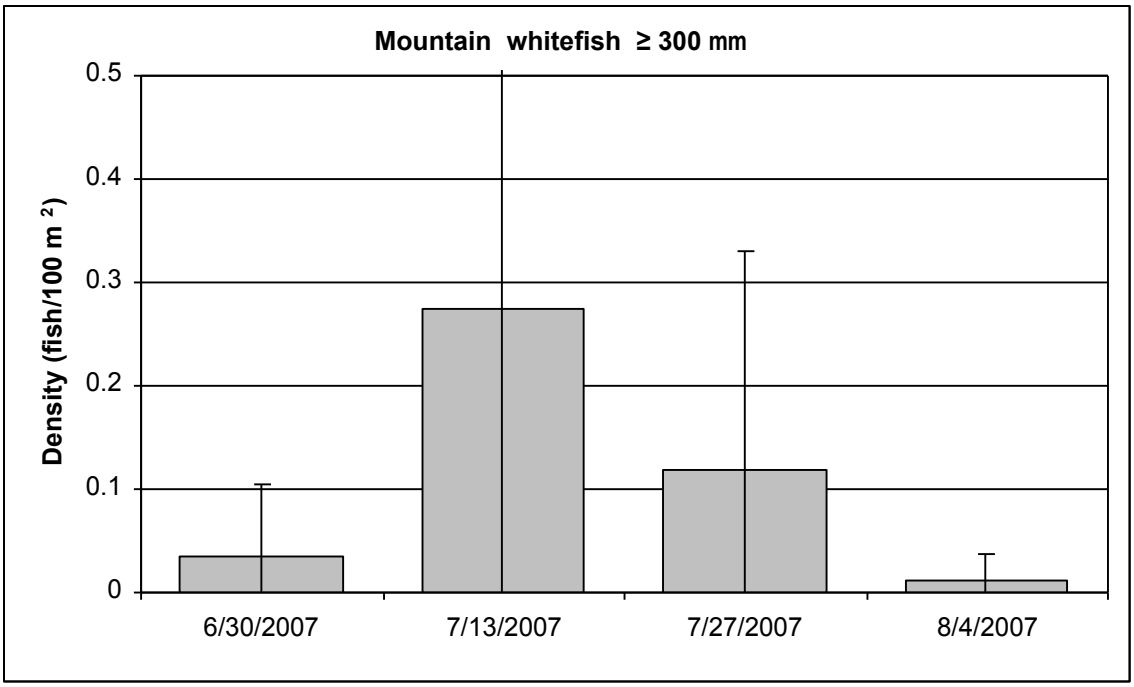


Figure 14. Densities of mountain whitefish ≥ 300 mm in side channel reaches at least 60 m upstream from the main North Fork Coeur d'Alene River, Idaho during four time periods. The average density of mountain whitefish ≥ 300 mm that was observed in the main river during August, 2007 was 1.3 fish/100 m^2. The bars are 90% confidence intervals.

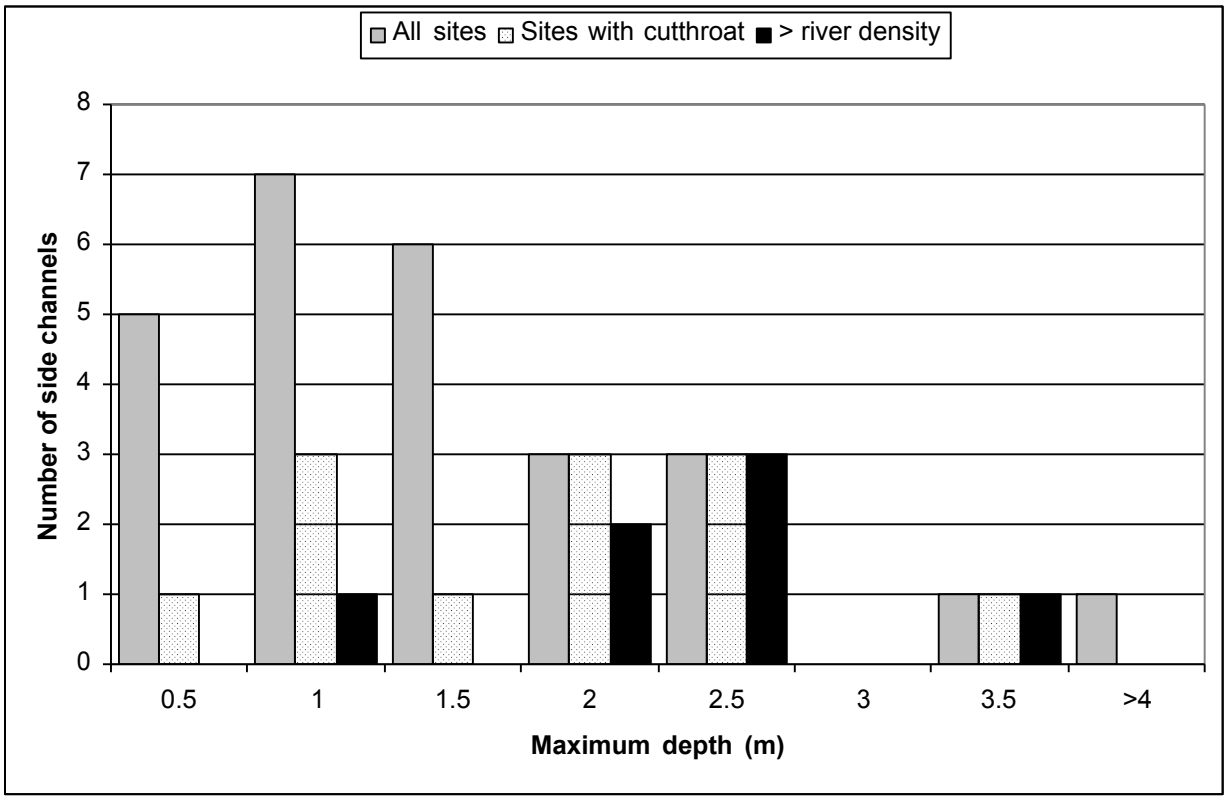


Figure 15. A frequency histogram showing the maximum depth recorded in each side channel snorkeled in comparison to the number of side channels that had at least one cutthroat trout ≥ 300 mm observed, and the number of side channels that had densities of cutthroat trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

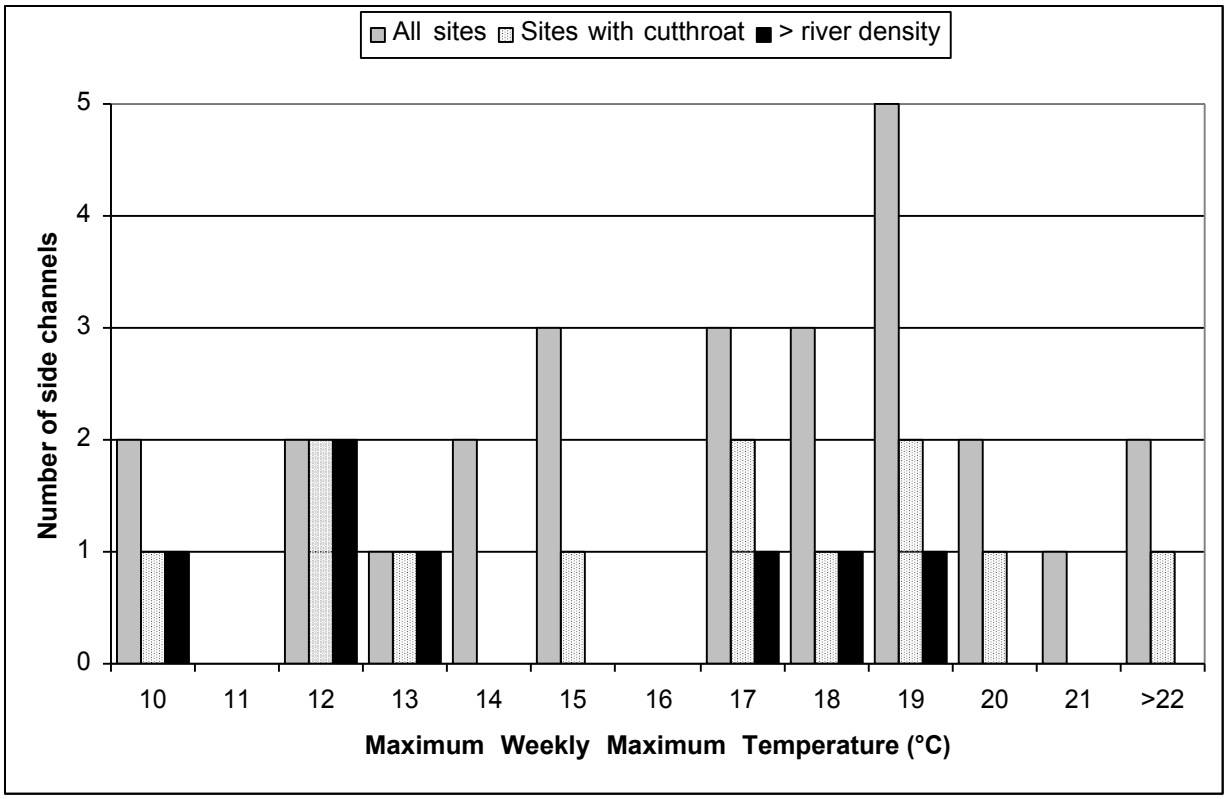


Figure 16. A frequency histogram showing the maximum weekly maximum temperature recorded in each side channel transect snorkeled in comparison to the number of transects that had at least one cutthroat trout ≥ 300 mm observed, and the number of transects that had densities of cutthroat trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

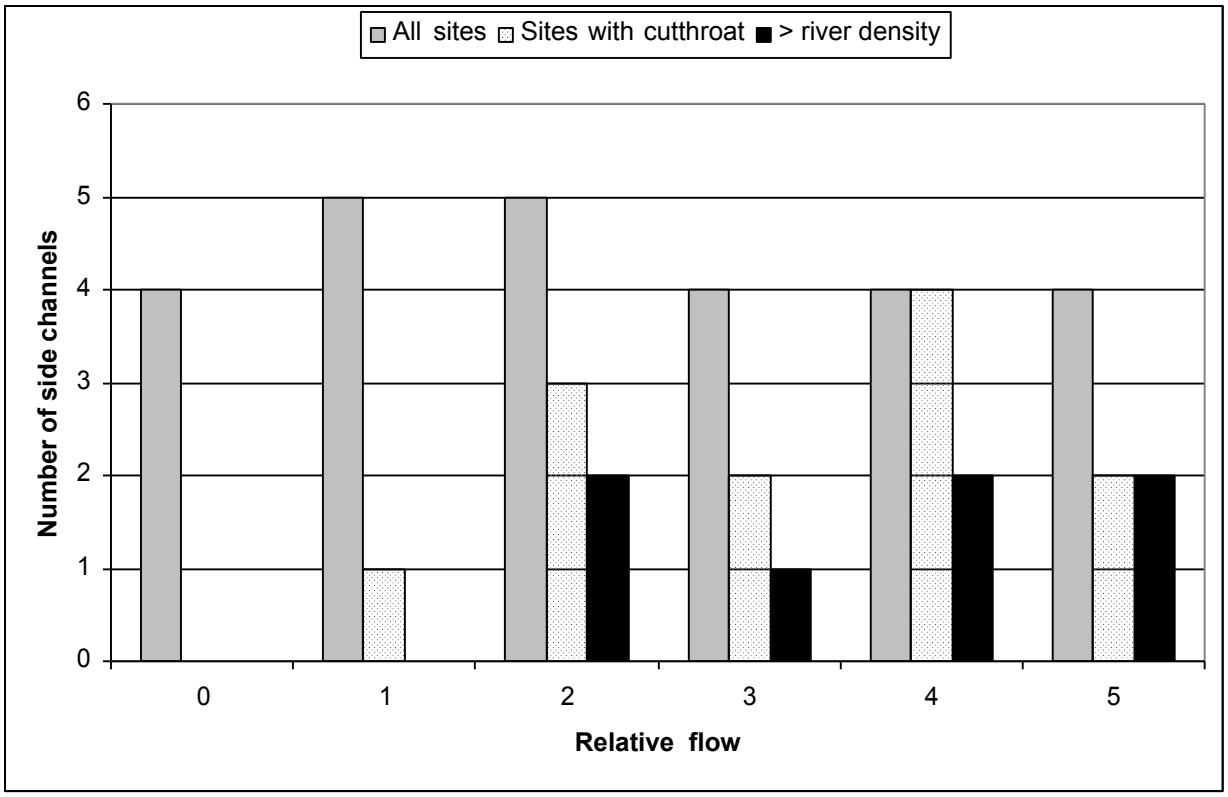


Figure 17. A frequency histogram showing the relative flow determined in each side channel snorkeled in comparison to the number of side channels that had at least one cutthroat trout ≥ 300 mm observed, and the number of side channels that had densities of cutthroat trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

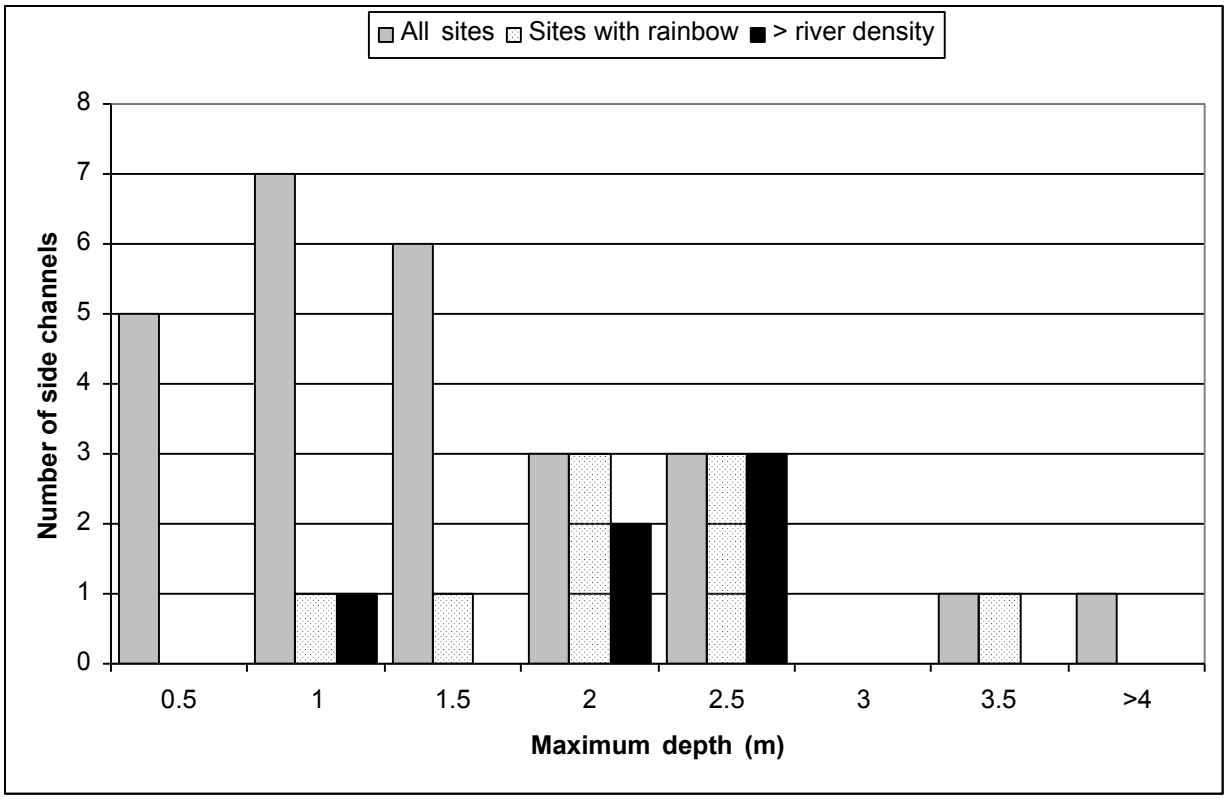


Figure 18. A frequency histogram showing the maximum depth recorded in each side channel snorkeled in comparison to the number of side channels that had at least one rainbow trout ≥ 300 mm observed, and the number of side channels that had densities of rainbow trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

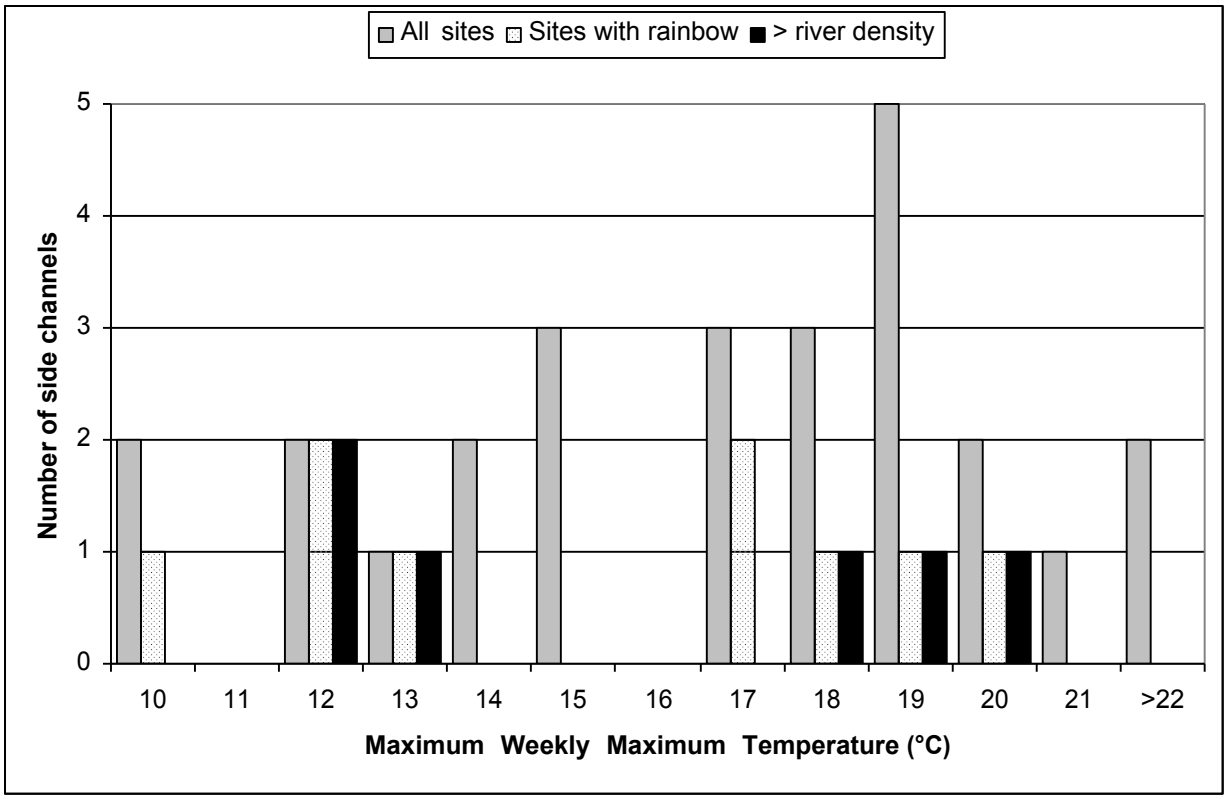


Figure 19. A frequency histogram showing the maximum weekly maximum temperature recorded in each side channel snorkeled in comparison to the number of side channels that had at least one rainbow trout ≥ 300 mm observed, and the number of side channels that had densities of rainbow trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

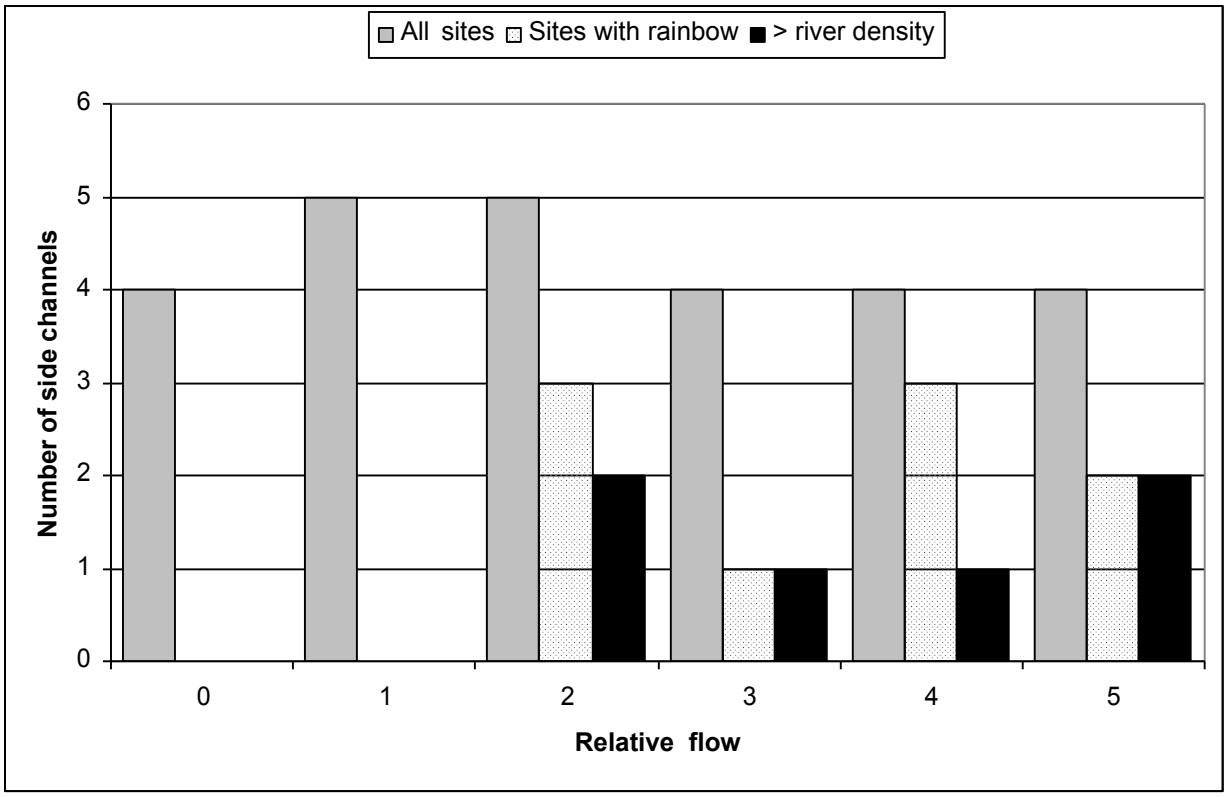


Figure 20. A frequency histogram showing the relative flow determined in each side channel snorkeled in comparison to the number of side channels that had at least one rainbow trout ≥ 300 mm observed, and the number of side channels that had densities of rainbow trout ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

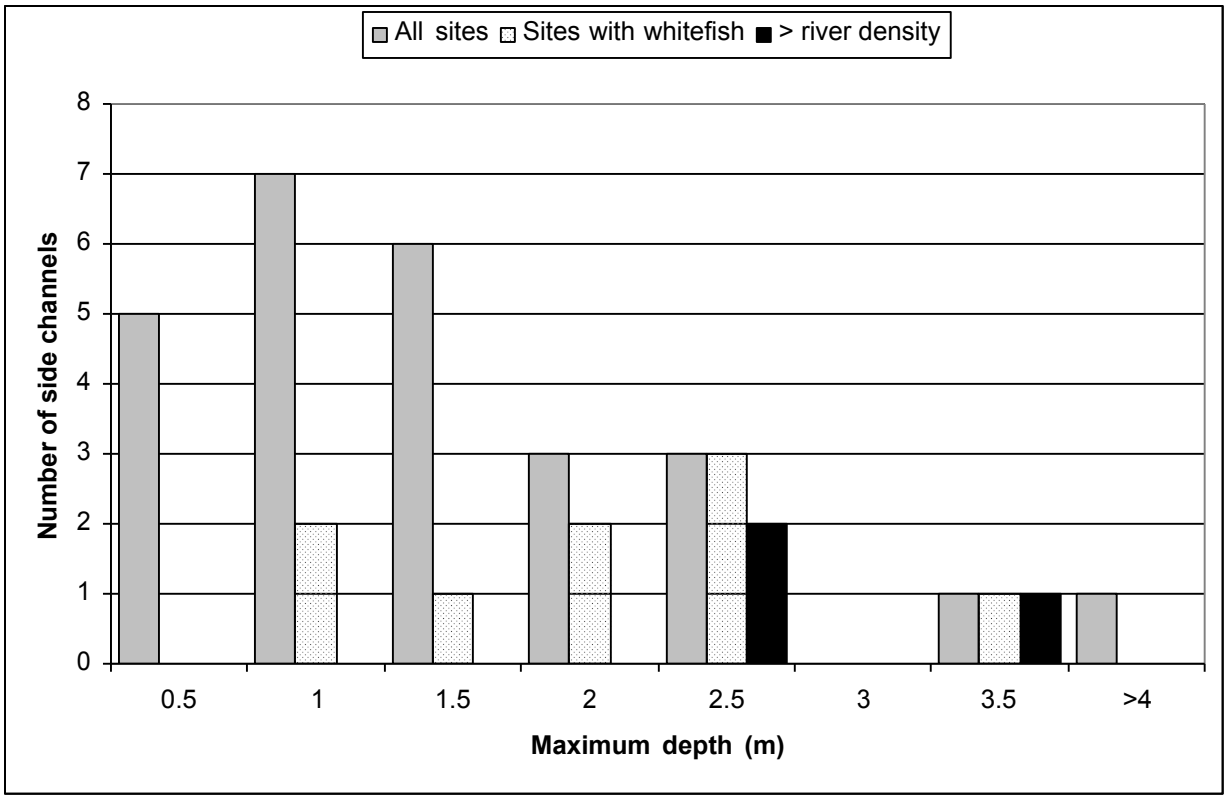


Figure 21. A frequency histogram showing the maximum depth observed in each side channel snorkeled in comparison to the number of side channels that had at least one mountain whitefish ≥ 300 mm observed, and the number of side channels that had densities of mountain whitefish ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

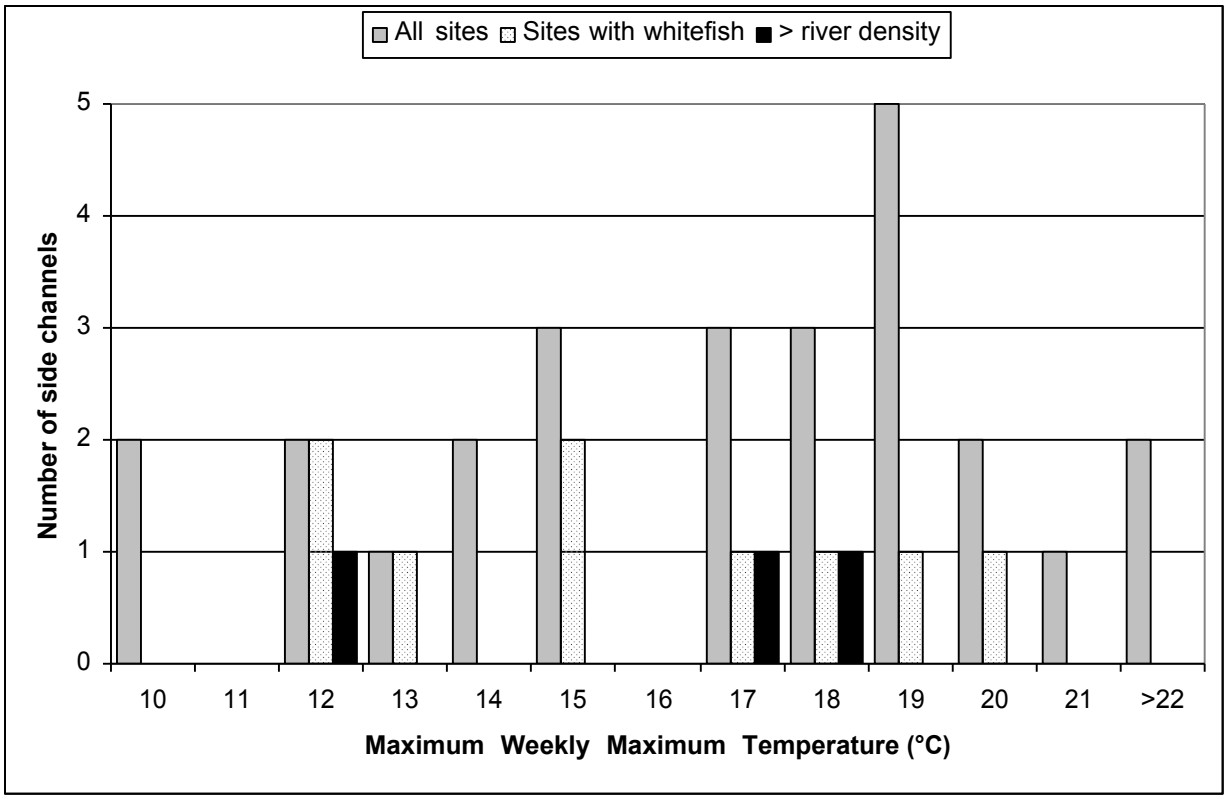


Figure 22. A frequency histogram showing the maximum weekly maximum temperature in each side channel snorkeled in comparison to the number of side channels that had at least one mountain whitefish ≥ 300 mm observed, and the number of side channels that had densities of mountain whitefish ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

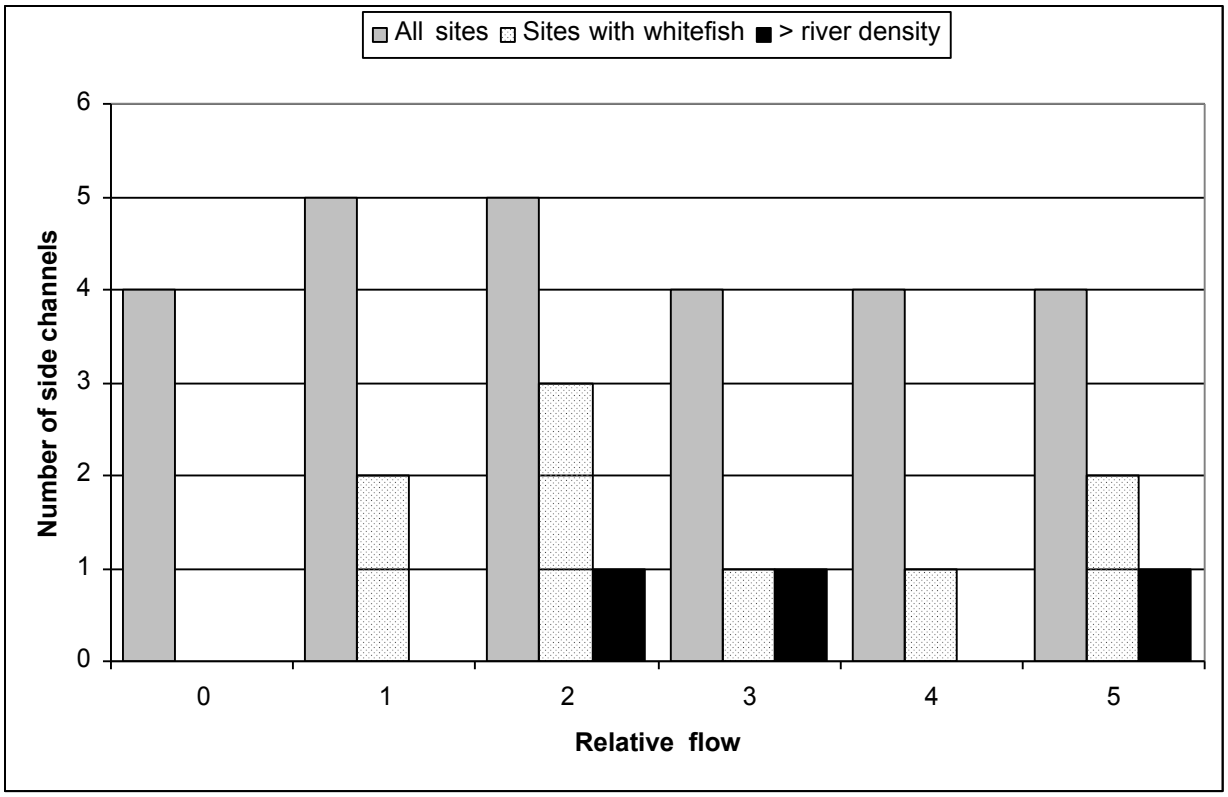


Figure 23. A frequency histogram showing the relative flow determined in each side channel snorkeled in comparison to the number of side channels that had at least one mountain whitefish ≥ 300 mm observed, and the number of side channels that had densities of mountain whitefish ≥ 300 mm that exceeded what was observed in the main North Fork Coeur d'Alene River, Idaho, during the summer of 2007.

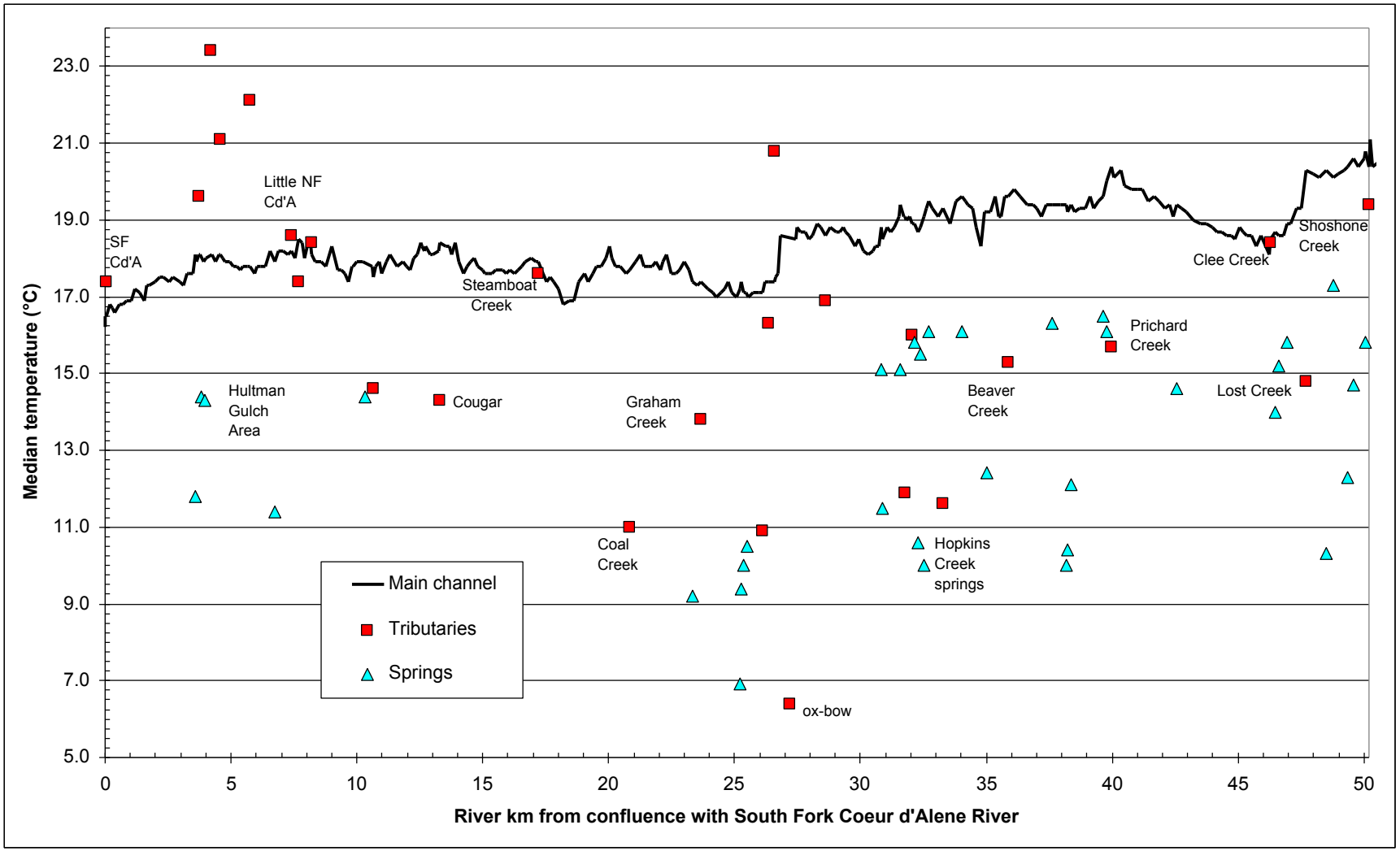


Figure 24. A longitudinal temperature profile of the North Fork Coeur d'Alene River, Idaho, from the South Fork Coeur d'Alene River to Shoshone Creek showing the median water temperatures in the main channel including temperatures of contributing streams and surrounding springs on August 9, 2007 (as reported in Watershed Sciences, Inc. 2007).

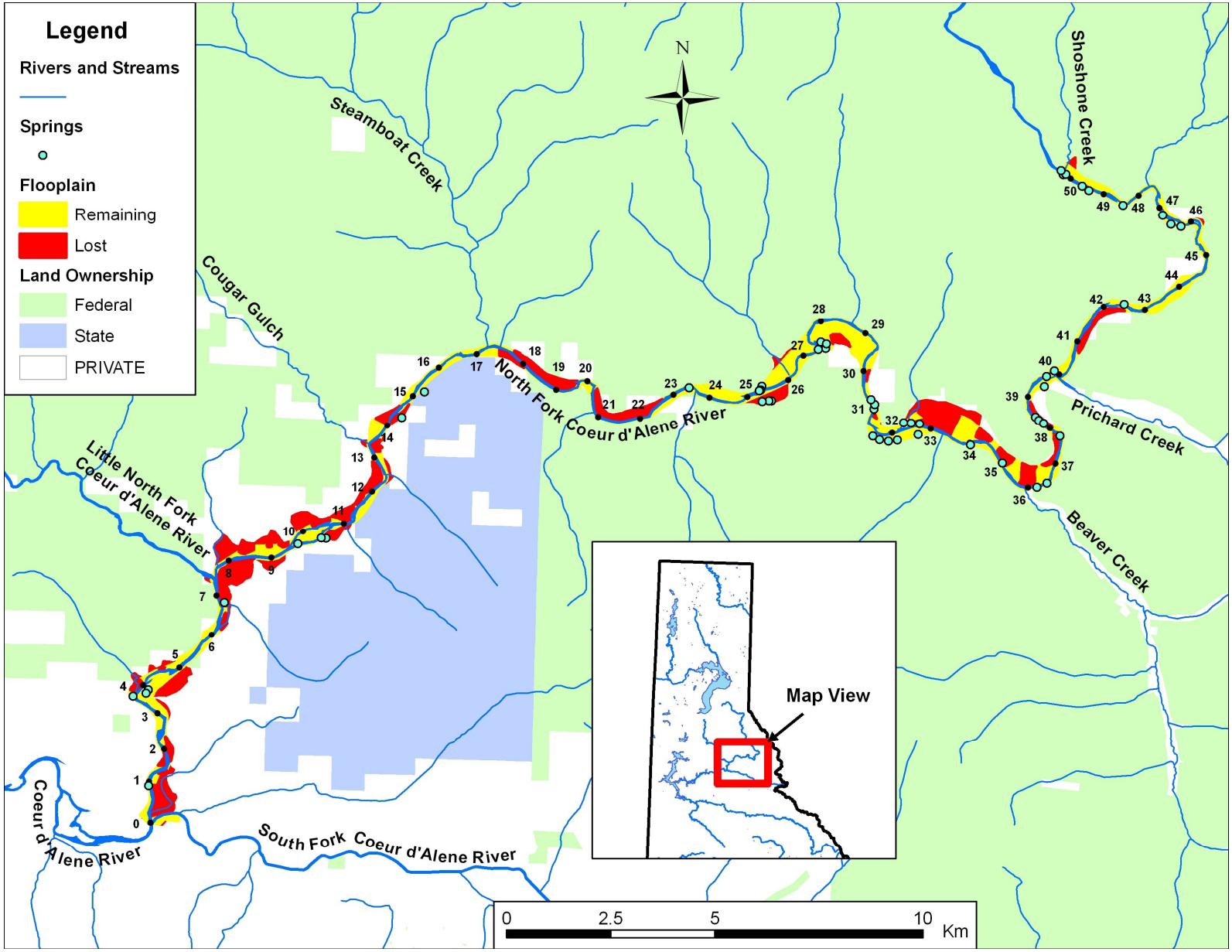


Figure 25. Coldwater springs identified in the floodplain of the lower North Fork Coeur d'Alene River, Idaho, on August 9, 2007 using airborn thermal sensing. The black dots indicate the river km starting at the South Fork Coeur d'Alene River.

Appendix A. Data sheets used to collect fish and habitat data at snorkel sites in side channels along the North Fork Coeur d'Alene River, Idaho during 2007.

N.F. Coeur d'Alene River Side Channel Study - Snorkel Data

Side channel: _____ **Reach Number:** _____

GPS Datum: _____

Observers:_____ No. of Snorkelers:_____ GPS Coord: (Easting) _____

_____ (Northing) _____

Length	WCT		RBT		BLT		BRK		MWF		LSS		NPM		Other
	1	2	1	2	1	2	1	2	1	2	1	2	1	2	
<3"															
3"-6"															
6"-9"															
9"-12"															
12"-15"															
15"-18"															
18"-21"															
>21"															
Total															

Abbreviations: **WCT** = Westslope Cutthroat Trout; **RBT** = Rainbow Trout; **BLT** = Bull Trout; **BRK** = Brook Trout; **MWF** = Mountain Whitefish
MWF = Mountain Whitefish; **LSS** = Large Scale Sucker; **NPM** = Northern Pike Minnow; **RSS** = Redside Shiner; **LND** = Long Nose Dace.

Comments: _____

N.F. Coeur d'Alene River Side Channel Study - Habitat Data

Side Channel: _____ **Reach Number:** _____ **Photo ID:**_____

Date:_____ Time:_____ Temperature: _____ (surface) _____ (bottom) Visibility:_____

Habitat composition (%): _____ (Pool) _____ (Glide) _____ (Run) _____ (Riffle) Max depth (m):_____ Percent aquatic veg:_____

Length snorkeled (m): _____ Stream Width (m): _____ _____ _____ _____ _____ _____

Cover (%):_____ (Total coverage) _____ (Large wood) _____ (Small wood) _____ (Large substrate) _____ (Undercut bank) _____ (Overhead cover) _____ (Other)

Substrate composition (%):_____ (fines; < 2mm) _____ (gravel; 2-64 mm) _____ (cobble; 64-256 mm) _____ (boulder; > 256 mm) _____ (bedrock)

Flow into side channel

Depth										
Width										
Velocity (60%) < 0.75 m										
Velocity (20%) > 0.75 m										
Velocity (80%) > 0.75 m										
	1	2	3	4	5	6	7	8	9	10

Flow from tributary Tributary temp:_____ Side channel Temp (above):_____ Side channel Temp (below):_____

Depth										
Width										
Velocity (60%) < 0.75 m										
Velocity (20%) > 0.75 m										
Velocity (80%) > 0.75 m										
	1	2	3	4	5	6	7	8	9	10

Flow at snorkel site

Depth										
Width										
Velocity (60%) < 0.75 m										
Velocity (20%) > 0.75 m										
Velocity (80%) > 0.75 m										
	1	2	3	4	5	6	7	8	9	10

Appendix B. Data sheets used to characterize the habitat in side channels along the North Fork Coeur d'Alene River, Idaho, during 2007.

N.F. Coeur d'Alene Side Channel Study - Habitat Inventory

Side channel: _____ **Photo ID at mouth:**_____

Date:_____ Observers:_____

For channels < 8 m wide don't fill out 1/4 and 3/4 intervals

Transect ___: Length from mouth:_____

GPS **E:**_____**N:**_____

Left Bank	1/4 interval	Stream Center	3/4 interval	Right Bank

Dominant veg:_____Avg height_____

Habitat type :_____

Max Depth (m):_____ Width (m):_____

Temp - bottom (°C):_____ Time:_____

Substrate

	(fine)	(sand)	(cob)	(bld)	(bed)
bottom:	_____	_____	_____	_____	_____
bank-river:	_____	_____	_____	_____	_____
bank-op:	_____	_____	_____	_____	_____

Transect ___: Length from mouth:_____

GPS **E:**_____**N:**_____

Left Bank	1/4 interval	Stream Center	3/4 interval	Right Bank

Dominant veg:_____Avg height_____

Habitat type :_____

Max Depth (m):_____ Width (m):_____

Temp - bottom (°C):_____ Time:_____

Substrate

	(fine)	(sand)	(cob)	(bld)	(bed)
bottom:	_____	_____	_____	_____	_____
bank-river:	_____	_____	_____	_____	_____
bank-op:	_____	_____	_____	_____	_____

Transect ___: Length from mouth:_____

GPS **E:**_____**N:**_____

Left Bank	1/4 interval	Stream Center	3/4 interval	Right Bank

Dominant veg:_____Avg height_____

Habitat type :_____

Max Depth (m):_____ Width (m):_____

Temp - bottom (°C):_____ Time:_____

Substrate

	(fine)	(sand)	(cob)	(bld)	(bed)
bottom:	_____	_____	_____	_____	_____
bank-river:	_____	_____	_____	_____	_____
bank-op:	_____	_____	_____	_____	_____

Transect ___: Length from mouth:_____

GPS **E:**_____**N:**_____

Left Bank	1/4 interval	Stream Center	3/4 interval	Right Bank

Dominant veg:_____Avg height_____

Habitat type :_____

Max Depth (m):_____ Width (m):_____

Temp - bottom (°C):_____ Time:_____

Substrate

	(fine)	(sand)	(cob)	(bld)	(bed)
bottom:	_____	_____	_____	_____	_____
bank-river:	_____	_____	_____	_____	_____
bank-op:	_____	_____	_____	_____	_____

Transect ___: Length from mouth:_____

GPS **E:**_____**N:**_____

Left Bank	1/4 interval	Stream Center	3/4 interval	Right Bank

Dominant veg:_____Avg height_____

Habitat type :_____

Max Depth (m):_____ Width (m):_____

Temp - bottom (°C):_____ Time:_____

Substrate

	(fine)	(sand)	(cob)	(bld)	(bed)
bottom:	_____	_____	_____	_____	_____
bank-river:	_____	_____	_____	_____	_____
bank-op:	_____	_____	_____	_____	_____

Comments