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THE EFFECTIVENESS OF TROUT HABITAT RESTORATION IN EUSTACHE  
CREEK, A FORMERLY PLACER-MINED STREAM IN WESTERN MONTANA

By

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Bachelor of Arts, Southwestern University, Georgetown, TX

Thesis

Presented in partial fulfillment of the requirements  
for the degree of

Master of Science  
in  
Environmental Studies

The University of Montana  
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July 2010

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## The Effectiveness of Trout Habitat Restoration in Eustache Creek, a Formerly Placer-Mined Stream in Western Montana

Committee Chair: Dr. Daniel Spencer

Aquatic ecosystems in the western U.S. have been severely degraded over the last century by anthropogenic activities such as mining, logging and grazing. Habitat heterogeneity in streams of the western United States has been lost as a result of both in-stream activities (i.e. dredging and straightening channels) and riparian zone activities (i.e. logging and vegetation removal). A commonly stated objective of stream channel restoration projects is to restore stream habitat quality and thereby improve aquatic species habitat and ultimately increase fish populations.

The Ninemile drainage of the Clark Fork River watershed was historically a thriving native Bull trout and Westslope cutthroat trout (WCT) fishery. Intensive mining and logging activities throughout the watershed have severely impaired native fish habitat and reduced fish populations. In 2006, Lolo National Forest partnered with Trout Unlimited to restore a 1.3-mile section of Eustache Creek at the headwaters of the Ninemile drainage. This study used pre- and post-restoration habitat and fish sampling data from 2005-2009 to analyze changes in habitat quality and fish abundance in three reaches of Eustache Creek. Habitat quality was assessed using six metrics: width to depth ratio, percent of pool habitat (based on site area), residual pool depth, large woody debris per 100 meters, large woody debris median diameter and percent fine sediment in pool tails. A repeated measures ANOVA model was used to detect significant increases in habitat quality and fish populations over the four-year period in Eustache Creek. A univariate ANOVA model was created to detect significant relationships between individual habitat quality variables and fish populations. Overall, statistical analysis does not necessarily point to a significant increase in habitat quality for Eustache Creek, and the restored stream condition is still far from its reference condition. However, a non-statistical assessment of trends in individual habitat metrics shows an improvement in trout habitat quality. There was a significant increase in total fish densities in Eustache Creek over the study period. Additionally, there was a significant increase in total WCT, Adult WCT, and Adult Eastern Brook trout (EBT) densities over time. However, there was no statistically significant difference in total fish density, total WCT density, adult WCT density, total EBT density and adult EBT density between reference and treatment reaches, indicating that the increased fish populations may reflect the influence of external factors such as climatic variability rather than the improvement in habitat quality. No habitat variables are significantly correlated to total fish density. There was a statistically weak positive correlation between percent pool habitat and total fish density.

While Eustache Creek appears to be trending toward improved fish habitat, the high variability of the habitat and fish data within certain reaches, including the reference reach, from year to year suggest that the stream is a seasonally and environmentally dynamic system to which fish populations are quite sensitive, and that recovery will be a long term process. Fish density in this watershed could be influenced by other factors of habitat quality such as food, stream temperature and seasonal and environmental variation. Best measures of habitat quality in this study were percent pool habitat, LWD frequency and LWD median diameter.

Recommendations for future monitoring include: 1) continue monitoring for the next 15-20 years, 2) collect more pre-project data, 3) increase the number of sampling sites, 4) maintain consistency in sampling dates, number of netters and number of electroshocking passes, and 5) investigate the effects of non-native EBT populations on native WCT in the Ninemile watershed and the potential need for EBT removal.

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## INTRODUCTION

Aquatic ecosystems in the western United States have been severely degraded over the last century as a result of in-stream activities (i.e. dredging and straightening channels), riparian zone activities (i.e. logging and vegetation removal) (Bond and Lake 2003), and watershed scale disturbances such as grazing, resulting in a decline in native fish populations (Minckley and Deacon 1991). In recent years, growing sensitivity to and awareness of environmental degradation has led to a rapid increase in the number of stream restoration projects aimed at reversing the damage caused to streams by human activity (Bond and Lake 2003). A commonly stated objective of stream channel restoration projects is to improve aquatic species habitat and increase native fish populations. However, few stream habitat restoration projects are evaluated to determine whether these objectives were met (Bond and Lake 2003). Direct evidence of the recovery of aquatic communities following the restoration of degraded streams is scarce (Everest et al. 1989, Liermann and Roni 2008), but the limited data available indicate that the success rates for projects targeting increases in fish populations are low (Bond and Lake 2003). It is not clear whether the lack of documentation of the effectiveness of stream restoration projects is due to a lack of interest, budgetary constraints, or the complexities of designing and sampling response variables, but this information gap prevents future projects from learning from the success and/or failures of current restoration projects (Baldigo and Warren 2008).

Successful restoration of stream habitats, while assisted through human manipulation of physical environments, is likely a long-term process, and managers face uncertainty about how much monitoring to do in the first several years after restoration. Many agencies spend large amounts of money in monitoring efforts, and would benefit from more studies that may determine whether significant changes occur in the short term, and could therefore help determine more cost efficient monitoring schedules over time.

Methods for conducting detailed inventories of stream habitat, such as R1/R4 and PIBO, are widely used by management agencies as a monitoring tool; however, relatively few studies have used the information that these inventories provide to determine the effectiveness of habitat

restoration and its effect on fish populations. Additionally, few studies set out to determine which of the various measures used to assess habitat quality are most closely correlated to fish population trends. This information could provide a useful tool to aid in the attempt to link physical components of stream restoration with biological responses. This information would also be useful during the design phase of stream restoration projects and could be incorporated into the design process.

The objectives of this study are: 1) to evaluate whether the restoration of a placer-mined stream in western Montana has improved the quality of fish habitat and/or increased fish populations in the first three years following project completion, and, 2) to examine which of six commonly used habitat metrics can be best used to assess trends in habitat quality and/or fish populations. The findings from this study will thus contribute to efforts to determine the short-term effectiveness of stream restoration projects, and will provide improved understanding of the value of some of the most commonly used habitat metrics.

## SECTION 1 - TROUT HABITAT QUALITY METRICS AND THEIR RELATIONSHIP TO FISH POPULATIONS

### Habitat Quality and Complexity

The abundance, diversity and sustainability of fish populations depend, in part upon the quality and complexity of stream habitat (Fausch and Northcote 1992; Horan et al. 2000). Improving stream habitat quality and/or complexity is therefore often a primary goal of stream restoration projects. Habitat quality reflects the ability of a stream to support fish, within the constraints created by external factors such as the presence of non-native species and watershed scale limitations on fish abundance such as upstream or downstream dams and diversions. Habitat quality is often measured by such metrics as the riffle to pool ratio. Habitat complexity is generally defined as the diversity of different habitat types available to fish (Pearsons et al. 1992), or as the variability and diversity of certain metrics of habitat quality (i.e. width to depth ratios, riffle to pool ratios, pool depth, etc.). Complex habitats are needed to support the various life stages of fish, provide refugia during extreme environmental events such as flooding (Poff and Ward 1990; Horan et al. 2000) and reduce predation efficiency (Horan et al. 2000). Complexity may be quantified in terms of the structural components of a stream (McMahon and Hartman 1989), hydraulic variation (Pearsons et al. 1992), and diversity of depth, velocity, and substrate (Gorman and Karr 1978; Angermeier and Schlosser 1989). For the purposes of this study, habitat quality will be defined by six habitat variables commonly found in the literature to contribute to habitat quality: large woody debris size and frequency, width to depth ratio, percent area of pool habitat, residual pool depth, and percent surface fines. This section will briefly discuss how these metrics affect fish populations.

### Large Woody Debris Size and Frequency

Large woody debris (LWD) plays a crucial role in the formation and maintenance of fish habitat (Bryant 1983). LWD contributes to habitat complexity and quality (Meehan 1991) by

increasing spatial variability in stream energy, creating localized areas of reduced flow velocity (in pools), increasing sediment storage capacity and increasing channel stability (Beschta and Platts 1986). Studies have shown an increase in pool and off-channel rearing habitat after the introduction of LWD (Crispin et al. 1993). Other studies have tested the effects of large woody debris on salmonid densities and shown that the pool habitat created by LWD enhances coho salmon populations year round and benefits winter populations of cutthroat and rainbow trout (Roni and Thomas 2001). Subsequently, LWD positively affects fisheries primarily by providing varying degrees of habitat development and complexity, in-stream cover, a hydraulic mechanism for the reduction of fine sediment (0.00-6.35 mm) within substrates, and a nutrient source for aquatic biota (Bilby and Bisson 1998). In general, larger LWD is more stable and has a longer residence time in the channel, resulting in an increased beneficial effect compared to smaller pieces of wood.

#### Width:Depth Ratio

Stream width-to-depth ratio (W:D) is a key indicator of channel condition and stability (Rosgen, 1996). Low width-to-depth ratios are associated with deeper, cooler water and a higher water table to support growth of riparian and meadow vegetation (Frazier et al. 2005). Thus, lower width to depth ratios are associated with higher quality fish habitat. Conversely, if the channel grows wider and shallower due to bank erosion or bed aggradation, W:D values increase, further reducing the ability for the stream to transport sediment (Rosgen 1996). Increases in fine sediment particles and shallower water results in increased water temperatures and loss of habitat, which can negatively impact salmonid populations.

#### Percent Pool Habitat

Pools are areas of deep slow water that are created by accumulations of LWD or large substrate and which provide critical habitat for adult salmonids by providing deep cooler waters in summer, winter refuge, and areas for rearing (Frazier et al. 2005). Thus there is a positive

correlation between the availability of pool habitat and salmonid abundance, and the percent surface area of pools is commonly used as a measure of habitat quality for fish populations (Bowlby and Roff 1986; Murphy et al. 1986). In a study of two coastal Oregon streams, following winter rearing habitat modification that increased surface area of dam pools by adding LWD, the summer juvenile coho salmon and cutthroat trout migrant populations increased (Solazzi et al. 2000). Habitat restoration that increases pool habitat therefore results in an increase in habitat quality.

#### Residual pool depth

Residual pool depth is the difference in elevation between the deepest part of the pool and the outlet. In other words, it is the maximum depth of a pool when the water level is just low enough that no water is running out of it. Because it is independent of discharge, this is a useful measure because it allows for comparisons of depth among streams of different sizes. For salmonids, the summer rearing capacity of a stream is directly correlated to pool depth, and when sedimentation decreases pool depth, fish densities also decrease (Waters 1995). A study on a small coastal stream in British Columbia found that yearling and adult salmonid biomass was strongly correlated with pool volume and depth (Fausch and Northcote 1992).

#### Substrate Size/Pool Tail Fines

Salmonids spawn, and many of the insects that provide food for salmonids hatch within gravelly stream substrate (Horan et al. 2000). Watershed and streambank disturbance from anthropogenic activities can result in increased fine sediment input to streams, and an increase in fine particles in the substrate can negatively affect aquatic food production and decrease survival of young salmonids. Sediment can destroy eggs and juveniles by suffocation, and pre-larval mortality can occur from smothering, entrapment and abrasion by silt (Helfman 2007). High sediment loads can lead to clogged gills in young fishes, resulting in the malfunction of oxygen exchange sites and leading to death (Helfman 2007). When water inter-change between streams

and redds (trout spawning “nests”) is reduced by fine sediment that fills interstitial spaces, salmonid mortality increases. Sub sand size (< 2mm) particles are the most detrimental, however increases in the percentage of particles up to 8mm can result in increased mortality rates (Frazier et al. 2005). Additionally, increased sediment concentrations are known to cause a decrease in spawning frequency of tricolor shiner (*Cyprinella trichroistia*), disrupted timing of spawning and a reduction in the number of viable eggs (Burkhead and Jelks 2001). The percentage of fine sediment in the stream substrate can therefore be used as a measure of habitat quality.

## SECTION 2 – A CASE STUDY: CHANGES IN HABITAT QUALITY AND FISH ABUNDANCE PRE/POST RESTORATION OF EUSTACHE CREEK, MONTANA

### INTRODUCTION

This study used data collected by the Lolo National Forest and Trout Unlimited over a four-year period (2005-2009) to explore changes in habitat quality and fish populations before and after channel and riparian restoration of Eustache Creek. The results will contribute to the understanding of the role that habitat quality plays in fish abundance, and subsequently contribute to the understanding of that role in stream restoration design. Results will additionally add to the working knowledge of monitoring practices and potentially help determine more cost-effective and scientifically sound strategies for agencies to implement in future stream restoration projects.

### BACKGROUND

#### **Site Description and History: Eustache Creek**

Eustache Creek is a first order headwater tributary of Nine-mile Creek, which flows into the Clark Fork River approximately 25 miles west of Missoula, Montana (Figures 1a and 1b). The entire Eustache watershed is on Lolo National Forest land. Over a mile of lower Eustache Creek was intensively placer mined from the late 1800's thru the early 1900's for gold and other metals. There are approximately 10 closed mining claims and one active mining claim within the Eustache Creek drainage (Lolo NF 2006). Mining has caused major stream, floodplain, and riparian impacts including: 1) intermittent large tailings piles 10-15 feet high that confine the stream channel and limit riparian vegetation establishment and function; 2) altered streambed conditions resulting in water flowing sub-surface in sections and loss of sediment transport capacity with subsequent detrimental effects on channel form and aquatic habitat; 3) channel simplification from loss of flow and large wood recruitment potential; and 4) channel instability and hillslope slumping and erosion. All of these limit native fish production and recovery

potential, thus reducing the capacity of one of the better native fish producing streams in the Nine-mile watershed (Lolo NF 2006).

Despite habitat degradation resulting from historic mining, Eustache Creek is one of the few watersheds in the Nine-mile drainage that supports native Westslope cutthroat trout (*Oncorhynchus clarki lewisi*) in substantial numbers (Lolo NF 2006). While the Ninemile watershed has historically been a native Bull trout (*Salvelinus confluentus*) fishery, only one Bull trout (possibly a hybrid) was observed in Eustache Creek in recent years. Eastern brook trout (*Salvelinus fontinalis*) and Rainbow trout (*Oncorhynchus mykiss*), both non-native species, are also found in the watershed. The characteristics of Eustache Creek are somewhat different from those found in the other tributaries of Ninemile Creek (Lolo NF 2006). Despite historical disturbance to the watershed, Lower Eustache/Upper Ninemile has higher native fish densities relative to other tributaries. Additionally, this is one of the only areas in the Ninemile watershed with recent bull trout juvenile presence. Lastly, sections of Eustache Creek have a more intact riparian area and more favorable stream temperatures relative to other tributaries in the Ninemile watershed. If this section of stream is restored to a more natural and functional state it could provide a unique native trout production setting compared to most other Ninemile tributaries (Lolo NF 2006).

In September of 2006 Trout Unlimited, the Ninemile Watershed Group, and the Lolo National Forest restored 1.3 miles of Eustache Creek, as part of a wider effort to improve water quality and native fisheries in the Nine-mile watershed. Streamside tailings piles along a 1.3 mile of Eustache Creek were rearranged with an excavator to: 1) create a channel that can transport discharge and bedload more efficiently, 2) provide a more natural array of instream habitat including more and higher quality pools, 3) reduce the amount of fine sediment that is recruited annually from encroached and over-steep hillslopes, and 4) reconnect local intermittent channel segments for fish migration where water currently flows subsurface. Large wood was added to the channel to create pool habitat and stabilize banks. Native red osier dogwood (*Cornus sericea*), thinleaf alder (*Alnus incana*), sitka alder (*Alnus sinuate*), mixed native willows (*Salix* spp.),



western redcedar (*Thuja plicata*), western white pine (*Pinus monticola*), lodgepole pine (*Pinus contorta*) and engelmann spruce (*Picea engelmanni*) species were planted on disturbed sites within the rehabilitated sections to facilitate local riparian recovery and help moderate stream water temperatures in the summer and winter. A culvert at the upstream end of the project site was also upgraded.

There were two separate implementation phases to the design. Phase 1 was the initial stream channel reconstruction phase, which began July 2006 with all in-stream channel work completed by September 2006. This included culvert replacement at the upper end of the site, channel and floodplain reconstruction, importation and creation of large woody material and soil surface amendments and erosion control. Phase 2 involved transplanting of native vegetation in April/May, 2007, when conditions were more favorable to transplant survival (Lolo NF 2006).

#### **Reference Site: Devil's Creek**

The majority of streams in the Nine-mile watershed have been impacted by a combination of mining, logging, grazing and road building. Devil's Creek, a tributary in the upper watershed approximately 1.5 miles west of Eustache Creek (Figure 1b) that has been relatively undisturbed by anthropogenic activities, was identified as the reference stream for the Eustache Creek restoration. Eustache Creek and Devil's Creek join to form Upper Nine-mile Creek. Devil's Creek most closely approximates the natural biological, physical and chemical integrity of the upper Ninemile Creek watershed, and therefore is categorized as a Tier 2 reference stream under the MT DEQ's definition of naturally occurring condition. Devil's Creek has no heavy metal risks and no agricultural activities. Part of the Devil's Creek watershed was logged in the 1970s but is believed to have suffered no direct effects from riparian roads or harvest. Riparian, habitat and fish population surveys in Devil's Creek suggest that instream habitat in Devil's Creek falls within the Lolo National Forest's riparian management objectives (RMOs) that were developed based upon habitat conditions in relatively pristine watersheds across the forest (Trout Unlimited 2008).

## METHODS

This study depends largely upon pre- and post-project data collected by Trout Unlimited (TU) and the Lolo National Forest, so methods used were consistent with those used by the two agencies throughout this project. TU and the USFS have collected annual data on fish populations and habitat at three reaches within the restored section of Eustache Creek and one reach at the downstream end of Devil's Creek from 2005 until the present (Table 1). Total length for each reach was approximately 30 bank-full widths, or 100 meters. I coordinated the collection of both fish and habitat data for 2009 at these four sites for the purposes of this study as well as for fulfilling annual monitoring obligations of the Eustache Creek project. Before analysis of the data was begun, a thorough quality check of the data was performed to ensure that the data I was using for this study were accurate. This included checking all formulas in Excel spreadsheets and making sure data was entered correctly and consistently. I then compiled all needed data into a new spreadsheet.

### **Habitat Data**

Pre-project habitat data were collected in the summer of 2005 by TU volunteers and the Lolo NF at the four sites. Post-project data were first collected in the summer of 2007, one year after project completion, and again in 2008 and 2009. Habitat quality was assessed using the following six metrics: width to depth ratio, percent of pool habitat (based on site area), residual pool depth, LWD per 100 meters, LWD median diameter and percent fine sediment in pool tails. An increase in habitat quality is defined by any of the following: a decrease in width to depth ratio, an increase in the percent of pool habitat, an increase in residual pool depth, an increase in LWD, an increase in LWD median diameter, or a decrease in the percent of fine sediment in pool tails.

Pre-restoration habitat data were collected using the R1/R4 Inventory procedures often used by the USFS. All post-restoration habitat data (years 2007-2009) were collected using the protocol of the PACFISH/INFISH Biological Opinion (PIBO) used by the Lolo NF (Heitke et al.

2007). See Appendix A for detailed methods associated with PIBO habitat data collection. R1/R4 procedures can be found in Appendix C.

### R1/R4 vs. PIBO

The R1/R4 habitat inventory procedure is generally a more detailed method of collecting habitat data, and requires more specific characterization of habitat units than the PIBO protocol. R1/R4 includes habitat characteristics such as percent undercut bank, bank stability, substrate composition and channel shape. Another difference in the two methods is the collection of LWD information. With PIBO, the observer estimates and measures the first ten pieces of wood, then continues to estimate and only measures every fifth piece (others are ocularly estimated). Then lengths and diameters are corrected through linear regression. With R1/R4, the observer never measures wood, but rather estimates all single pieces. Pieces in aggregates are never measured or estimated, just counted. For these reasons, the PIBO method likely produces more accurate lengths and diameters of large woody debris. The use of two different methods of habitat data collection pre- to post-restoration did not create any major issues with data analysis, as both methods collected essentially the same data needed for the study.

### **Fish Abundance Data**

Pre-project fish abundance data were collected in summer of 2005 and again in summer of 2006 just prior to commencement of channel and floodplain restoration by TU volunteers and the Lolo NF at the four sites. Post-project data were first collected in the summer of 2006, after restoration activities were complete, and again in the summers of 2007, 2008 and 2009.

Fish populations were sampled using an electroshocking backpack in three reaches along the same three reaches in Eustache Creek and the one reach in Devil's Creek where physical habitat data were collected. Fish population estimates were made using the three-pass depletion methodology (three passes per site). Often, only two passes were made per site due to time

constraints, but as was confirmed by Lolo National Forest Fisheries Biologist Scott Spaulding, two passes is typically sufficient when capture efficiency is acceptable. Each site took approximately one field day to survey.

The shocker and one netter started at the downstream end of the site and systematically shocked all habitats from bottom to top. Approximately the same level of effort (seconds) among shocking passes occurred. Assumptions of the 3-pass depletion and maximum likelihood population estimates are: equal sampling effort among passes; no emigration or immigration of fish from, or into the site, respectively; and that fish capture efficiency among passes does not change. Voltage settings were established based on conductivity measures and were delivered in a direct current (DC) setting to minimize harm to the fish. Captured fish were classified by species and measured to the nearest millimeter. Young of year (YOY) Westslope cutthroat trout (WCT) were considered to be those  $\leq 50$  mm. YOY Eastern brook trout (EBT) were considered to be those  $\leq 70$  mm. The fish were placed into a bucket of water after they were measured and identified until all passes were completed. Fish were then released in various pools in the reach they were caught. The fish sampling was conducted to document the types of fish that are living in Eustache Creek and Devil's Creek and their relative abundance. All fish sampling was conducted in coordination with MTFWP and the USFS since the use of electrofishing equipment requires a permit.

### **Data Analysis**

Fish data for each year were entered into Microfish 3.0 (Van Deventer and Platts 1989), a software program that calculates maximum likelihood abundance estimates based upon the three-pass methodology. Data were entered into the "Quick Population Estimate" program, which produced abundance estimates by species within a particular reach. These data were then entered into Excel spreadsheets for determination of fish densities by reach ( $\#/100\text{m}^2$ ) and trend analysis. Habitat data for each year were entered into Excel spreadsheets where six habitat metrics determined to contribute to "habitat quality" were calculated for the four reaches over the years

2005-2009. A general analysis of trends in fish populations by species and habitat variables was performed over the four-year period. SPSS statistical software was utilized for statistical analyses.

Based upon the given dataset and small sample size (only three treatment sites), options for statistical analysis to detect significant change in habitat quality and fish density were somewhat limited. A significance level of  $p=0.1$  was chosen based on the small sample size and sensitivity of data to statistical analysis. The repeated measures ANOVA model was used to detect significant change in both habitat variables and fish densities over time. I compared habitat quality metrics before restoration (2005), and at years one (2007), two (2008) and three (2009) after restoration, and fish density estimates before restoration (2005 and 2006) and at years one (2007), two (2008) and three (2009) after restoration. In the repeated measures design, each trial represents the measurement of the same characteristic under a different condition. Here the characteristics measured are the six habitat metrics and fish abundance, and the condition that changes is the year. To determine whether individual habitat variables are directly correlated to fish density, a univariate ANOVA general linear model was created to detect significance.

## RESULTS

### **HABITAT QUALITY**

Prior to restoration, the Devil's Creek (reference) reach had higher width to depth ratios, approximately 60% more pools, higher residual pool depths, approximately 90% more LWD, approximately three times as wide median diameter of LWD and lower percentage of fine sediment than reaches in Eustache Creek.

Based on habitat data from the three reaches, results of the repeated measures ANOVA test for significance are summarized in Table 4. I found that there was no significant decrease in width to depth ratio ( $p = .442$ ) and no significant difference in reference and treatment reaches (Table 5). There was a significant increase ( $p = .033$ ) in percent pool habitat (Table 4) and a significant difference between reference and treatment reaches ( $p = .072$ ). There was no significant change in residual pool depth over time (Table 4), but a significant difference between

reference and treatment reaches ( $p=.049$ ). There was no significant increase in LWD per 100 meters, but there was a very statistically weak increase in LWD median diameter ( $p=.155$ ) over time (Table 4). There was a significant difference between reference and treatment reaches for both LWD per 100 meters and LWD median diameter (Table 5). There was no significant change in percent fine sediment in pool tails (Table 4), but a significant difference between reference and treatment reaches ( $p=.073$ ). Overall, statistical analysis doesn't point to a significant increase in habitat quality for Eustache Creek, although a significant increase in percent pool habitat and a statistically weak increase in LWD median diameter *suggest* Eustache Creek is becoming better quality trout habitat. Significant differences of percent pool habitat, residual pool depth, LWD per 100 meters, and LWD median diameter between reference and treatment reaches demonstrates that Eustache Creek has not reached its reference condition.

### **Trends by reach**

Due to the sensitivity of this dataset to statistical analysis, a non-statistical analysis of trends by reach is warranted. With the varying degrees of disturbance to the three restored reaches on Eustache Creek and the dynamic nature of this system from year to year from environmental factors, changes in habitat metrics were highly variable within the reaches (Table 2). That being said, the middle reach appears to be most strongly trending toward an overall increase in habitat quality three years after restoration. Increases in LWD numbers, LWD diameter and increases in percent pool habitat are variables appearing to be the greatest sources of increases in quality.

#### *Lower Devil's (Reference)*

Habitat variables in Devil's Creek were generally consistent across the four year period, aside from percent fine sediment, which increased greatly from year one to four (Table 2). Width to depth ratios remained fairly unchanged from 2005 to 2008, but dropped by almost 50% in 2009 (Figure 8). Percent pool habitat also remained fairly unchanged from 2005 (42.6%) to 2009 (44.5%) (Figure 9). Residual pool depth was somewhat variable over time but only 3 cm less in

2009 than in 2005 (Figure 10) . LWD numbers were somewhat variable over time, from 100 per 100m in 2005 to 158 per 100m in 2008 and 132.5 per 100m in 2009 (Figure 11). LWD median diameter remained largely unchanged from 2005-2009 (Figure 12). Percent fine sediment was variable and increased from 7.2% in 2005 to 26.2% in 2009 (Figure 13). Variability in LWD numbers and percent fine sediment in the reference reach indicate a dynamic system and could be attributed to annual variation in spring runoff, stream flow, or other environmental factors. While no streamflow data is available for Devil's Creek, and only limited data available for Ninemile Creek, historical streamflow data for the Clark Fork River below Missoula show higher peak flows in years 2006, 2008 and 2009 (Figure 14) (USGS 2010). Although no habitat data was collected in 2006, increases in LWD counts and percent fine sediment in the reference reach for the years 2008 and 2009 may be attributed to higher flows and bigger peaks in this watershed.

#### *Lower Eustache*

The Lower Eustache reach was the least disturbed reach and received the least amount of channel re-construction of all three reaches. For these reasons and due to the high variability in the data, lower Eustache doesn't appear to be increasing in quality very substantially, although some metrics suggest a slight trend toward a more complex habitat (Table 2). The width to depth ratio was only slightly lower in 2009 than pre-restoration (Figure 8). Percent pool area increased from 20.8% to 34.4% three years after restoration, but was as low as 15.6% in 2008 (Figure 9). Residual pool depth increased from 9 to 11 cm by 2009, but was as high as 15 cm in 2008 (Figure 10). LWD counts were variable as well, and in 2009 were much lower than pre-restoration counts (Figure 11). The median diameter of LWD increased by 2 cm three years after restoration (Figure 12). After a large increase in the percentage of fine sediment one year after restoration likely due to the disturbance caused by the restoration itself, in 2009 the percentage was 2% below pre-restoration measurements (Figure 13). While the percent pool is much closer to the reference condition, residual pool depth, LWD, and LWD median diameter are nowhere near the desired state.

### *Middle Eustache*

The width to depth ratio in Middle Eustache decreased from 29 to 20.1 by 2009, but was as low as 9.3 in 2008 (Figure 8). Percent pool habitat increased from 9.6% pre-restoration to 17.3% in 2009 and was as high as 23.5% in 2008 (Figure 9). Residual pool depth has decreased over time, from 18 cm in 2005 to 14 cm in 2009 (Figure 10). Due to addition of LWD during restoration, LWD amounts have greatly increased, from 7 per 100m pre-restoration to 49.8 per 100m three years after restoration (Figure 11). However, LWD numbers are still nowhere near reference conditions. The LWD median diameter also increased from 6 cm in 2005 to 20 cm one year post-restoration and was 16 cm in 2009 (Figure 12). After a large increase in the percentage of fine sediment one year after restoration, in 2009 the percentage was 3% below pre-restoration measurements (Figure 13). Aside from the decrease in residual pool depth, all other habitat metrics suggest an overall increase in habitat quality for the middle Eustache reach three years after restoration. While moving closer to reference conditions, percent pool habitat, residual pool depth, LWD, and LWD median diameter are still far from a desired condition.

### *Upper Eustache*

The Upper Eustache reach lies within the most disturbed section of stream, and the section that received the most intensive channel re-construction. The width to depth ratio hasn't changed significantly over the four year period and actually increased slightly, from 22.6 in 2005 to 23.5 in 2009 (Figure 8). The percent pool habitat has increased slightly from 11.6% in 2005 to 16.2% in 2009 (Figure 9). There was a large decrease in pool habitat one year after restoration to 6.7%. This could be a result of what is defined as a "pool" and lower flows that may have affected pool classification on the survey date. Residual pool depth in the upper Eustache reach has decreased from 18 cm in 2005 to 13 cm in 2009 (Figure 10). Again, due to inputs of LWD into the channel, LWD frequency increased from 0 in 2005 to 37.8 in 2007 and 45.6 in 2009 (Figure 11). Median diameter also increased significantly from 2005 to 2007 and was 19 cm in 2009 (Figure 12). Percent fine sediment remained fairly unchanged from pre- to post-restoration



until 2009 when it significantly increased from 8.9% to 20.4% (Figure 13). This is unclear as to why, but is likely due to increased runoff and upland erosion, resulting in increased fine sediment inputs. Aside from the increases in LWD, LWD median diameter and percent pool habitat, the variability of the data in the upper Eustache reach show that while some gains in quality are made, the recovery of this reach will be a long-term process. This is due to the slow process of riparian vegetation recovery, which in the long-term will provide bank stability, reduce inputs of fine sediment and increase woody debris inputs, which will create better quality fish habitat.

### **FISH ABUNDANCE**

Prior to restoration activities, the Devil's Creek (reference) reach had, on average, 5% lower total fish density, approximately 2% lower WCT density, and approximately 3% lower EBT density than Eustache Creek. This suggests that despite habitat quality differences in the reference and treatment reaches, Eustache Creek is still able to maintain healthy fish populations. Alternately, it could point to high variability of fish densities in the watershed or migration of populations.

Based on fish density data from the three reaches and accounting for the treatment factor, results of the repeated measures ANOVA test for significance are summarized in Table 6. There was a significant increase in total fish densities in Eustache Creek over time, with a p-value of .039 (Table 6). No significant difference in total fish density was detected between treatment and reference reaches (Table 7). There was a significant increase in total WCT densities over time (Table 6), with a p-value of .05 and no significant difference between treatment and reference reaches. Additionally, there was a significant increase in Adult WCT densities over time (Table 6), with a p-value of .039 and no significant difference between reference and treatment reaches. There was no significant increase in Total EBT densities over time (Table 6), and no significant difference between reference and treatment reaches (Table 7). There was a significant increase, however, in Adult EBT densities over the study period with a p-value of .043 (Table 6), and no significant difference between reference and treatment reaches (Table 7).

Overall, statistical analysis shows positive results for fish abundance post-restoration of Eustache Creek.

### **Trends by reach**

With the varying degrees of disturbance to the three restored reaches on Eustache Creek and the dynamic nature of this system from year to year from environmental factors, changes in fish densities were also highly variable within reaches (Table 3). That said the middle reach appears to be most strongly trending toward an overall increase in fish abundance from pre- to post-restoration. Total WCT and EBT densities across all reaches of Eustache Creek show an increase in both species over the study period (Figure 22).

#### *Lower Devil's (Reference)*

Total fish density in the lower Devil's reach was highly variable over the four-year study period (Figure 19). This variability was seen in both WCT and EBT densities, and there doesn't appear to be a noticeable increase or decrease in either species over time. Again, the reference reach showed lower fish densities than the treatment reaches before restoration, and post-restoration continues to have even lower fish densities than Eustache reaches.

#### *Lower Eustache*

Total fish density in the lower Eustache reach is also variable but has increased over time (Figure 19). WCT densities were highly variable across years, and do not appear to have increased over time (Figure 20). EBT densities, also highly variable, are difficult to interpret, but there is a slight increase in EBT young-of-year (YOY) in this reach over time and post-restoration trends of adult EBT are increasing (Figure 21).

### *Middle Eustache*

Total fish density in the middle Eustache reach isn't nearly as variable over time, and shows an increase from pre- to post-restoration (Figure 19). While EBT densities are variable and make it difficult to interpret any trends (Figure 21), WCT densities are less variable and appear to be increasing over time (Figure 20).

### *Upper Eustache*

Total fish density for the upper reach was quite variable as well, so trends cannot be determined (Figure 19). Due to an unusually high WCT density for this reach in 2009, it appears that WCT densities are increasing, but I would hesitate to jump to this conclusion, based on the variability seen in other reaches (Figure 20). EBT densities are variable and difficult to interpret (Figure 21).

## **MEASURES OF HABITAT QUALITY**

After running a linear univariate Anova model on the data with a significance level of  $p=0.1$ , no habitat variables are significantly correlated to total fish density (Table 8). That said percent pool habitat had a p-value of .118, showing a statistically weak relationship to total fish density. When plotting total fish density against percent pool habitat, a steep, positive linear relationship can be observed for treatment reaches (Figure 23).

## **DISCUSSION/CONCLUSIONS**

### **HABITAT QUALITY**

The results of this study show that channel and riparian re-construction of Eustache Creek has not significantly increased habitat quality three years after restoration. While Eustache Creek appears to be trending toward more complex fish habitat, the high variability of the habitat data within certain reaches, including the reference reach, from year to year suggests that the stream is a seasonally and environmentally dynamic system and that recovery will be a long-term process. Again, years 2006, 2008 and 2009 had higher peak flows (Figure 14), suggesting that the

effects inter-annual differences in streamflow could be a potential source of the variability seen in habitat data for both reference and treatment reaches. Additionally, there was evidence of significant differences of percent pool habitat, residual pool depth, LWD per 100 meters and LWD median diameter between reference and treatment reaches, demonstrating that Eustache Creek has not reached its reference condition. As discussed in Section 1, a major component of habitat quality is an intact and healthy riparian zone, which the restored section of Eustache Creek still does not have. Without thick riparian vegetation, inputs of fine sediment into this stream will continue, which is what was shown in the data. Additionally, woody debris inputs will continue to be limited and pools will be less likely to form and get deeper. While re-vegetation was a major part of this restoration project, it will take years before the riparian zone fully recovers, if full recovery is even possible.

## **FISH ABUNDANCE**

Despite a lack of significant increases in habitat quality, there are significant increases in total fish density, including both adult WCT and EBT in Eustache Creek, *suggesting* an improvement in fish habitat and increases in fish densities post-restoration. It should be noted that the middle Eustache reach showed the most promising increase in quality *and* increases in fish densities, suggesting a possible link between habitat quality and fish abundance. Again, the high variability of fish densities over time in certain reaches including the reference reach, points to a dynamic system to which fish populations are quite sensitive, and one in which trends are difficult to detect. This is evident in the data: there is no statistically significant difference in total fish density, total WCT density, adult WCT density and adult EBT density between reference and treatment reaches. In some years treatment reaches had higher densities than the reference reach and vice-versa. This might lead one to believe that Eustache Creek may only be capable of supporting the numbers of fish it currently does, regardless of any further increases in habitat quality. According to Schlosser's framework, due to a lack of deep pools and competition as well as high variability of annual physical conditions, the number of species and fish densities are low

in headwater streams (Schlosser 1987), and this appears to hold true for both Eustache and Devil's Creek. The significant increases in fish density we see in the data could possibly be a short-term trend. Fish density in this watershed could be influenced by other components of habitat quality or other factors not observed in this study such as food, stream temperature and seasonal and environmental variation. Having several more years of pre-restoration data would be helpful in the analysis, but unfortunately this data doesn't exist. Only long-term monitoring will help determine whether restoration of Eustache Creek has in fact increased fish populations. Potential sources of error and recommendations are explored in Section 3.

## **MEASURES OF HABITAT QUALITY**

The six habitat metrics used in this study to assess habitat quality provided varying degrees of usefulness. The strongest metrics for habitat quality were percent pool habitat, LWD per 100 m, and LWD median diameter. The least useful metrics were W:D ratio and percent fine sediment.

Percent pool habitat showed the strongest correlation to fish abundance and was simple and straightforward to measure. For this reason, it is less likely to be subject to observer opinion, and provides a clear and consistent way to assess habitat quality. LWD per 100 m and LWD median diameter also provided a straightforward and easily measurable assessment of habitat quality, and again, data collected is less likely to vary between different observers. For these reasons, these three metrics show the most reliable assessment of habitat quality.

Residual pool depth in theory is an excellent measure of habitat quality. However, in a stream such as Eustache Creek, where water goes subsurface in several reaches, the metric is less useful, especially when survey dates are inconsistent across years.

The width to depth ratio was the least useful metric in this particular study. There are some limitations of the width to depth ratio that should be addressed. First, the width to depth ratio is typically measured using the bankfull width and mean bankfull depth. I didn't have bankfull data for some years so wetted widths and mean depths were used, and were taken at

varying streamflows, therefore making the width to depth ratio inconsistent across all sampling dates and hence, meaningless. If the stream isn't at bankfull flow, the data is subject to the observer's eye. For these reasons, it is recommended that width to depth ratio only be used when bankfull data will be collected by the same observer across all survey dates and that survey dates be consistent from year to year.

### SECTION 3 – FINAL CONCLUSIONS AND RECOMMENDATIONS FOR MONITORING AND MANAGEMENT OF EUSTACHE CREEK

Through observations made during the collection and analysis of fish and habitat data I want to provide recommendations to Trout Unlimited and Lolo NF regarding present and future monitoring of Eustache Creek and the Ninemile watershed. In general, the pre and post-restoration monitoring activities associated with Eustache Creek were well planned and implemented, and covered all important aspects of stream monitoring, including habitat, fisheries, macro-invertebrates, riparian vegetation, geomorphology and stream temperature. With so many variables to monitor, it is well understood that funding, time and personnel may be lacking, and decisions must be made about which monitoring activities to do, if any, and how often to conduct them. In this section I will explore observations made during this study about current monitoring practices on Eustache Creek, identify potential sources of error in data collection, and provide recommendations to managers about future monitoring and management activities both on Eustache Creek and the Ninemile watershed.

#### Monitoring Recommendations

The most important recommendation I will make here is this: continue monitoring activities on Eustache Creek for the next 15-20 years, if not longer. This watershed provides a unique opportunity for monitoring, especially since Trout Unlimited is continuing to restore lower streams in the Ninemile watershed, and has a long term plan for its restoration. The current Sampling and Analysis plan for Eustache Creek is to collect data on fish, habitat, temperature and invertebrates for five years after restoration, and vegetation data for ten years. The results of this study demonstrate that there is a dynamic nature to fish abundance in Eustache Creek which may not be attributed solely to habitat quality, and that significant increases in habitat quality may take many years to achieve. Again, a major component of habitat quality is an intact and healthy riparian zone, which Eustache Creek is lacking. While there are positive trends in fish abundance

and habitat quality in Eustache Creek, the field of restoration needs more long-term studies to provide scientific evidence that can link physical changes to biological responses. Five or ten years in my opinion, does not seem adequate for long-term monitoring. As the lower Ninemile watershed is restored, opportunities for trout production will improve, and monitoring fish populations on Eustache Creek and other streams will be vital. One important recommendation for future monitoring on other restoration projects is to collect as many years of pre-restoration baseline data as possible so that trends can be better interpreted. Additionally, if statistical analysis is important to future monitoring projects, it is recommended that there be significantly more sampling sites.

One aspect of fish sampling that could be improved upon is consistency in sampling dates from year to year. WCT and EBT spawn at different times (EBT emerge earlier in the summer than WCT) and depending on when fish were sampled, YOY numbers could differ from year to year. Although this was accounted for by increasing the length of EBT that qualified as “YOY” (they would have had more time to grow throughout the summer), sampling all reaches in the same month each year would ensure the quality of the data and consistency when comparing fish densities from year to year.

A potential source of error involving fish sampling data throughout this project involves one of the key assumptions in the three-pass methodology of fish sampling: no emigration or immigration of fish from, or into the site, respectively. This assumption is typically met by using block-nets at both the upstream and downstream ends of the sampling reach. Block nets were never used when sampling the reaches in this study, and could have over or underestimated fish populations if any unknown emigration or immigration of fish occurred. According to Scott Spaulding of the Lolo National Forest, “you are much less likely to violate this assumption in small streams such as Eustache Creek where fish tend to have fewer avoidance options...and our shocking suggested that these fish stay in cover until shocked,” (Spaulding 2010). Additionally, sites were chosen based on geomorphic breaks with drops or faster water that might help avoid



violation of this assumption. I would recommend further investigation of this issue including sampling reaches both with and without block nets to study differences in population estimates.

Another potential source of error in the fish data involved the number of netters used during sampling. In some years one netter was used, while in others, two netters were used. Having two netters versus one netter would increase fish capture efficiency and potentially violate another assumption: that fish capture efficiency among passes does not change. This was evident when, during sampling of a Eustache Creek reach in 2009, a second netter joined the crew. More fish were caught in the third pass than in the second pass. It was unclear whether the increase in fish capture was due to the second netter, or to immigration of fish, but the reach was re-sampled at a different date due to this happening. Situations like these can be largely avoided by consistently using one or two netters from this point on. Additionally, it will produce more confident population estimates and ensure the quality of the data analysis when comparing those estimates from year to year.

On a similar note, there were some years in which fish sampling was done with two passes and others with three passes. While not a major issue, the three pass methodology produces more confident population estimates whereas the two pass requires acceptance of broader errors. Although it may not be realistic due to time constraints in the field season, using the three pass method every year would create more consistency and quality in the data across years, resulting in a greater degree of confidence in population estimates.

Regarding a monitoring schedule for Eustache Creek, it is my opinion that fish sampling should occur every year from this point forward. This will be important to observe trends in WCT and EBT populations over time as the Ninemile watershed is restored. As the habitat data has reached somewhat of a “plateau” it makes sense to only survey habitat every 3-5 years and allocate those resources to other monitoring activities. While macro-invertebrates have been sampled twice, in 2006 pre-restoration and in 2007 post-restoration, these data have not been fully analyzed. I would recommend doing so and sampling invertebrates every 3-5 years as they can be a good indicator of water quality and stream health. Additionally, macroinvertebrate data

could help explain the variability in fish densities in Eustache Creek. Stream temperature should continue to be monitored annually. Due to the slow nature of its recovery, riparian vegetation could be monitored every 5 years.

#### Other Recommendations

Another factor to consider in this entire watershed is the increase in EBT populations. Invasion by nonnative brook trout often results in replacement or displacement of cutthroat trout in the western United States, but the causes are not well understood (Petersen et al. 2004). Results of a study by Petersen et al. (2004) demonstrate that 1) biotic interactions with brook trout suppress cutthroat trout populations, especially during years one and two, and 2) that brook trout are invaders that can quickly increase their abundance. The same study suggests that water temperature, fine sediment, and abundance of pools and woody debris may influence brook trout invasion and the displacement of WCT (Petersen et al. 2004). Although displacement of WCT by EBT has not occurred in Eustache Creek, due to its small size and low habitat quality, there is limited food and habitat, and WCT populations may only recover to a certain degree with increases in EBT. Competition with EBT may limit WCT abundance, and may even decrease WCT populations at some point in the future. Further investigation into effects of increases in EBT populations in the Ninemile watershed is recommended, along with investigation into the need for and effectiveness of non-native EBT removal efforts.

While placer mining activities left Eustache Creek in varying states of ecological impairment, restoration efforts are showing indication of positive results for habitat quality and fish populations. While full recovery may take decades, with continued monitoring and downstream restoration efforts, there is certainly potential to return a thriving native trout fishery to Eustache Creek and the Ninemile watershed.

### Literature Cited

- Angermeier, P.L. and Schlosser, I.J. 1989. Species-area relationships for stream fishes. *Ecology* 70: 1450-1462.
- Baldigo, B.P. and Warren, D.R. 2008. Detecting the Response of Fish Assemblages to Stream Restoration: Effects of Different Sampling Designs. *North American Journal of Fisheries Management* 28: 919-934.
- Beechie, T. J. S. and Thomas, H. 1997. Relationships between channel characteristics, woody debris, and fish habitat in northwestern Washington streams. *Transactions of the American Fisheries Society* 126(2): 217-229.
- Beschta, R. and Platts, W. 1986. Morphological Features of Small Streams: Significance and Function. *Water Resources Bulletin* 22(3): 369-379.
- Bilby, R. and Bisson, P. 1998. Function and Distribution of Large Woody Debris. *River Ecology and Management: Lessons from the Pacific Coastal Ecoregion*. Springer. New York, NY: 324-346.
- Bisson, P. A., Nielsen, J.L., Palmasson, R.A., and Grove, L.W. 1982. A system of naming habitat types in small streams with examples of habitat utilization by salmonids during low stream flow. Acquisition and utilization of habitat information in streams, Portland, OR.
- Bond, N.R. and Lake, P.S. 2003. Local habitat restoration in streams: Constraints on the effectiveness of restoration for stream biota. *Ecological Management and Restoration* 4(3): 193-198.
- Bowlby, J.N., and Roff, J.C. 1986. Trout biomass and habitat relationships in southern Ontario streams. *Transactions of the American Fisheries Society* 115: 503-514.
- Bryant, M. D. 1983. The role and management of woody debris in west coast salmonid nursery streams. *North American Journal of Fisheries Management* 3: 322-330.
- Burkhead, N.M., and Jelks, H. 2001. Effects of suspended sediment on the reproductive success of the tricolor shiner, a crevice-spawning minnow. *Transactions of the American Fisheries Society* 130:959-968.
- Colburn, K. 2001. Measures of stream complexity along a continuum of recovery. *Environmental Studies, Missoula, University of Montana. M.S.*: 103.
- Crispin, V., House, R. and Roberts, D. 1993. Changes in instream habitat, large woody debris, and salmon habitat after the restructuring of a coastal Oregon stream. *American Journal of Fisheries Management* 13(1): 96-102.
- Everest, F.H., Reeves, G.H., and Sedell, J.R. 1989. Salmonid habitat: New beginnings through enhancement, but not without uncertainty, risk and failure. Pgs 9-19 in D. Guthrie (ed), Proceedings of wild trout, steelhead, and salmon in the 21<sup>st</sup> century, Portland, Oregon, July 19 1986.
- Fausch, K. D., and Northcote, T.G. 1992. Large woody debris and salmonid habitat in a small coastal British Columbia stream. *Canadian Journal of Fisheries and Aquatic Sciences* 49: 682-693.
- Frazier J.W., Roby, K.B., Boberg, J.A., Kenfield, K., Reiner, J.B., Azuma, D.L., Furnish, J.L., Staab, B.P., and Grant, S.L. 2005. Page 29. In: *Stream Condition Inventory Technical Guide*. USDA Forest Service, Pacific Southwest Region - Ecosystem Conservation Staff. Vallejo, CA. 111 pp.
- Gorman, O.T. and Karr, J.R. 1978. Habitat structure and stream fish communities. *Ecology* 59: 507-515.
- Heggenes, J., Northcote, T.G., and Peter, A. 1991. Spatial stability of cutthroat trout (*Oncorhynchus clarki*) in a small, coastal stream. *Canadian Journal of Fisheries and Aquatic Sciences* 48: 757-762.

- Heitke, Jeremiah D., Archer, Erik J., Dugaw, Dax D., Bouwes, Boyd A., Archer Eric A., Henderson, Richard C., and Kershner, Jeffrey L. 2007. Effectiveness monitoring for streams and riparian areas: sampling protocol for stream channel attributes. Unpublished paper on file at: <http://www.fs.fed.us/biology/fishecology/emp>. 75 p.
- Helfrich, L.A. and Parkhurst, J. 2009. Sustaining America's Aquatic Biodiversity, Aquatic Habitats: Homes for Aquatic Animals. *Virginia Cooperative Extension Publication 420-522*. Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University. Petersburg, VA. 4 pp.
- Helfman, G.S. 2007. *Fish Conservation: A guide to understanding and restoring global aquatic biodiversity and fishery resources*. Island Press. 584 pp.
- Horan, D.L., Kershner, J.L., Hawkins, C.P., and Crowl, T.A. 2000. Effects of Habitat Area and Complexity on Colorado Cutthroat Trout Density in Uinta Mountain Streams. *Transactions of the American Fisheries Society* 129: 1250-1263.
- House, R. A. and Boehne, P. L. 1986. Effects of Instream Structures on Salmonid Habitat and Populations in Tobe Creek, Oregon. *North American Journal of Fisheries Management* 6: 38-46.
- Liermann, M. and Roni, P. 2008. More Sites or More Years? Optimal Study Design for Monitoring Fish Response to Watershed Restoration. *North American Journal of Fisheries Management* 28: 935-943.
- Lolo National Forest, Water Resources. 2006. *Eustache Creek Stream Rehabilitation Design*. 151 pp.
- McMahon, T.E. and Hartman, G.F. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Onchorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 46: 1551-1557.
- Meehan, W. R., editor (1991). Influences of forest and rangeland management on salmonid fishes and their habitats. *American Fisheries Society Special Publication* 19.
- Minckley, W.L., and Deacon, J.E. 1991. *Battle Against Extinction: Native Fish Management in the American West*. University of Arizona Press, Tucson, Arizona, 517 pp.
- Murphy, M.L., Heifetz, J., Johnson, S.W., Koski, K.V., and Thedinga, J.F. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan stream. *Canadian Journal of Fisheries and Aquatic Sciences* 43: 1521-1533.
- Pearsons, T.N., Li, H.W., and Lamberti, G.A. 1992. Influence of habitat complexity on resistance to flooding and resilience of stream fish assemblages. *Transactions of the American Fisheries Society* 121: 427-436.
- Petersen, D.P., Fausch, K.D., and White, G.C. 2004. Population Ecology Of An Invasion: Effects Of Brook Trout On Native Cutthroat trout. *Ecological Applications* 14(3), pp. 754-772.
- Poff, N.L., and Ward, J.V. 1990. Physical habitat template of lotic systems: recovery in the context of historical pattern of spatiotemporal heterogeneity. *Environmental Management* 14: 647-659.
- Ralph S.C., Poole, G.C., Conquest L.L., and Naiman, R.J. 1994. Stream channel morphology and woody debris in logged and unlogged basins of western Washington. *Canadian Journal of Fisheries and Aquatic Sciences* 51: 37-51.
- Reeves, G.H., Bisson, P.A., and Dambacher, J.M. 1998. Fish Communities. Pages 200-234. In: *River Ecology and Management* (R. Naiman and R. Bilby, editors), Spring-Verlag New York, Inc., 705 pp.

- Roni, P. Q. and Thomas, P. (2001). Density and size of juvenile salmonids in response to placement of large woody debris in western Oregon and Washington streams. *Canadian Journal of Fisheries & Aquatic Sciences* 58(2): 282-292.
- Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO. 376 pp.
- Schlosser, I.J. 1987. Fish community structure and function along low habitat gradients in a headwater stream. Pages 17-24. In: *Community and evolutionary ecology in North American stream fishes* (W.J. Matthews and D.C. Heins, editors), University of Oklahoma Press, Norman, Oklahoma, USA.
- Solazzi, M.F., Nickelson, T.E., Johnson, S.L., and Rodgers, J.D. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. *Canadian Journal of Fisheries & Aquatic Sciences* 57: 906-914.
- Spaulding, Scott. [Personal communication], Fish Biologist, Lolo National Forest, Missoula, MT, 59801. Email correspondence on June 1, 2010.
- Trotter, E. H. 1990. Woody debris, forest-stream succession, and catchment geomorphology. *Journal of the North American Benthological Society* 9: 141-156.
- Trout Unlimited. 2008. *Sampling and Analysis Plan for Project Monitoring, Eustache Creek*. 34 pp.
- USGS National Water Information System, 2010. 12353000 Clark Fork below Missoula MT. [[http://waterdata.usgs.gov/mt/nwis/dv?cb\\_00060=on&cb\\_00065=on&format=gif\\_default&begin\\_date=2005-01-01&end\\_date=2010-08-18&site\\_no=12353000&referred\\_module=sw](http://waterdata.usgs.gov/mt/nwis/dv?cb_00060=on&cb_00065=on&format=gif_default&begin_date=2005-01-01&end_date=2010-08-18&site_no=12353000&referred_module=sw)]. Accessed on 08/18/2010.
- Van Deventer, J., and Platts, W.S. 1989. Microcomputer software system for generating population statistics from electrofishing data. *General Technical Report INT-254*. Ogden, UT: US Dept. of Agriculture, Forest Service, Intermountain Research Station. 29 pp.
- Waters, T.E. 1995. *Sediment in streams: Sources, biological effects, and controls*. Bethesda, MD: American Fisheries Society.

**Table 1. Fish and Habitat Sampling Sites/Locations.**

Site	GPS Location	Physical Location
Lower Devil's	47.2367 114.7355	Lower Devil's Creek, Reference
Lower Eustache	47.2379 114.732	Lower Eustache Creek, light channel construction, 1/3 way up reclaimed lower access road
Middle Eustache	47.250025 114.73316	Middle Eustache, aggraded, heavy construction, station 24+00 to 21+00
Upper Eustache	47.25367 114.7347	Upper Eustache, confined and aggraded, heavy construction, stations 15+00 to 12+00

Table 2. Summary of Habitat Quality Metrics in Devil's and Eustache Creeks, 2005-2009.

SITE	HABITAT METRIC	YEAR			
		2005 (pre)	2007	2008	2009
<b>Devil's Lower</b>		9/11/05	9/18/07	8/4/08	7/28/09
(REFERENCE)	FW Width:Depth Ratio	35.8	NA	31.5	15.3
	% pool (site area)	42.6	42.3	44.4	44.5
	Residual Pool Depth	0.24	0.22	0.28	0.21
	LWD (# per 100m)	100.4	122.9	158.1	132.5
	LWD Median Diameter	0.22	0.21	0.18	0.20
	% surface fines	7.2	11.6	31.0	26.2
<b>Eustache Lower</b>		9/11/05	9/19/07	8/5/08	8/3/09
(TREATMENT)	FW Width:Depth Ratio	18.3	NA	19.81	17.60
	% pool (site area)	20.8	26.5	15.6	34.4
	Residual Pool Depth	0.09	0.14	0.15	0.11
	LWD (# per 100m)	20.8	11.5	21.3	12.5
	LWD Median Diameter	0.14	0.16	0.17	0.16
	% surface fines	12.0	11.9	24.4	10.0
<b>Eustache Middle</b>		9/17/05	9/19/07	7/17/08	7/27/09
(TREATMENT)	FW Width:Depth Ratio	29.0	NA	9.26	20.13
	% pool (site area)	9.6	6.5	23.5	17.3
	Residual Pool Depth	0.18	0.10	0.16	0.14
	LWD (# per 100m)	7.0	46.8	45.0	49.8
	LWD Median Diameter	0.06	0.20	0.18	0.16
	% surface fines	12.3	21.2	11.8	9.3
<b>Eustache Upper</b>		9/17/05	9/19/07	7/17/08	8/3/09
(TREATMENT)	FW Width:Depth Ratio	22.6	NA	26.74	23.53
	% pool (site area)	11.6	6.7	13.6	16.2
	Residual Pool Depth	0.18	0.15	0.18	0.13
	LWD (# per 100m)	0.0	37.8	41.9	45.6
	LWD Median Diameter	0.00	0.20	0.15	0.19
	% surface fines	8.7	9.2	8.9	20.4

Table 3. Summary of fish densities by species and reach, Devil's and Eustache Creeks, 2005-2009.

		FISH DENSITY (#/100m <sup>2</sup> )					
Site	Species	YEAR					
		2005 (pre-restoration)	2006 (pre-restoration)	2006 (post-restoration)	2007	2008	2009
<b>Lower Devils</b>		<b>7/29/2005</b>	<b>7/20/2006</b>	<b>9/21/2006</b>	<b>7/28/2007</b>	<b>8/19/2008</b>	<b>8/19/2009</b>
(REFERENCE)	WCT	17.9	4.8	10.1	9.9	19.3	14.4
	WCT (YOY)	0.0	0.0	0.0	0.0	0.0	0.0
	EBT	4.1	0.7	1.1	1.4	9.1	6.4
	EBT (YOY)	0.0	0.0	0.4	0.0	0.4	0.3
	BT	0.4	0.0	0.0	0.0	0.0	0.0
	UNK	0.0	0.0	0.0	0.0	0.0	0.3
	<b>TOTAL</b>	<b>22.3</b>	<b>5.6</b>	<b>11.5</b>	<b>11.4</b>	<b>28.8</b>	<b>21.4</b>
<b>Lower Eustache</b>		<b>9/11/2005</b>	<b>7/21/2006</b>	<b>9/16/2006</b>	<b>8/25/2007</b>	<b>8/14/2008</b>	<b>7/15/2009</b>
(TREATMENT)	WCT	8.0	15.3	9.2	17.0	25.2	12.7
	WCT (YOY)	0.0	0.0	18.4	0.7	0.0	0.0
	EBT	5.8	19.2	6.9	5.4	10.1	15.9
	EBT (YOY)	0.0	0.0	0.0	0.7	3.4	11.5
	BT	0.0	0.0	0.0	0.0	0.0	0.0
	UNK	0.0	0.0	0.0	0.0	0.0	0.0
	<b>TOTAL</b>	<b>13.9</b>	<b>34.5</b>	<b>34.5</b>	<b>23.8</b>	<b>38.7</b>	<b>40.1</b>
<b>Middle Eustache</b>		<b>7/30/05</b>	<b>7/22/06</b>	<b>9/16/06</b>	<b>7/27/07</b>	<b>7/28/08</b>	<b>7/16/09</b>
(TREATMENT)	WCT	15.6	10.1	12.0	26.0	30.4	22.9
	WCT (YOY)	0.0	0.0	17.5	4.0	0.0	0.0
	EBT	0.8	1.6	1.1	1.0	5.9	1.4
	EBT (YOY)	0.0	0.0	0.0	0.0	0.0	0.0
	BT	0.0	0.0	0.0	0.0	0.0	0.0
	UNK	0.0	0.0	0.0	0.0	0.7	8.3
	<b>TOTAL</b>	<b>16.4</b>	<b>11.7</b>	<b>30.6</b>	<b>31.0</b>	<b>37.0</b>	<b>32.7</b>
<b>Upper Eustache</b>		<b>9/17/05</b>	<b>7/27/06</b>	<b>9/16/06</b>	<b>7/27/07</b>	<b>7/28/08</b>	<b>8/17/09</b>
(TREATMENT)	WCT	13.7	17.3	5.1	4.3	8.3	32.3
	WCT (YOY)	0.0	0.0	0.9	0.0	0.0	0.0
	EBT	1.7	2.2	0.9	0.0	4.8	2.3
	EBT (YOY)	0.0	0.0	0.0	0.7	0.0	0.0
	BT	0.0	0.0	0.0	0.0	0.0	0.0
	UNK	0.0	0.0	0.0	0.0	0.0	0.0
	<b>TOTAL</b>	<b>15.4</b>	<b>19.5</b>	<b>6.9</b>	<b>5.0</b>	<b>13.1</b>	<b>34.6</b>



**Table 4. Changes in habitat variables over time on Eustache Creek (pre- to post-restoration) based on repeated measures ANOVA.**

Measure	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Width to Depth Ratio	204.984	1	204.984	14.868	.442
Percent Pool Habitat	54.179	1	54.179	11.537	.033
Residual Pool Depth	.000	1	.000	.353	.580
LWD per 100 meters	1743.665	1	1743.665	4.689	.233
LWD Median Diameter	.001	1	.001	.592	.155
Percent Fines on Pool Tails	266.704	1	266.704	7.783	.652

**Table 5. Habitat variable differences between reference and treatment reaches, based on repeated measures ANOVA.**

Habitat Metric	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Width to Depth Ratio	102.786	1	102.786	3.618	.197
Percent Pool	2122.281	1	2122.281	12.361	.072
Residual Pool Depth	.027	1	.027	19.000	.049
LWD per 100m	30085.060	1	30085.060	66.524	.015
LWD med. diameter	.009	1	.009	17.286	.053
Percent Fines	96.901	1	96.901	12.265	.073

**Table 6. Changes in fish densities over time on Eustache Creek (pre- to post-restoration) based on repeated measures ANOVA.**

<b>Measure</b>	<b>Type III Sum of Squares</b>	<b>Degrees of freedom</b>	<b>Mean Square</b>	<b>F</b>	<b>Sig.</b>
Total Fish Density	373.507	1	373.507	14.288	.039
Total WCT Density	95.277	1	95.277	8.793	.050
Adult WCT Density	118.125	1	118.125	10.573	.039
Total EBT Density	65.409	1	65.409	2.315	.270
Adult EBT Density	29.870	1	29.870	60.065	.043

**Table 7. Fish density differences between reference and treatment reaches, based on repeated measures ANOVA.**

<b>Measure</b>	<b>Type III Sum of Squares</b>	<b>Degrees of freedom</b>	<b>Mean Square</b>	<b>F</b>	<b>Sig.</b>
Total Fish Density	257.683	1	257.683	.702	.490
Total WCT Density	132.573	1	132.573	.988	.425
Adult WCT Density	43.867	1	43.867	.714	.487
Total EBT Density	13.869	1	13.869	.056	.835
Adult EBT Density	4.805	1	4.805	.033	.873

**Table 8. Relationships between habitat variables and total fish density, based on univariate ANOVA. Percent pool habitat is the most strongly correlated with total fish density, but is not significant.**

Habitat Metric	Type III Sum of Squares	Degrees of freedom	Mean Square	F	Sig.
Width to Depth Ratio	9.519	1	9.519	.106	.758
Percent Pool Habitat	226.451	1	226.451	2.931	.118
Residual Pool Depth	96.629	1	96.629	1.071	.325
LWD per 100 m	36.143	1	36.143	.375	.554
LWD Median Diameter	57.145	1	57.145	.607	.454
Percent Fines on Pool Tails	83.844	1	83.844	.916	.361

**Figure 1a. Project Site Location in the Ninemile Watershed. (Source: Eustache Stream Rehabilitation Design Document, Lolo, NF, 2006).**

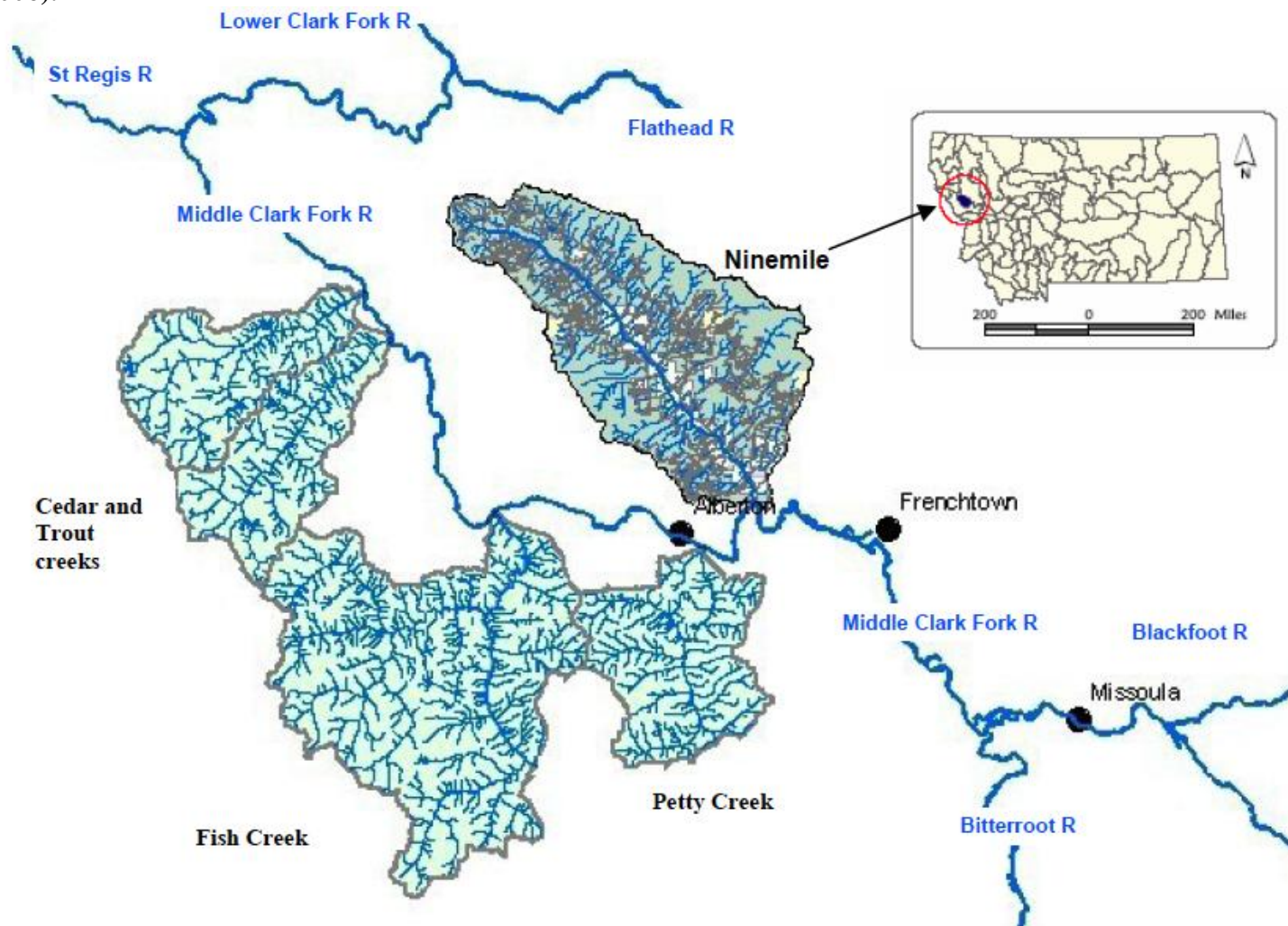
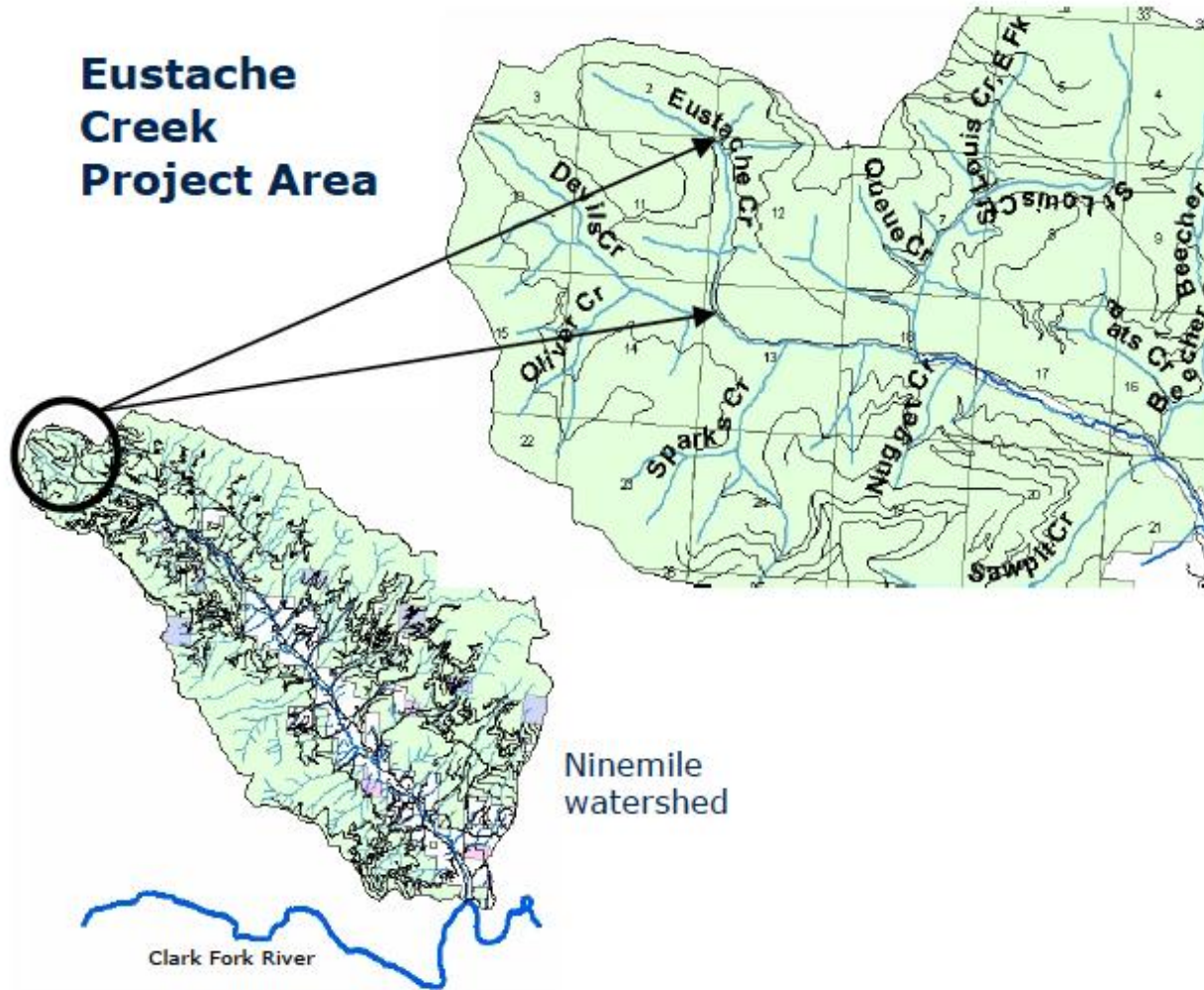
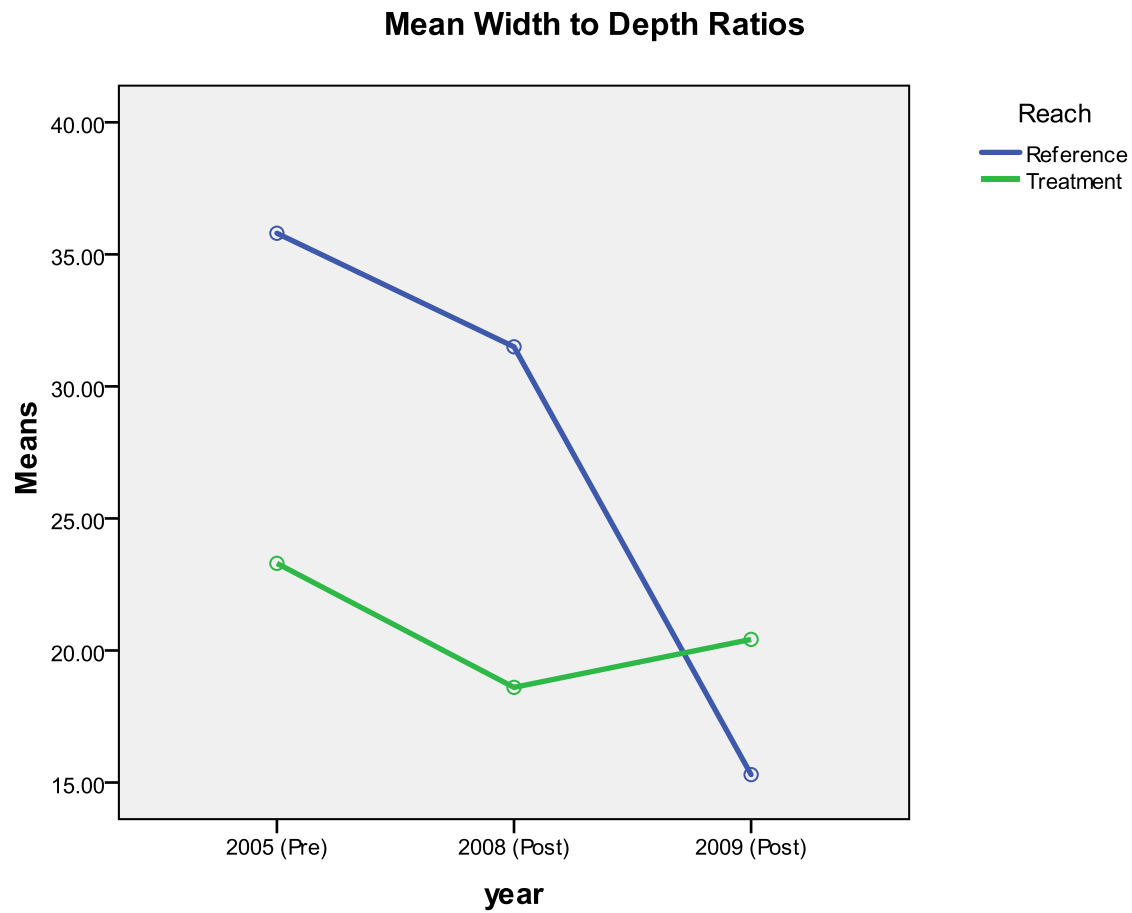


Figure 1b. Project Site Location.



**Figure 2. Mean width to depth ratios for Devil's (Reference) and Eustache (Treatment) Creeks, 2005-2009 (no data for 2007).**



**Figure 3. Mean percent pool habitat for Devil's (reference) and Eustache (treatment) Creeks, 2005-2009.**

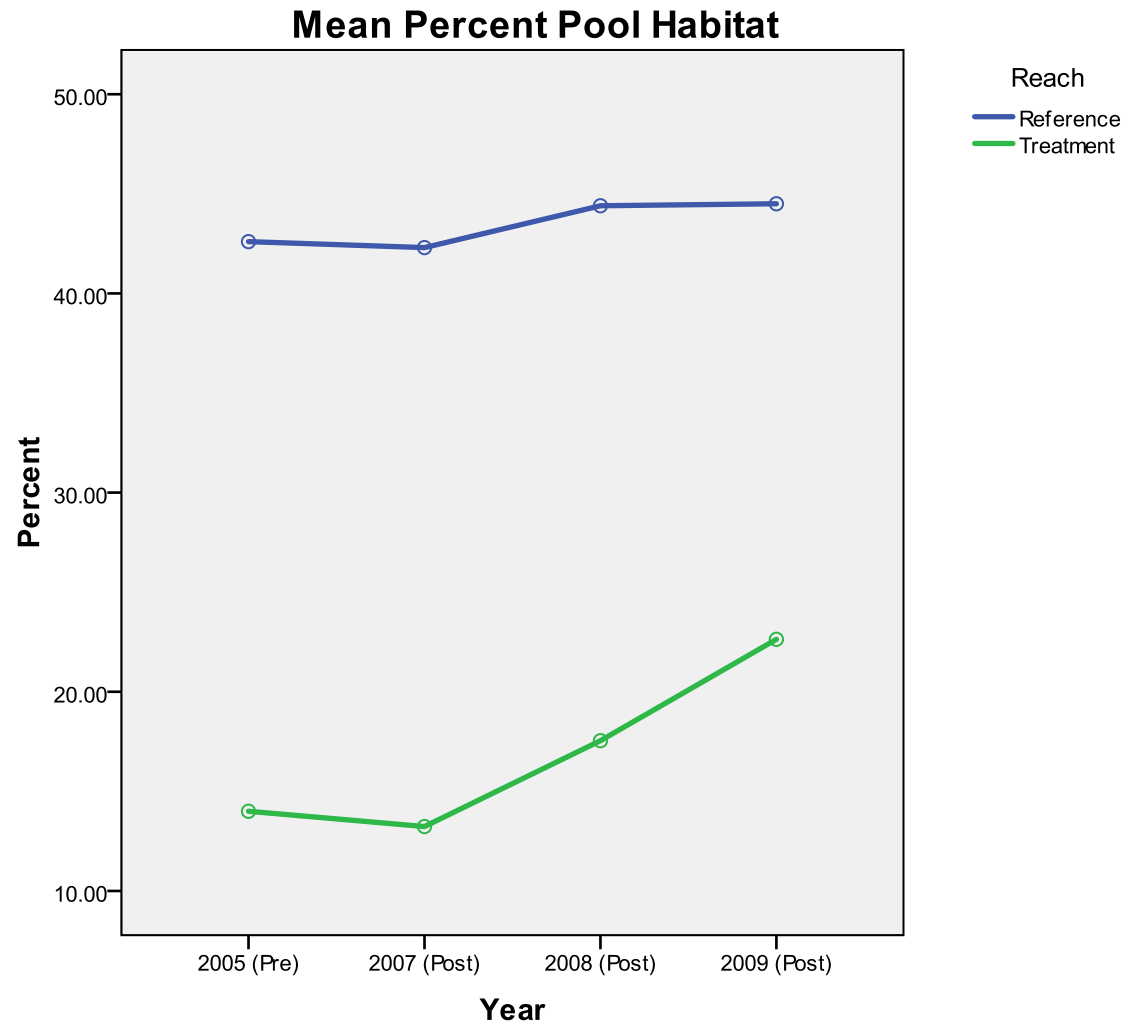
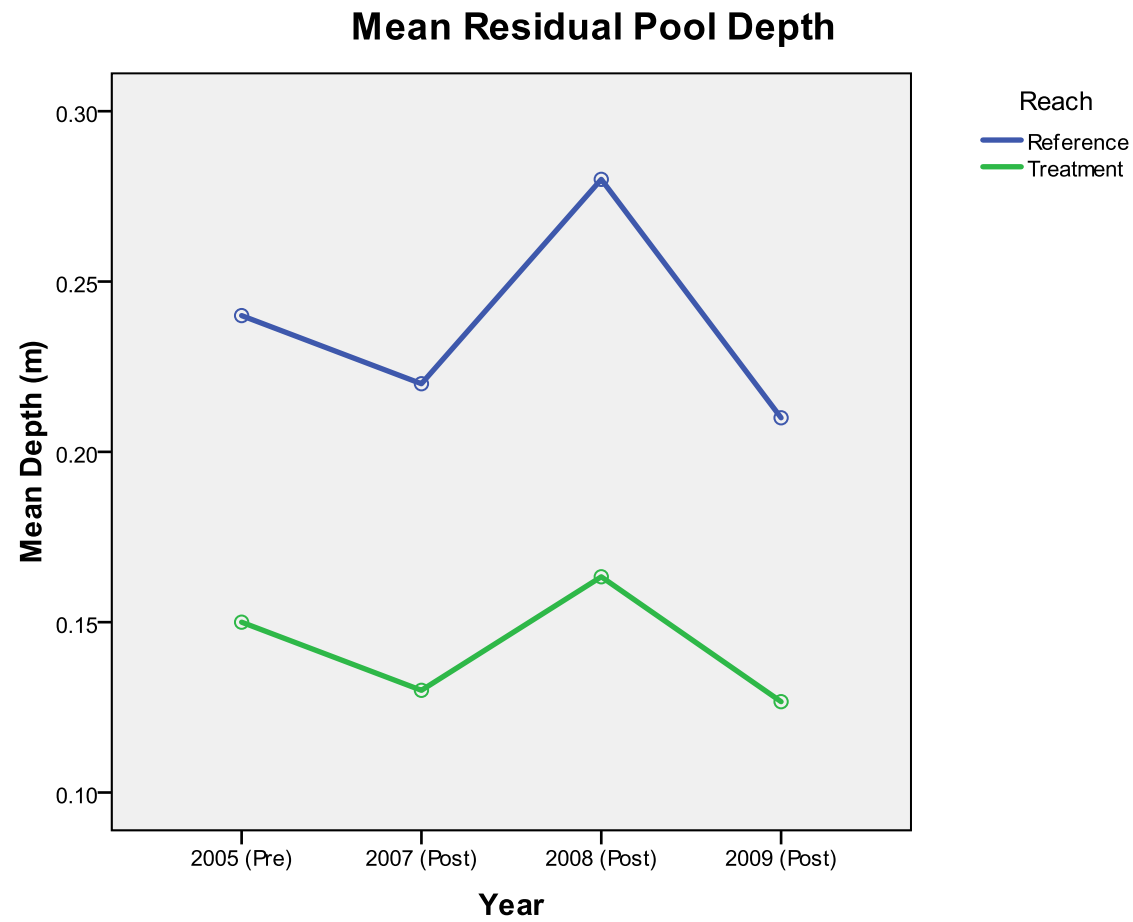


Figure 4. Mean residual pool depth in Devil's (reference) and Eustache (treatment) Creeks, 2005-2009.





**Figure 5. Mean LWD per 100 meters in Devil's (reference) and Eustache (treatment) Creeks, 2005-2009.**

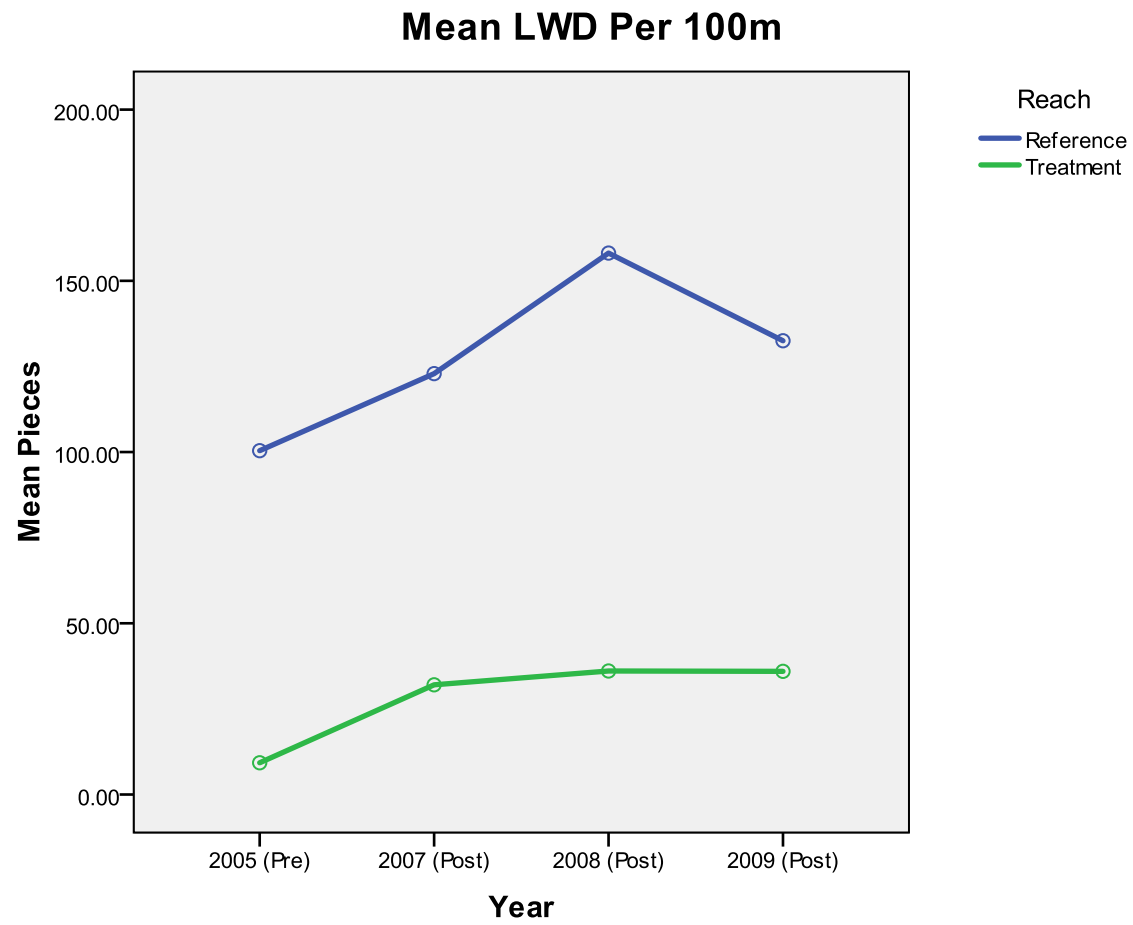


Figure 6. Mean LWD median diameter in Devil's (reference) and Eustache (treatment) Creeks, 2005-2009.

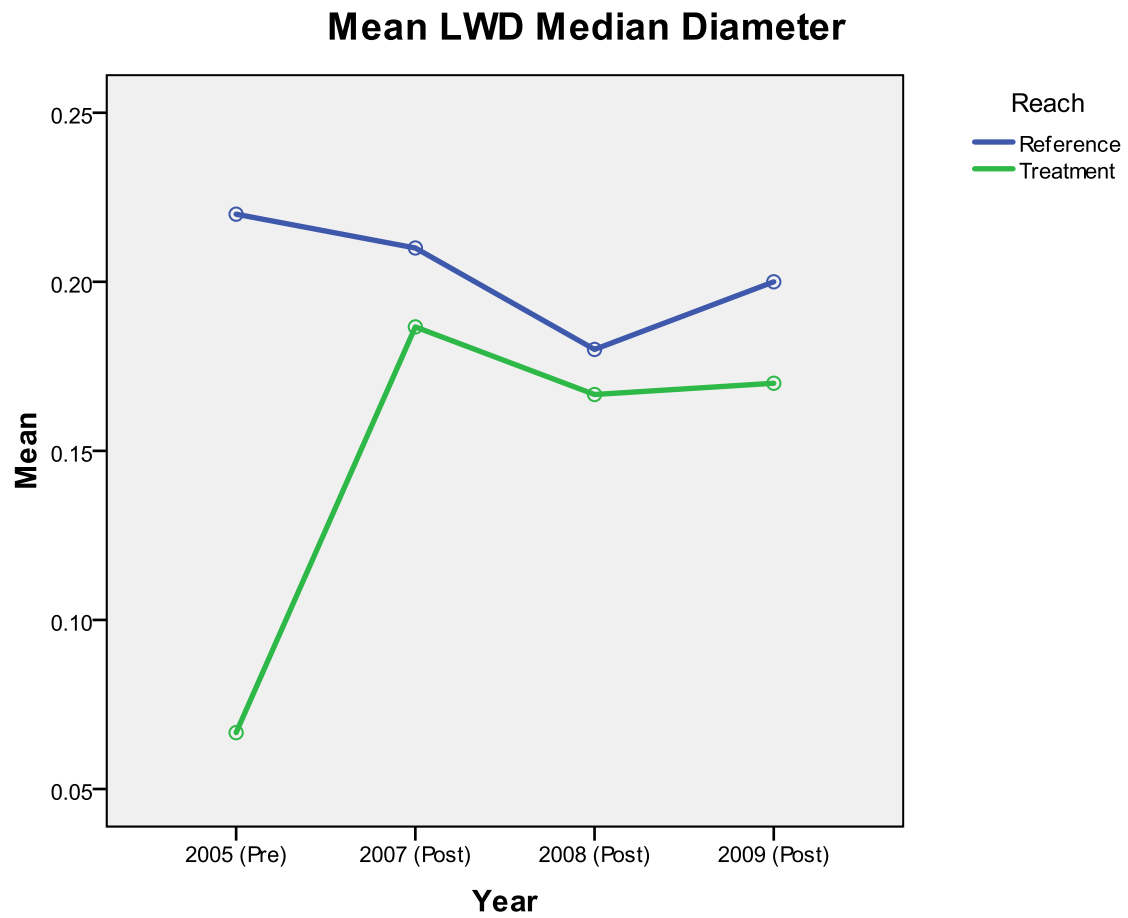
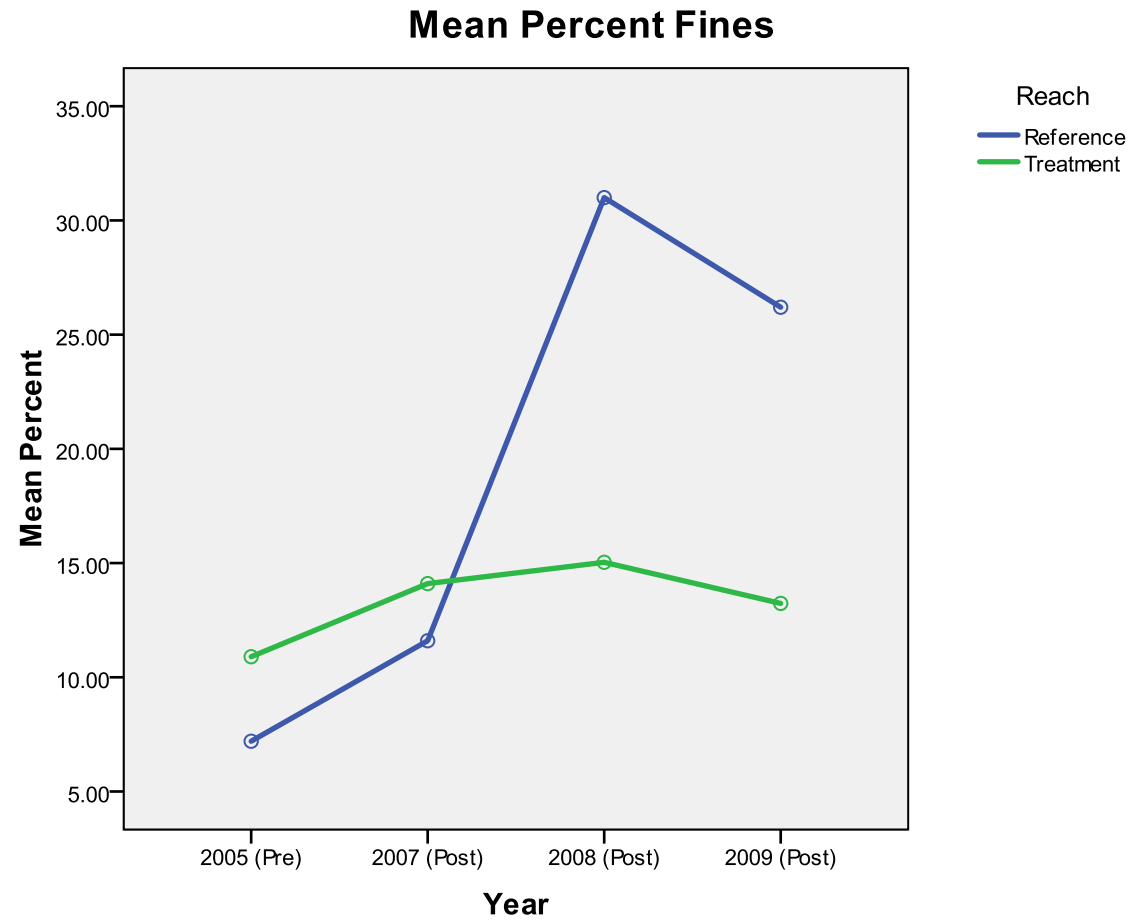
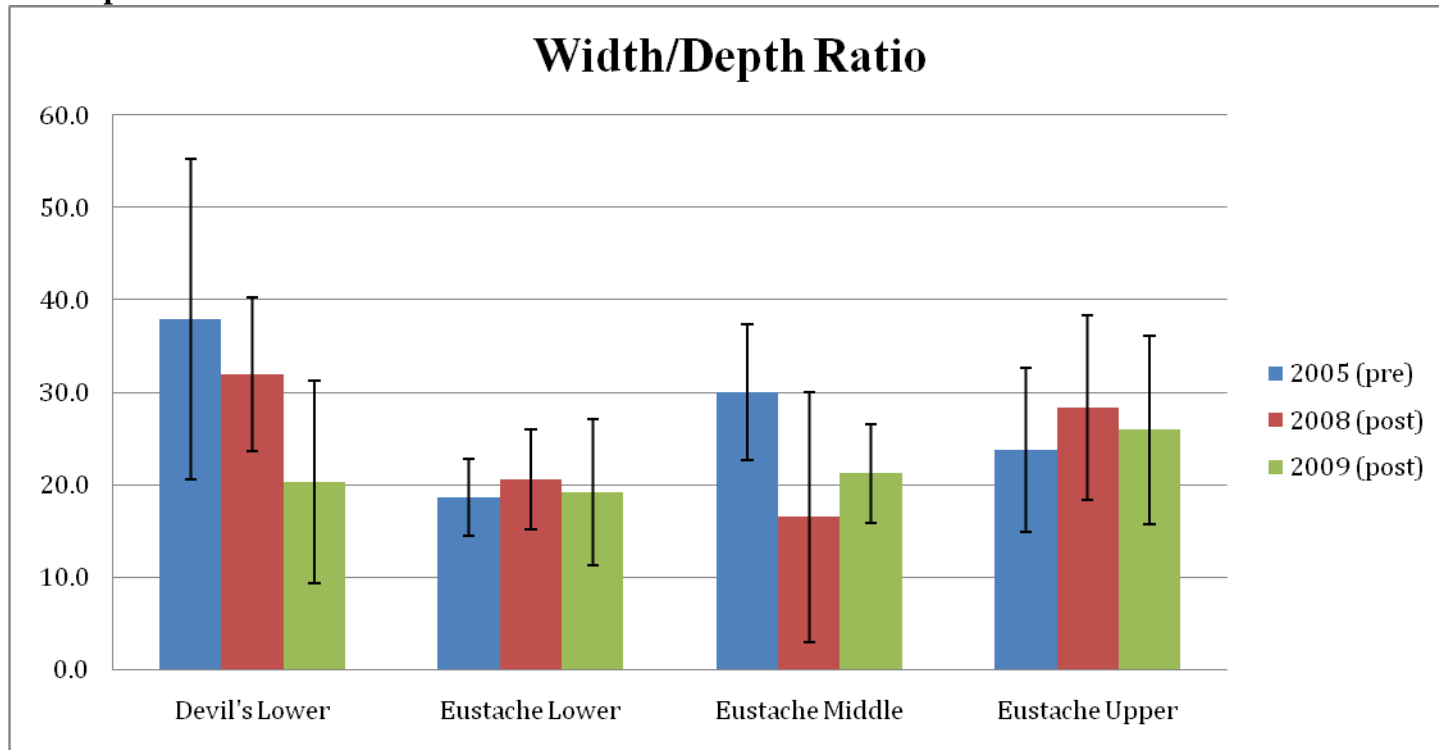


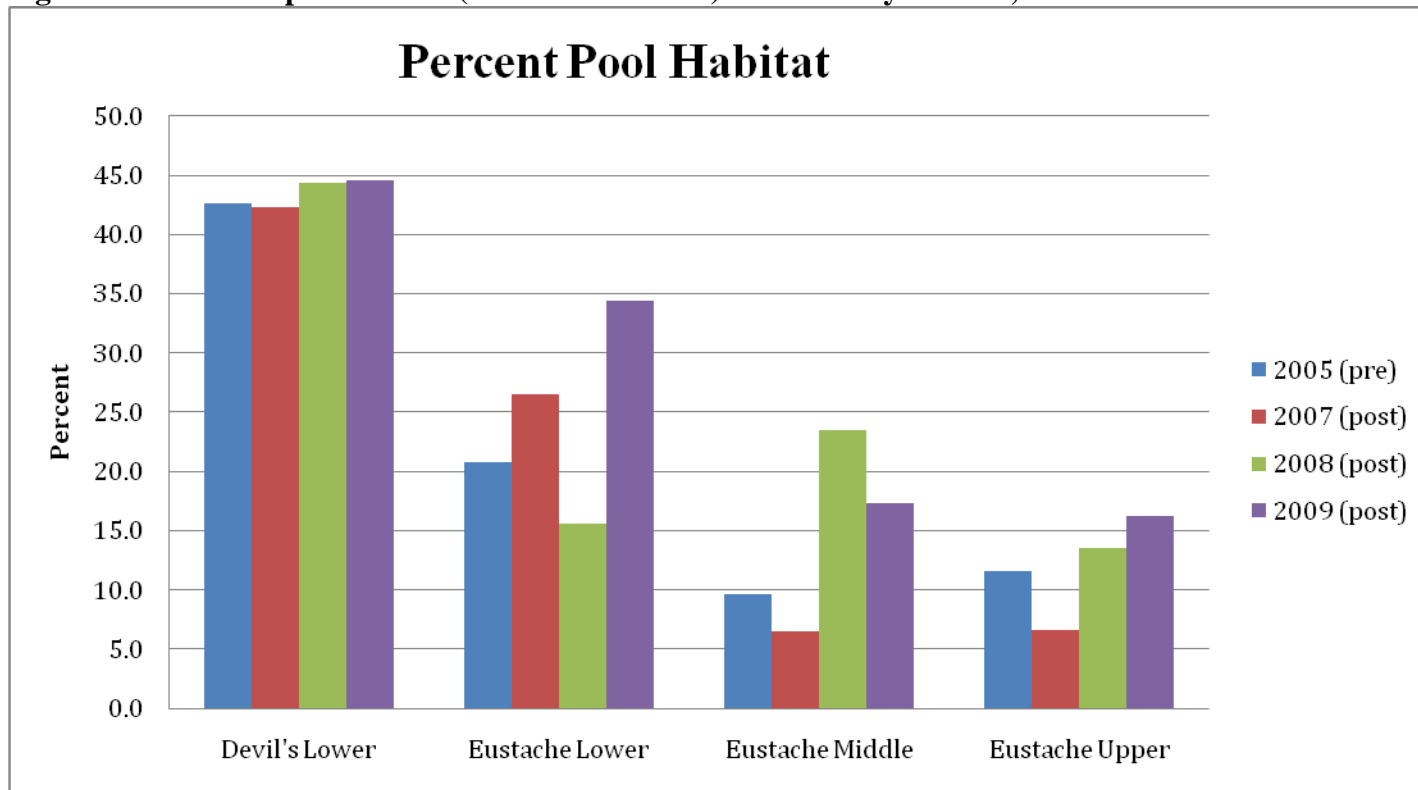
Figure 7. Mean percent fine sediment in pool tails in Devil's (reference) and Eustache (treatment) Creeks, 2005-2009.



**Figure 8. Fast water width to depth ratios for Devil's and Eustache Creeks, 2005-2009. (no fast water data for 2007). Error bars represent standard deviation.**



**Figure 9. Percent of pool habitat (based on site area) within study reaches, 2005-2009.**



**Figure 10. Residual pool depths for Devil's and Eustache Creeks, 2005-2009. Error bars represent standard deviation.**

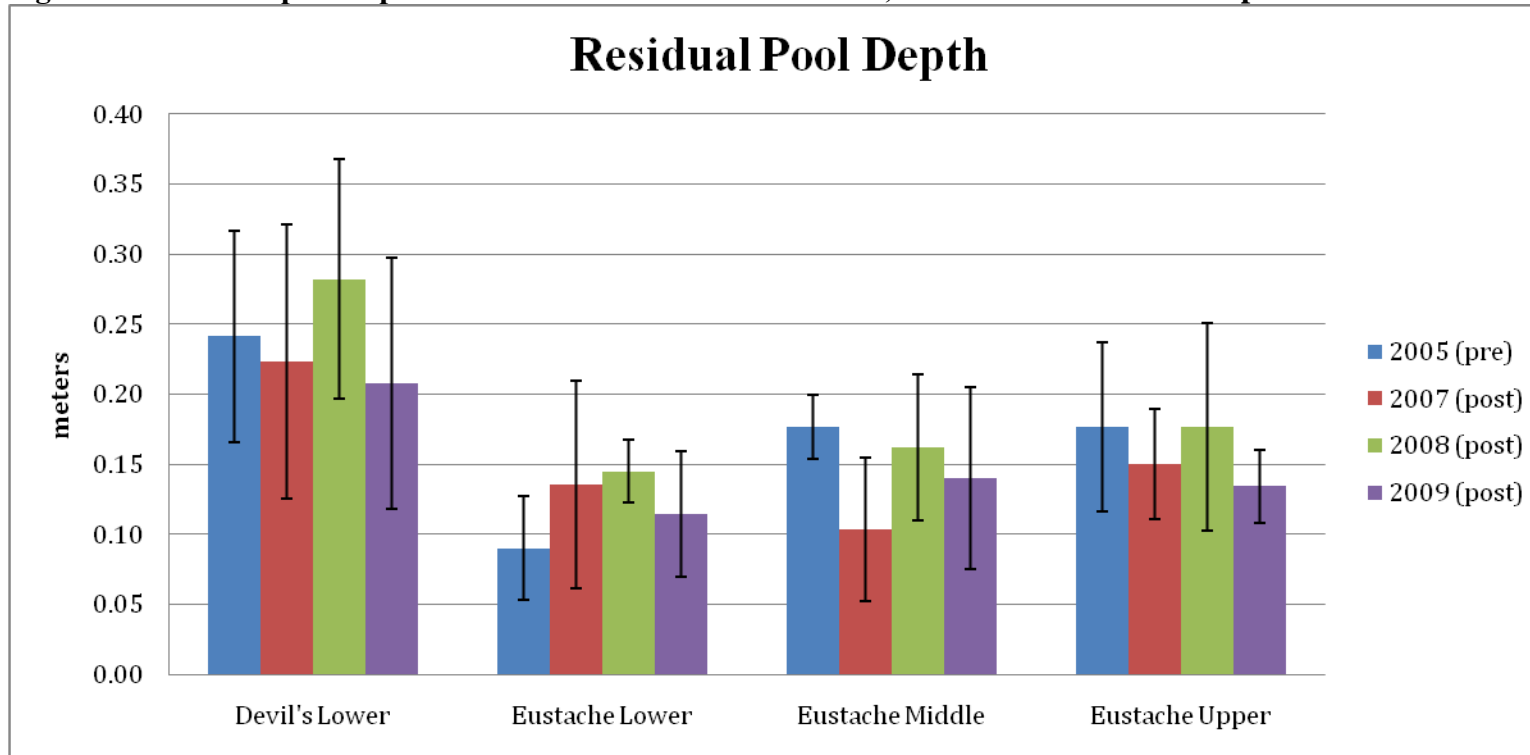


Figure 11. LWD frequency for Devil's and Eustache Creeks (# per 100 m), 2005-2009.

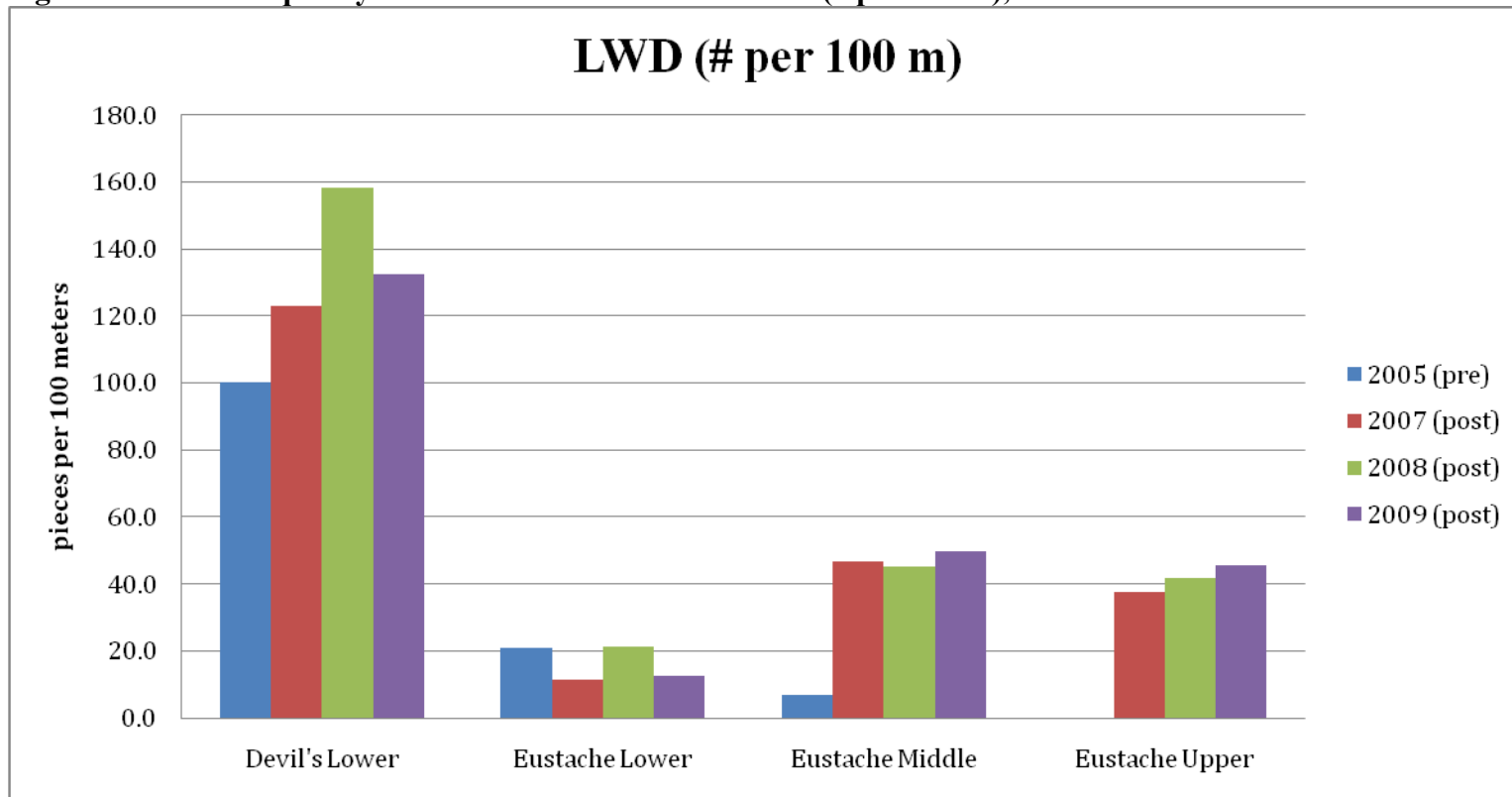


Figure 12. LWD median diameter for Devil's and Eustache Creeks, 2005-2009. Error bars based on standard deviation.

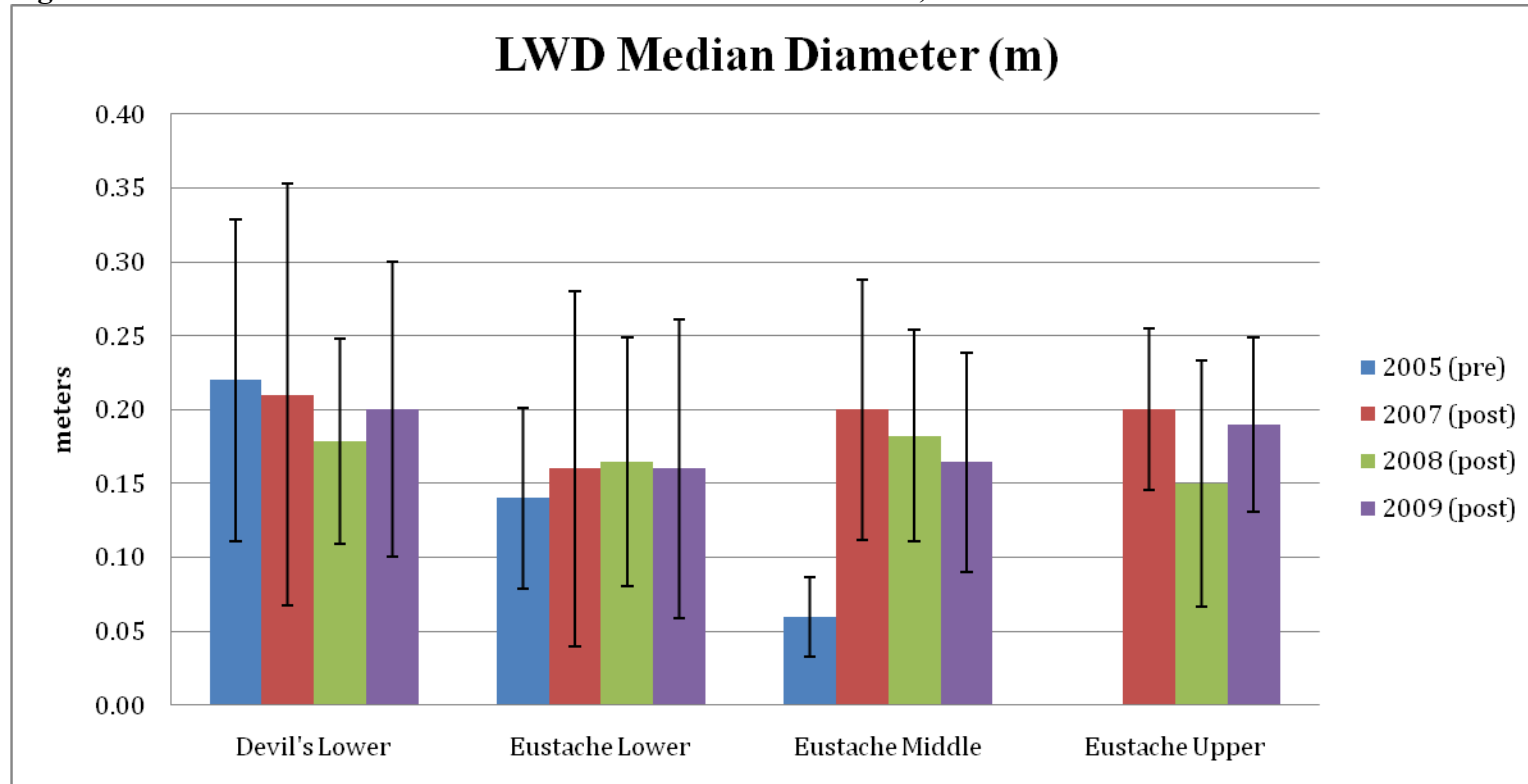




Figure 13. Average percent fine sediment in pool tails (<6 mm), Devil's and Eustache Creeks, 2005-2009.

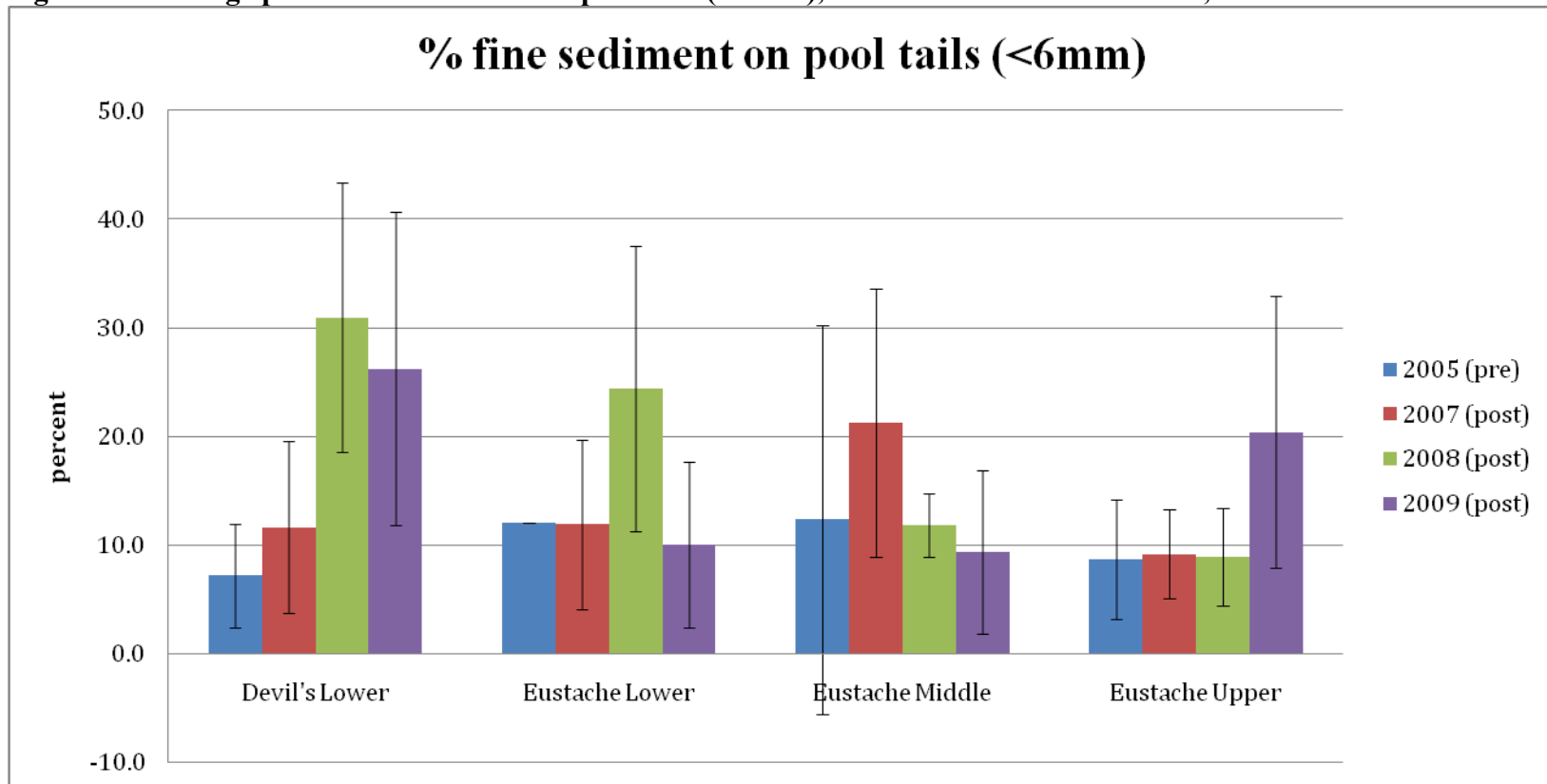


Figure 14. Peak flows for Clark Fork River, below Missoula, MT, 2005-2010. (Source: USGS National Water Information System, 2010)

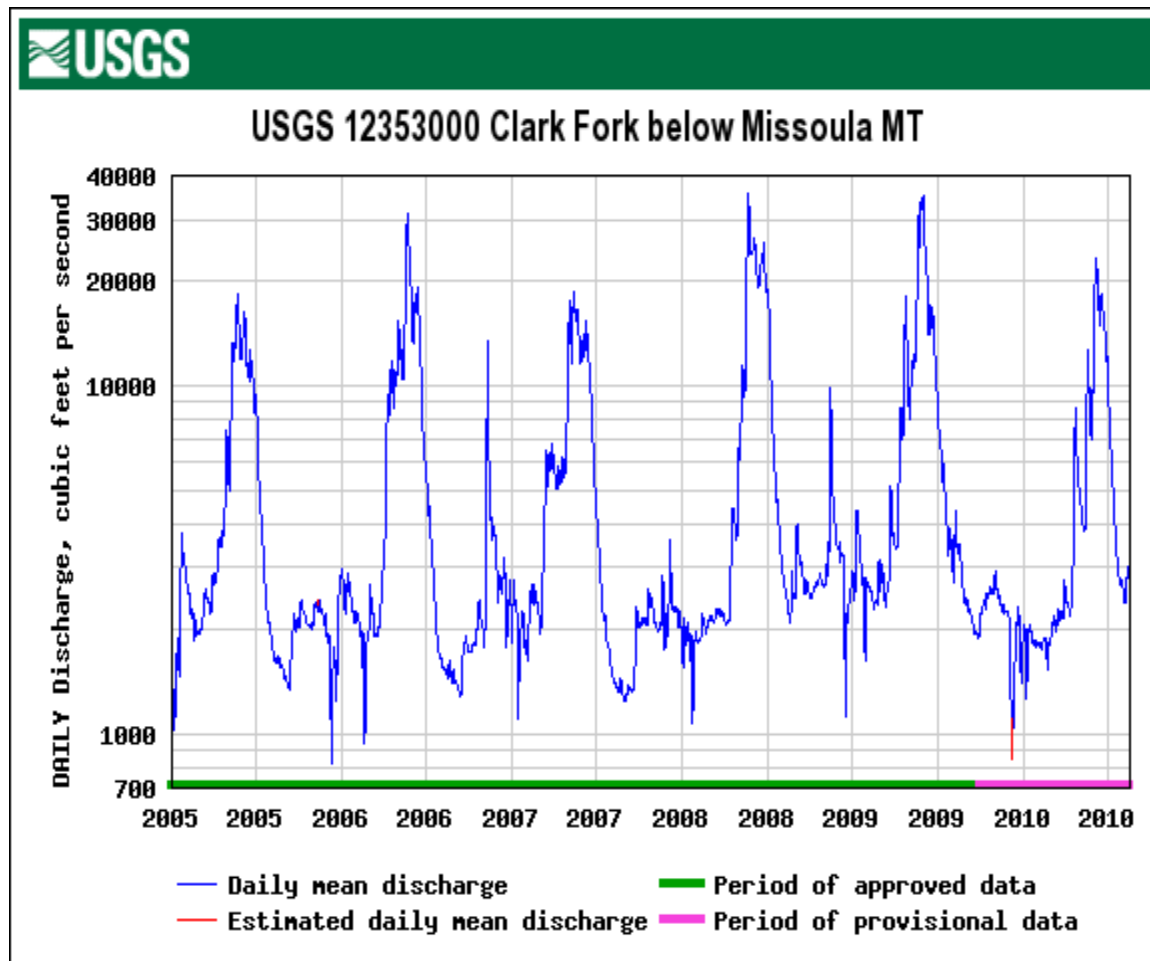


Figure 15. Mean total fish density in Devil's (reference) and Eustache (treatment) reaches, 2005-2009.

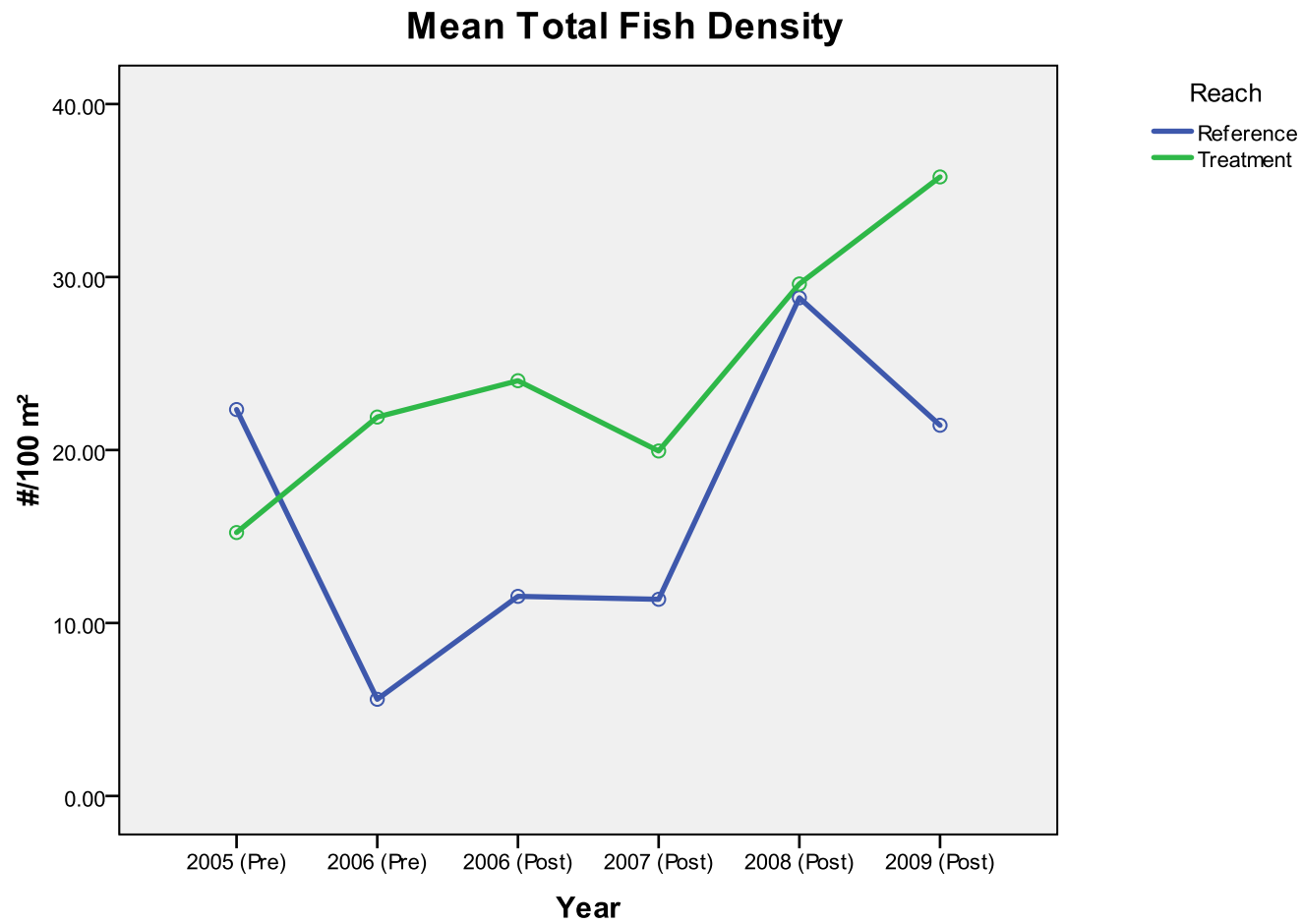


Figure 16. Mean Total WCT density in Devil's (reference) and Eustache (treatment) reaches, 2005-2009.

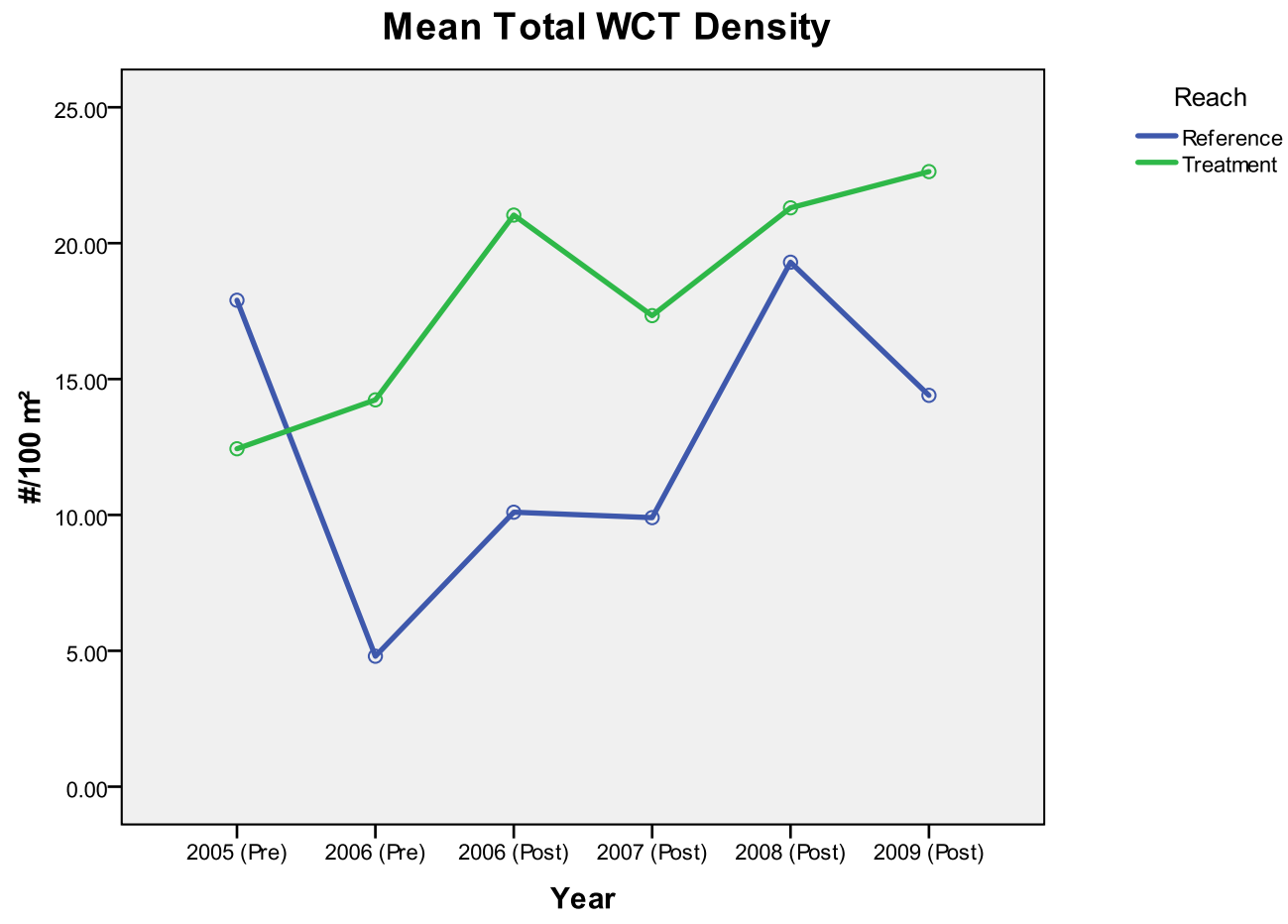


Figure 17. Mean Adult WCT density in Devil's (reference) and Eustache (treatment) reaches, 2005-2009.

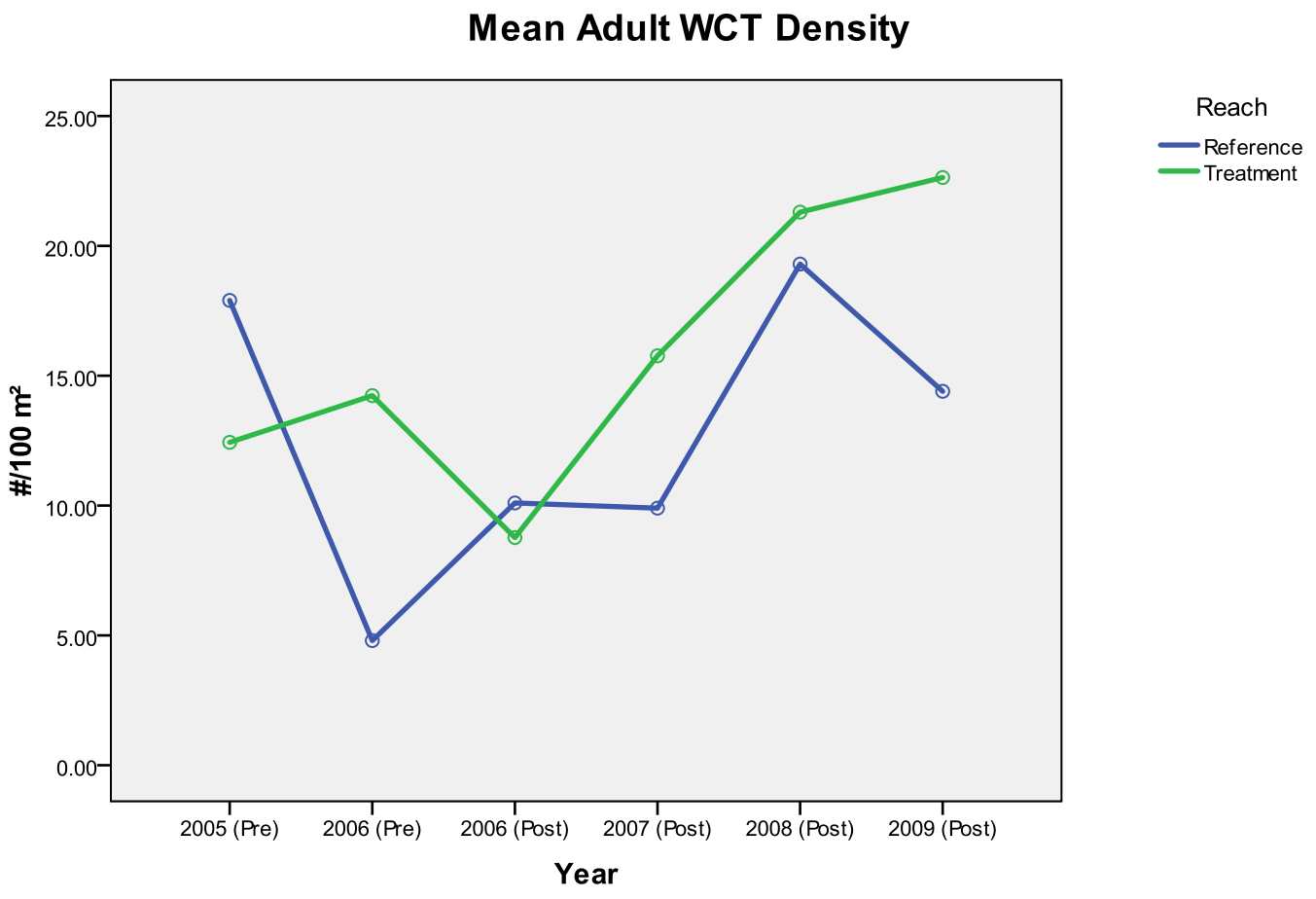
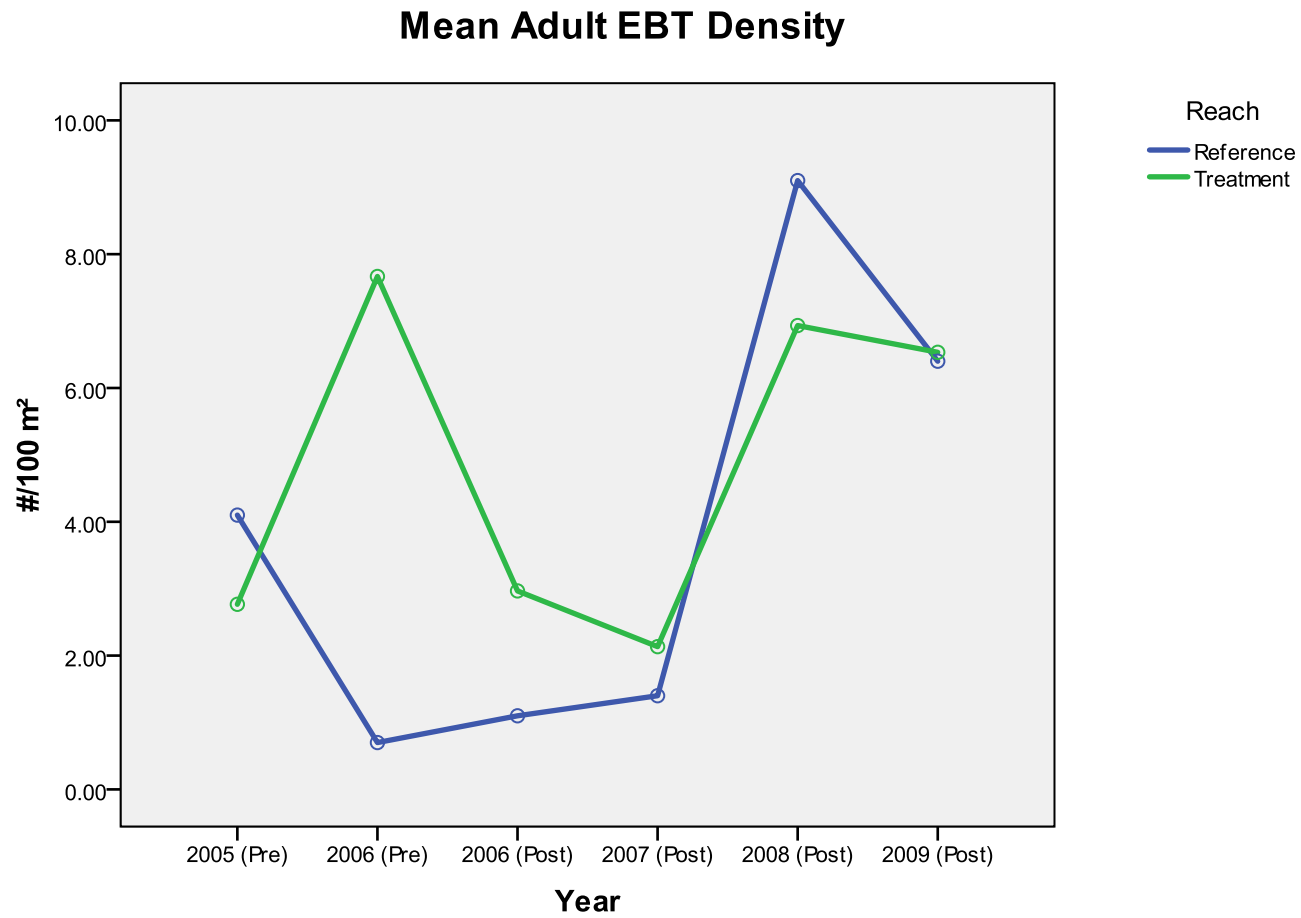


Figure 18. Mean Adult EBT density in Devil's (reference) and Eustache (treatment) reaches, 2005-2009.



**Figure 19. Total fish densities (#/100m<sup>2</sup>) in Devil's (Reference) and Eustache (Treatment) reaches, 2005-2009.**

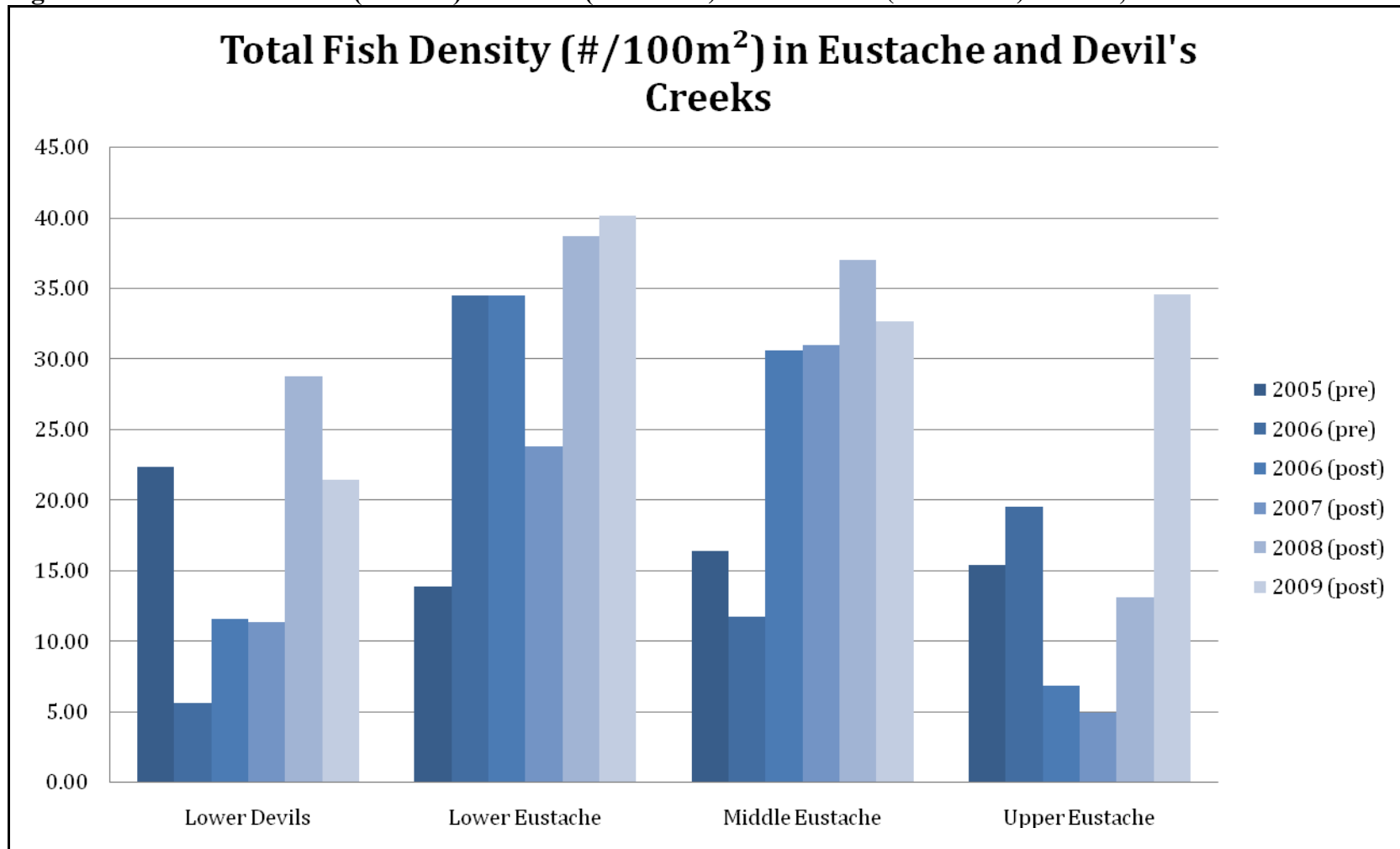


Figure 20. Total WCT densities for Eustache and Devil's reaches, 2005-2009.

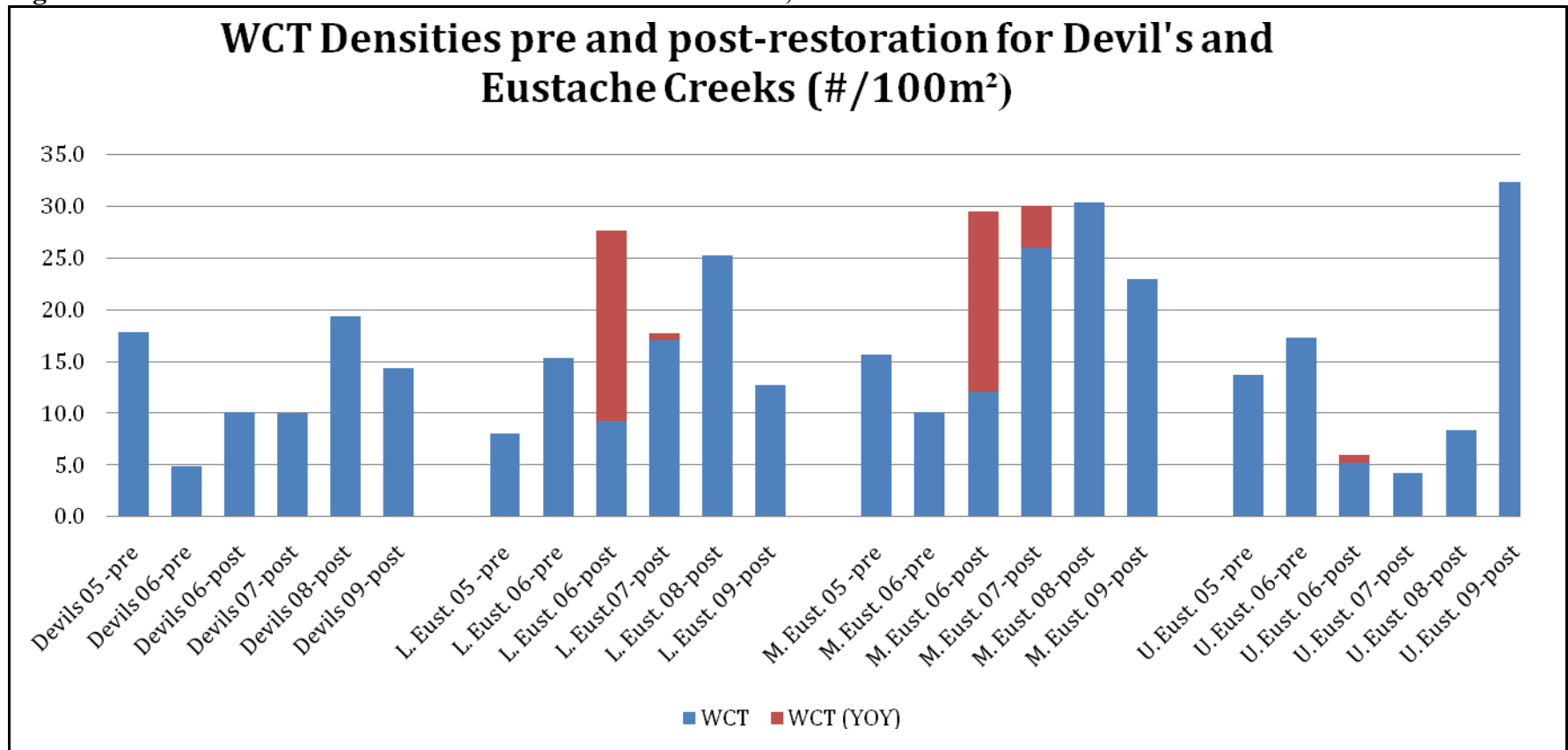
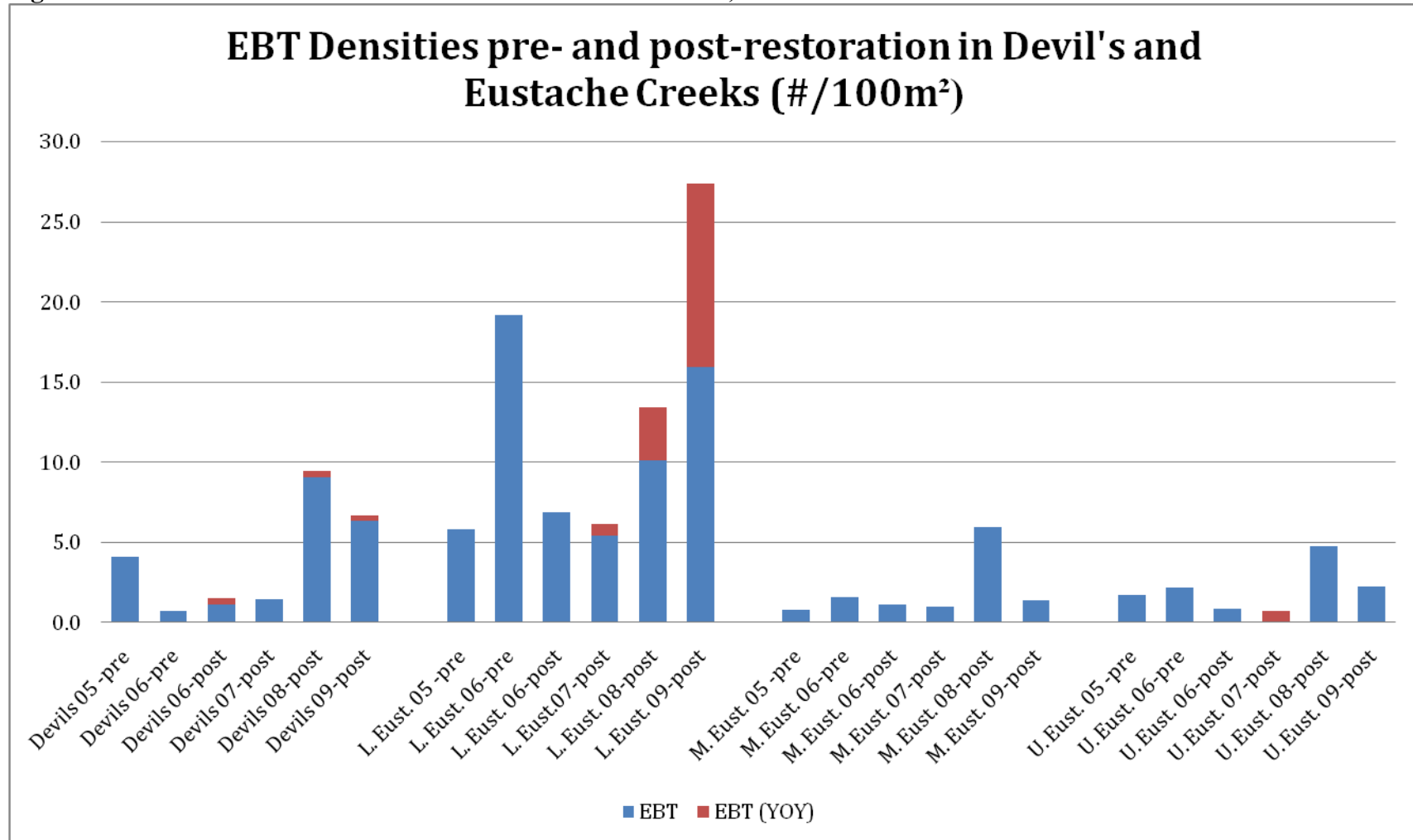
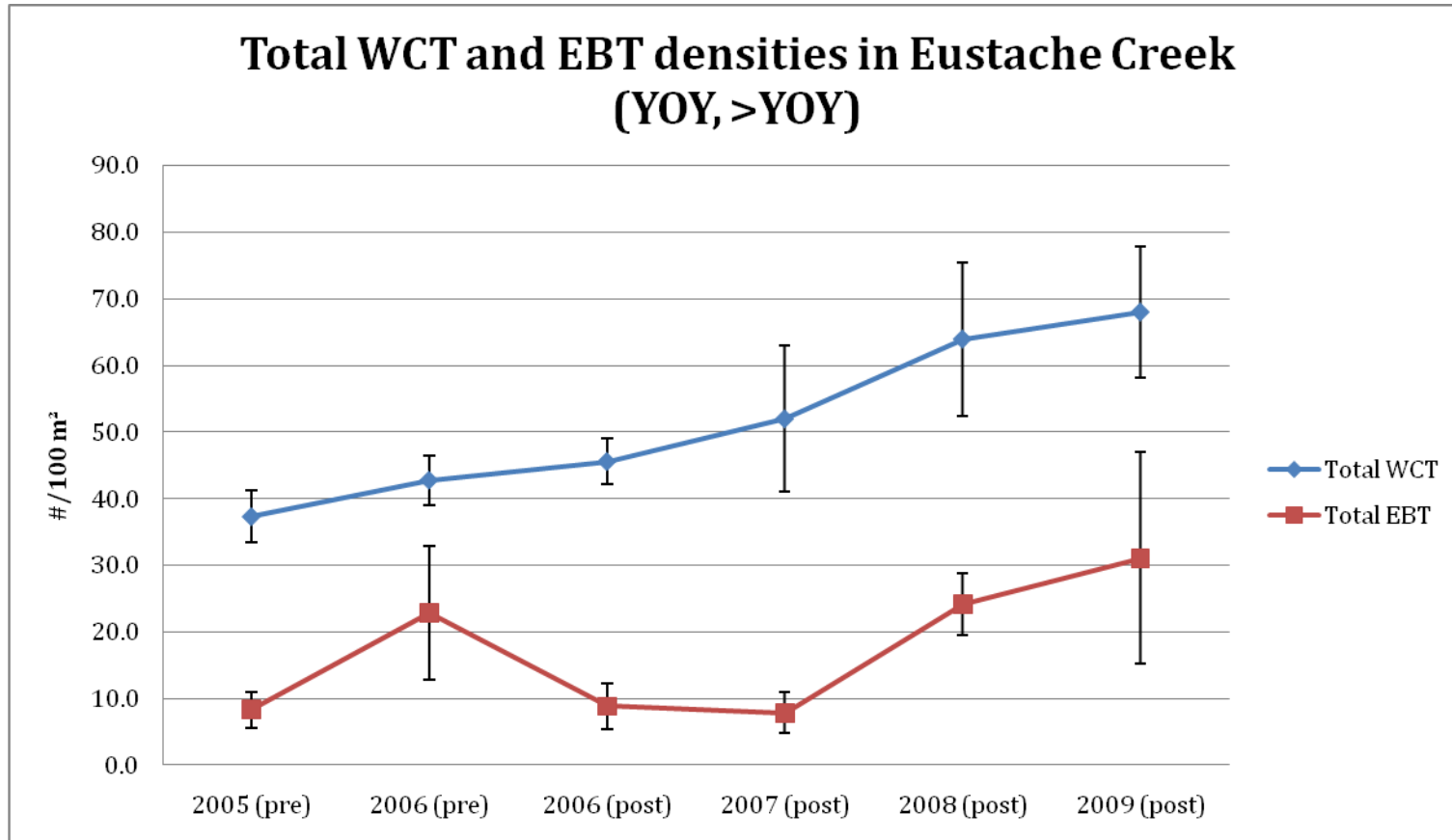




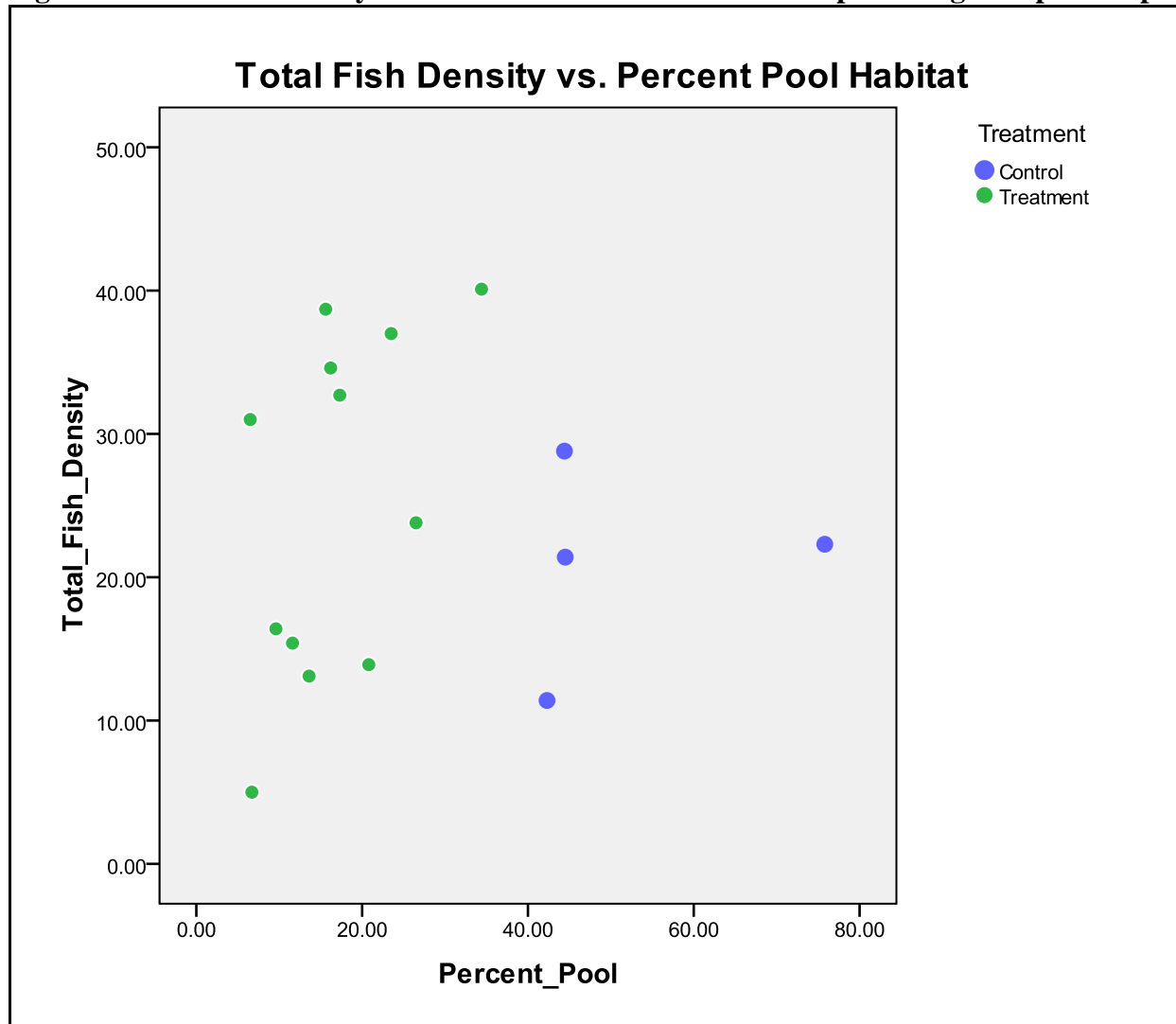
Figure 21. Total EBT densities for Eustache and Devil's reaches, 2005-2009.



**Figure 22. Total WCT and EBT densities (YOY and older) in Eustache Creek, 2005-2009. Error bars represent standard deviation.**



**Figure 23. Total fish density in reference and treatment reaches plotted against percent pool habitat.**



## APPENDIX A – PIBO Habitat Data Collection Protocol (Heitke et al. 2007)

### Pool Length and Residual Pool Depth

#### Objectives:

- Quantify the relative length and frequency of pool habitat in each reach.
- Determine the average residual depth of pools.

#### Pool Criteria: Scour, Dam, & Plunge Pools

Sample every pool within the reach that meets the following criteria for low flow conditions:

1. Pools are depressions in the streambed that are concave in profile, laterally and longitudinally.
2. Pools are bounded by a head crest (upstream break in streambed slope) and a tail crest (downstream break in streambed slope).
3. Only consider main channel pools where the thalweg runs through the pool, and not backwater pools.
4. Pools span at least 50% of the wetted channel width at any location within the pool.
5. Maximum pool depth is at least 1.5 times the pool tail depth.

#### Pool Criteria: Scour & Dam Pools

6. Pool length, measured along the thalweg, is greater than the pool's width, measured perpendicular to the thalweg, at the widest point.

#### Pool Criteria: Plunge Pools

7. Pool length, measured along the thalweg, is less than the pool's width, measured perpendicular to the thalweg, at the widest point.
8. The thalweg drops vertically over an obstruction (log, boulder, etc) at the pool's head crest.
9. Pool's maximum depth must be within 0.5m of the obstruction.

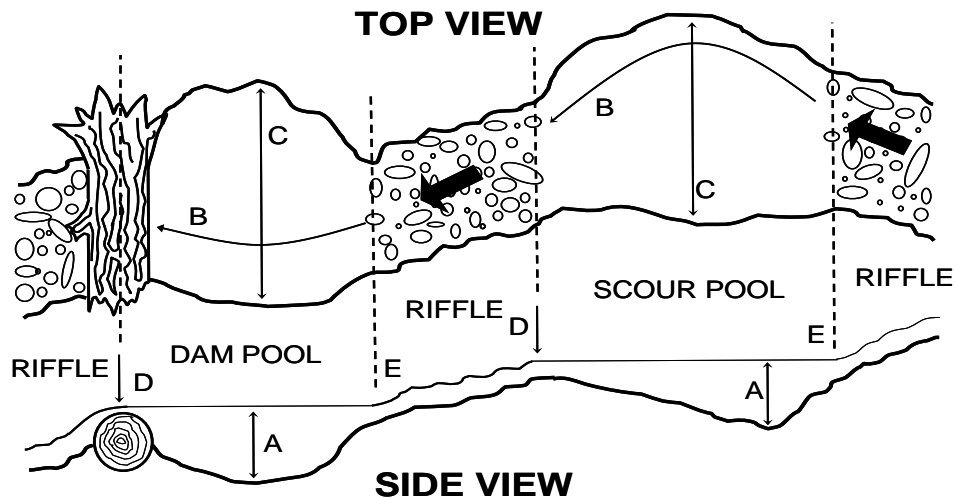
Note: If a pool meets criteria 8 & 9 above, but not 7, then classify the pool as 'scour'.

Note: When islands are present, describe the habitat unit in the main channel regardless of the habitat type in the side channel. Include only the wetted portion of the main channel for width criteria (# 4 above and # 5 below).

#### Sampling Method:

1. Measure the pool length (nearest 0.1m), maximum depth (nearest cm), and pool tail crest depth (nearest cm) for each pool (Figure 1) that meets the above criteria.
2. Measure pool length along the thalweg between the head crest and tail crest.
3. The maximum depth represents the deepest point in the pool and is found by probing with a depth rod until the deepest point is located. NOTE: estimate maximum depth if it is unsafe to measure.
4. The pool tail crest depth is measured at the maximum depth along the pool tail crest and is normally (but not always) at the thalweg.
5. Record the pool type.
  - a. Full-channel pool – Concave shape of the pool at any location is > 90% of the wetted channel.
  - b. Partial-channel pool – Concave shape of the pool at any location is between 50 and 90% of the wetted channel.
6. Record the pool's formation: scour, dam, or plunge. Consider a pool dammed if a wood obstruction is backing up water and forming the pool tail crest.
7. Measure the pool tail crest depth on dammed pools along the top of the obstruction if **all** flow is going over the obstruction. Conversely, measure to the streambed, just upstream, if some of the water is observed flowing under the obstruction.

Note: When considering whether to lump or split two potential pools, and both habitat units meet the above criteria for pools, consider them two pools if the pool tail depth of the upstream pool is  $\leq 10\text{cm}$  of the depths from other pools within the reach. Conversely, consider it one pool if that pool tail depth is  $>10\text{cm}$  deeper than other pools within the reach.



**Figure 1.** Top and side views of scour and dam pools. Max depth (A), length (B), width (C), tail crest (D) and head crest (E) are labeled.

### Percent Surface Fines on Pool Tails

#### Objective:

- Quantify the percentage of fine sediments on the pool tail surface of scour pools and plunge pools.

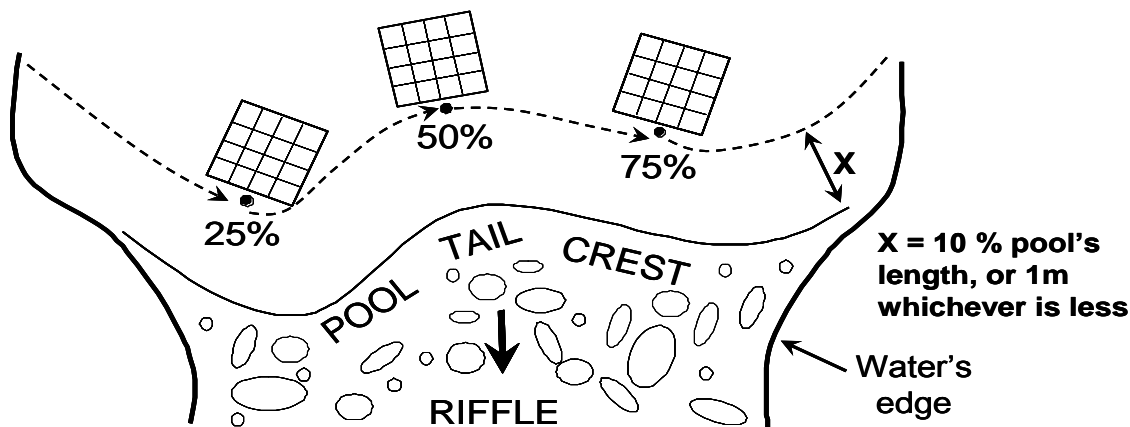
#### Where to take measurements:

1. Collect measurements in the first ten scour and plunge pools of each reach beginning at the downstream end. Exclude dam pools.
2. Sample within the wetted area of the channel.
3. Take measurements at 25, 50, and 75% of the distance across the wetted channel, following the shape of the pool tail.
4. Take measurements upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less.
5. Locations are estimated visually.

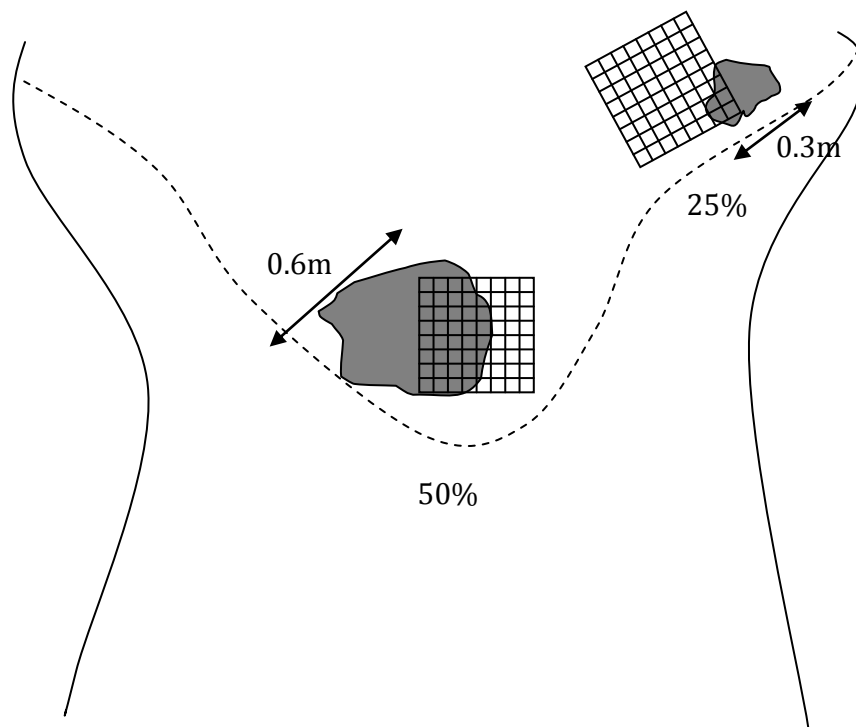
#### Sampling method:

1. Assess surface fines using a 14 x 14 inch grid with 49 evenly distributed intersections. Include the top right corner of the grid and there are a total of 50 intersections.
2. Take 3 measurements per pool.

- a. Place the bottom edge of the grid upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less (Figure 2).
  - b. Place the center of the grid at 25, 50, and 75% of the distance across the wetted channel, making sure the grid is parallel to and following the shape of the pool tail crest.
  - c. If a portion of the fines grid lands on substrate 512 $\mu$ m or larger in size (b-axis), record the intersections affected as non-measurable intersections (Figure 3).
3. Record the number of intersections that are underlain with fine sediment < 6 mm in diameter at the b-axis. Place a 6 mm wide piece of electrical tape on the grid and use this to assess the particle size at each intersection.
  4. Aquatic vegetation, organic debris, roots, or wood may be covering the substrate. First attempt to identify the particle size under each intersection. If this is not possible, then record the number of non-measurable intersections.



**Figure 2.** Location and orientation of pool tail fines grids relative to the pool tail crest



**Figure 3.** In this figure, all intersections of the fines grid at the 25% placement will be counted and recorded. For the 50% placement, the intersections of the fines grid that land on the boulder (substrate  $\geq 512\text{mm}$ ) will be recorded as non-measurement.

### Large Wood

#### Objective:

- Quantify the number and size of large wood pieces that are present within the bankfull channel.

#### Sampling Method:

1. In order to be counted, each piece must meet the following criteria:
  - a. Each piece must be greater than 1 meter in length and at least 10 cm in diameter one-third of the way up from the base. For pieces that are not evenly round, measure the widest axis.
  - b. Only include standing trees that lean within the bankfull channel if they are dead. Dead trees are defined as being devoid of needles or leaves, or where all of the needles and leaves have turned brown. Consider it living if the leaves or needles are green.  
*Note: Use caution when assessing the condition of a tree or fallen log. Nurse logs can appear to have living branches when seedlings or saplings are growing on them.*
  - c. Wood that is embedded within the streambank is counted if the exposed portion meets the length and width requirements.
  - d. Do not count a piece if only the roots (but not the stem/bole) extend within the bankfull channel.
  - e. Some pieces crack or break when they fall. Include the entire length when the two pieces are still touching at any point along the break. Treat them separately if they are no longer touching along the break.
2. Large wood within the riparian area is separated into two categories.
  - a. Category 1 – Pieces in which a portion of the stem extends below the bankfull elevation, thereby interacting with the active channel at bankfull flows.

- b. Category 2 – Pieces in which a portion of the stem extends over the bankfull channel, but lies above the bankfull elevation.
3. Record the piece number, category 1 or 2, estimated length (nearest 10 cm), and estimated diameter (nearest cm) of all qualifying pieces in the reach. The same person will make all estimates for a given reach. Record the name of the estimator on the datasheet.
4. Also measure the length (nearest 10 cm) and diameter (nearest cm) of the first 10 pieces beginning at the downstream end of the reach. The person estimating should not be made aware of the measured value.
5. An additional subset of pieces will be measured at sites with more than 10 pieces.
  - a. For sites estimated to have between 11 and 100 pieces, measure the first ten pieces, then starting at the 11<sup>th</sup> piece only measure every 5<sup>th</sup> piece.
  - b. For sites estimated to have over 100 pieces, measure the first ten pieces, then starting at the 11<sup>th</sup> piece only measure every 10<sup>th</sup> piece.
6. Measure the length of the main stem and not branches or roots. Begin measurements where the roots attach to the base of the stem when the roots are still connected.
7. Do not measure the length and/or diameter of standing dead trees, pieces buried in log jams, or other pieces that are unsafe to measure. If that piece was one that required measuring, record the estimated length/diameter and leave the measured length and/or diameter blank. Then measure the next required piece, maintaining established interval (see #5 above).
8. Begin counting from the BR to the TR, and from the bottom up when pieces are stacked on each other.
9. Large wood in isolated side channels, pools or depressions <bankfull elevation is not measured.
10. Tertiary channels: Code qualifying large wood located in tertiary channels. A tertiary channel begins and ends at the locations it becomes separated from the main channel by an island  $\geq$ bankfull.
  - a. If a piece of wood is in both the main channel and tertiary channel, don't code as tertiary.



**APPENDIX B – PIBO Fish Habitat Monitoring Data Sheets (Source: Lolo National Forest)**

<b>POOL DATA</b>					
Stream Name:		Reach ID:		Date:	
Pool #	Pool Tail Depth (cm)	Maximum Depth (cm)	Length (m)	Pool Type (Full or Partial )	Formation (Scour, Dam, or Plunge)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					

POOL-TAIL FINES									
Pool #	Grid 1			Grid 2			Grid 3		
	# Fines < 2mm	# Fines < 6mm	# Non-Meas.	# Fines < 2mm	# Fines < 6mm	# Non-Meas.	# Fines < 2mm	# Fines < 6mm	# Non-Meas.
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

## LARGE WOOD

Stream Name:							Estimator:							
Reach ID:							Date:							
Piece #	Wood Cat	Est. Length (m)	Est. Diam. (m)	Meas. Length (m)	Meas. Diam. (m)	Tert Chan?	Piece #	Wood Cat	Est. Length (m)	Est. Diam. (m)	Meas. Length (m)	Meas. Diam. (m)	Tert Chan?	
1						Y N	26						Y N	
2						Y N	27						Y N	
3						Y N	28						Y N	
4						Y N	29						Y N	
5						Y N	30						Y N	
6						Y N	31						Y N	
7						Y N	32						Y N	
8						Y N	33						Y N	
9						Y N	34						Y N	
10						Y N	35						Y N	
11						Y N	36						Y N	
12						Y N	37						Y N	
13						Y N	38						Y N	
14						Y N	39						Y N	
15						Y N	40						Y N	
16						Y N	41						Y N	
17						Y N	42						Y N	
18						Y N	43						Y N	
19						Y N	44						Y N	
20						Y N	45						Y N	
21						Y N	46						Y N	
22						Y N	47						Y N	
23						Y N	48						Y N	
24						Y N	49						Y N	
25						Y N	50						Y N	

**APPENDIX C – R1/R4 Habitat Inventory Procedures** (Source: *R1/R4 Northern/Intermountain Regions fish and fish habitat standard inventory procedures handbook*)

**Habitat Form 2:**

**Stream, Reach #, Forest, District, Observer, Recorder, Weather:**

**Page:** Sequential page #'s of each habitat data form (form 2)

**Date:** MM/DD/YY Write one date even if it takes longer to complete

**Habitat Unit #:** Sequential #'s of main channel habitat units starting with 1 at beginning of reach.

**Channel Code:**

**(M)** = Main Channel

**(S)** = Side Channel: Lateral channel separated by an island or midbar. Axis of flow parallels main channel – if side channel is only 1 habitat type and that habitat type is the same as the main channel habitat type into which it flows – Do not break out side channel – Consider it part of the main channel and subtract out any measurements that include the dry island and record side channel on the comments page (Form 5). If side channel occurs inventory main channel unit associated with side channel first then inventory side channel completely. Side channel habitat unit # corresponds to the main channel habitat unit in which side channel flows.

**(A)** = Adjacent Channel: Off channel unit – not in main stream flow – laterally adjacent to a unit that is a different habitat type (two different habitat types side by side). Adjacent unit must be >30% of stream in order for it to be considered. Habitat unit # for adjacent units is the same as the main channel unit it is adjacent to.

**Side Unit #:** Put “0” if you are inventorying the main channel. Side units are number sequentially upstream starting with 1- only One habitat unit # associated with each complete side channel. If you have a side channel of a side channel you keep the same habitat unit #, but for the side unit # you number the first complete side channel (say 1-4) then on the second side channel start with (5). Make a note of this on the comments page (Form 5).

**Habitat Type: (M,S,A)**

*Fast Water* – Moderate to fast current >.3 m/s or 1ft/s

*Turbulent* – Local velocities fluctuate and direction of flow changes abruptly and frequently, surface distortion, air bubbles.

*Cascade (CAS)* – Cascade, falls, steep gradient riffles >7% or bedrock chutes.

*High Gradient Riffle (HGR)* – Steep 4-7% gradient, swift water, low to moderate depth, lots of white water. Cobble of Boulder dominated.

*Low Gradient Riffle (LGR)* – Water flows swiftly over completely of partially submerged obstructions to produce surface agitation. <4% gradient. Gravel, Small Coble, Cobble dominated.

*Step Run (STR)* – Series of 3 or more runs separated by short stretches of turbulent water. Length of turbulent water cannot exceed its wetted width. A & B reach types.

*Non-Turbulent* – Fast water habitat types that don't have surface turbulence. Lack vertical scour, but are deep and lack surface agitation.

*Run (RUN)* – Deep & Fast >.3 m/s or 1 ft/s. defined thalweg & little surface agitation. Gravel, Small Cobble, Cobble, Small Boulder, and Boulder dominated.

Glide (GLD) – Low to moderate velocities, No surface agitation, No thalweg. Uniform, smooth, wide bottom. Pool like, but No scour depression Fines, gravel, and small cobble dominated.

Slow Water – Pools – Scouring water has carved out a non-uniform depression of dammed. Surface velocities are low to high, but subsurface velocities are low. Bounded by a head crest on upstream break in slope and a tail crest on the downstream break in slope.

Dammed Pools (D) – Downstream damming action, deepest part on downstream end.

1) Position:

Main (M) – Pool in the main body (thalweg area) of main or side channel.

Backwater (B) – Pool on the channel margin or in a cove having access to main body of water.

2) Formative Feature:

(W) – Woody debris

(B) – Boulder

(A) – Artificial Structure

(V) – Beaver

(L) – Landslide Debris

(O) – Other

Scour Pools (S) – Scour action forming pools by diverting flow from stream bank or channel obstacles.

1) Position:

Lateral (L) – Pool on one side of stream channel.

Mid-Scour (M) – Pool in middle of channel.

Plunge (P) – Scour from vertically falling water.

Under scour (U) – Scour from water flowing under an obstruction.

2) Formative Feature:

(W) – Woody Debris

(B) – Boulder

(A) – Artificial Structure

(R) – Bedrock

(T) – Tributary

(M) – Meander

(C) – Culvert – Mid-Scour and Plunge pools

(V) – Beaver – Plunge pools

(O) – Other

Step Pool Complex (STP) – 3 or more step like mid-scour pools separated by short turbulent water. Length of turbulent water cannot exceed its average wetted width. A & B reach types and pools formed by boulders and bedrock.

**Length: (M,S,A) – All habitat types:** Measured along the middle of the channel to the nearest .1 m. If STP measure length of entire complex.

**Width: (M,S,A) – All habitat types:** Measure average wetted width in a place representative of the unit to the nearest .1 m. If STP measure average width in representative pool. If channel is separated by a bar, subtract bar width.

**AVG. Depth: (M,S,A) – All habitat types:**

*Fast Water* – Measure depths at  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$  across the average width. Sum and divide by 4.

*Slow Water* – Add pool max depth and crest depth and divide by 2. Then find this depth in the thalweg. Measure the depths at  $\frac{1}{4}$ ,  $\frac{1}{2}$ ,  $\frac{3}{4}$  across this new transect. Sum and divide by 4.

*STP* – Measure average depth in the same pool as width and measure the depths as described for slow water.

**Pocket Pools #: (M,S,A) – Fast water habitat types:** Pocket pools are small 10-30% of the wetted width. Bed depressions around channel obstructions.

**AVG. Max Depth: (M,S,A) – Fast water habitat types:** Find the deepest part of each pocket pool and average these depths to nearest .01 m. If <3 pocket pools use what's available to get an average depth. If >3 pocket pools use first 3 pocket pools encountered.

**Pool Max Depth: (M,S,A) – Slow water habitat types:** The Deepest point in the pool to nearest .01 m. If STP take the deepest spot of all pools.

**Pool Crest Depth: (M,S,A) – Slow water habitat types:** Measure the max depth at the crest which is a break or transition in stream channel slope. Tail crest for scour pools and head crest for dammed pools. If STP do not record crest depth.

**Step Pool #: (M,S,A) – STP only:** The total # of pools in the complex.

**# Pools >1m Deep: (M,S,A) – STP only:** # of pools with max depth > 1m.

**AVG. Max Depth STP: (M,S,A) – STP only:** Measure the max depth of the first 3 pools and average.

**% Surface Fines: (M,S,A) – Scour pool tail crest & LGR:** Particles <6mm in flowing area. Ocular or grid toss. Randomly toss grid 3 times, count intersections that substrate cannot be seen under. Do not count organic matter. Add the 3 tosses together, multiply by 2 then divide by 3.

**Substrate Composition: (M) – LGR or Scour pool tails:** Ocular or Wolman. Wolman done on first LGR or Scour pool tail encountered on each page and place an "X" in the box, and refer to form 3. All other LGR or Scour pool tails an ocular estimation is recorded in the box.

**Bank Length: (M) – All habitat types:** Visually estimate bank lengths looking upstream using total length to assist. Exclude lengths where tributaries enter. Left and Right banks should not be shorter than the total length, but may be longer.

**Bank Stability: (M) – All habitat types:** After doing bank length visually estimate % or length or stable banks and circle % or length on form. Stable banks have No breakdown, slumping, tension cracking or fracture, are not vertical > 80°, not eroding, and not <50% vegetated with smaller substrate.

**Bank Undercut: (M) – All habitat types:** Visually estimate % or length, which ever was done for stability, bank undercut. Undercut banks are >5cm. back and <10cm. above the water.

**Channel Shape: (M) – All habitat types:**

- (T) – Triangular
- (R) – Rectangular
- (Z) – Trapezoidal
- (I) – Inverse Trapezoidal

**Water Temperature: (M) – All habitat types:** In °C on the

first habitat unit on each page and above and below tributaries and hot springs.

**Air Temperature: (M) – All habitat types:** In °C where and when water temperature is taken.

**Time of Temperature: (M) – All habitat types:** Military time when air and water temperature was taken.

**LWD Singles: (M,S) – All habitat types:** If present mark an “X” on the form and record habitat unit #, length, width, and % submerged on form 4.

**LWD Aggregates: (M,S) – All habitat types:** If present mark an “X” on the form and record habitat unit # and number of pieces in aggregate on form 4.

**LWD Root Wads: (M,S) – All habitat types:** Count number of root wads and record on form. Dead standing trees with roots visible or logs <3m. long with root structure are considered. If >3m. long it counts as a single.

**Riparian Community Type: (M) – All habitat types:** See Appendix 4.

**Comments:** If comments or photos are taken mark an “X” and record on form 5 the comment or photo.

**Snorkel Tally: (M) – All habitat types:** Used to tally habitat types. The first unit of a particular habitat type and every fifth unit after that of the same habitat type will be snorkeled, marked with an “X” in the box. Other habitat units are marked 1-4 in the box. Snorkel units will be flagged with the appropriate information written on the flag.

### **Substrate Composition Form, Form 3:**

**Stream, Reach #, Date:** See form 2.

**Habitat Unit #: (M) – Scour Pool Tails & LGR, Not STP:**

Record habitat unit # where wolman pebble count was performed. First main channel LGR or Scour Pool Tail encountered on each page.

**Method:** “WPC” wolman pebble count. See appendix 5.

### **Large Woody Debris Form, Form 4:**

**Stream, Reach #, Date:** See Form 2.

**Habitat Unit #:** Record habitat unit # where LWD data is collected.

**Singles:** Main and side channel if side channel is separated by a well vegetated island in all habitat types.

**Length:** Visually estimate length. It must be >3m. or 2/3 the wetted width in length to be considered.

**Diameter:** Visually estimate diameter. It must be  $>.1\text{m}$ . in diameter to be considered.

**% Submerged:** Visually estimate % submerged at the time of inventory.

**Aggregates:** 2 or more singles clumped together. Count the number of pieces that would qualify as singles.