Libby Mitigation Program

Mitigation for the Construction and Operation of Libby Dam

Annual Progress Report

2009

BPA-199500400
MFWP-31001

February 2011

This document should be cited as follows:

Dunnigan, J., J. DeShazer, L. Garrow, T. Ostrowski M. Benner, J. Lampton, B. Marotz, and J. Tohtz. 2011. Libby Mitigation Program, 2009 Annual Progress Report: Mitigation for the Construction and Operation of Libby Dam. BPA Project Number 199500400.

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

This project is funded by Bonneville Power Administration (BPA), as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities in the Columbia River Basin.

MITIGATION FOR THE CONSTRUCTION AND OPERATION OF LIBBY DAM

ANNUAL REPORT
2009
(Work Activities July 1, 2009 – June 30, 2010)

By:

James Dunnigan, Jay DeShazer, Larry Garrow, Tom Ostrowski,
Monty Benner, Jared Lampton, Brian Marotz, and Joel Tohtz

Montana Fish, Wildlife and Parks
385 Fish Hatchery Road
Libby, MT 59923

Funded by:
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208
Cecilia Brown, BPA Project Manager
Project Number 199500400
Contract Number 43258-Project Number 1994-004-00

February 2011

EXECUTIVE SUMMARY

"Mitigation for the Construction and Operation of Libby Dam" is part of the Northwest Power and Conservation Council's (NPCC) resident fish and wildlife program. The program was mandated by the Northwest Planning Act of 1980, and is responsible for mitigating damages to fish and wildlife caused by hydroelectric development in the Columbia River Basin. The objective of Phase I of the project (1983 through 1987) was to maintain or enhance the Libby Reservoir fishery by quantifying seasonal water levels and developing ecologically sound operational guidelines. The objective of Phase II of the project (1988 through 1996) was to determine the biological effects of reservoir operations combined with biotic changes associated with an aging reservoir. The objectives of Phase III of the project (1996 through present) are to implement habitat enhancement measures to mitigate for dam effects, to provide data for implementation of operational strategies that benefit resident fish, monitor reservoir and river conditions, and monitor mitigation projects for effectiveness. This project completes urgent and high priority mitigation actions as directed by the Kootenai Subbasin Plan.

Montana Fish, Wildlife & Parks (MFWP) uses a combination of techniques to collect physical and biological data within the Kootenai River Basin. These data serve several purposes including: the development and refinement of models used in management of water resources and operation of Libby Dam; investigations into the limiting factors of native fish populations, gathering basic life history information, tracking trends in endangered and threatened species, and the assessment of restoration or management activities designed to restore native fishes and their habitats. The following points summarize the biological monitoring accomplished from July 2009 to June 2010.

- MFWP has monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994, but catch rates have declined precipitously since. During the 2009/2010 trapping season we caught four burbot below Libby Dam after fishing a total of 362 trap days, for an equivalent catch rate of 0.011 burbot/trap/day. This catch represents the highest catch rate since 2005.

- We conducted juvenile salmonid population estimates within reference reaches on Therriault, Grave, Young, Libby, and Pipe creeks in order to evaluate fish population response to habitat work. Trend analyses and before/after/control analyses related to stream restoration projects are presented for Therriault, Young, Grave and Libby creeks.

- MFWP continued to monitor fish species composition, and species size and abundance within Libby Reservoir using spring and fall gill netting and present the results and trend analyses for 11 fish species. Average length and weight of kokanee in 2009 was 276.8 mm and 201.1 g, respectively. Kokanee mean length is significantly negatively correlated to catch rate in the fall nets. The catch rates of cutthroat trout and mountain whitefish during the past several years has remained low and not differed significantly from a stable population, but rainbow trout catch rates have exhibited a significantly increasing trend since 1994. The mean spring gill net catch of bull trout in 2010 was 4.4 bull trout per net, which was slightly higher than the previous year, but lower than the rolling ten year average. Bull trout catch rates on Libby Reservoir peaked in 2000 at 6.71 bull trout per net, and have generally exhibited a declining trend since. Catch rates for inland rainbow trout in fall gillnets has been low since 1996, averaging only 0.07 fish per gillnet. However, the catch rate in 2009 at the Rexford site was about double the mean, and overall, catch rates are significantly and positively correlated with the number of hatchery Inland rainbow trout stocked in the reservoir the previous year, especially yearling fish releases from 1989 through 2009.

- MFWP has monitored zooplankton species composition, abundance and size of zooplankton within the reservoir since the construction and filling of Libby Dam. Zooplankton abundance, species composition, and size distribution have also all been similar during the second half of the reservoir's history. *Cyclops* has been the most abundant genera of zooplankton present in the reservoir since 1997, and *Daphnia* was the second most abundant genera of zooplankton within the reservoir in most years, including 2009. Zooplankton abundance within the reservoir varies by month, with the monthly abundance peaks over the past ten years remaining relatively consistent. Area differences existed for all genera except *Bosmina, Diaptomus, and Diaphanosoma*.

- Bull trout redd counts in Grave Creek and the Wigwam River have both exhibited significant positive trends since the mid 1990s. There were a total of 1,575 bull trout redds within the index portion of the Wigwam River, which was approximately an order of magnitude higher than any other tributary within the Kootenai Basin. Bull trout core areas in the Kootenai River downstream of Libby Dam include Quartz, Pipe, Bear (Libby Creek drainage), O'Brien creeks and the West Fisher Creek. Bull trout redd counts within these individual core streams have been variable over the past several years, and have not increased in proportion to bull trout redd counts upstream of Libby Dam. Three of the four populations between Libby Dam and Kootenai Falls were below average over the period of record. West Fisher Creek was the only stream in this group that was approximately equal to the average. We observed the lowest redd counts in ten years in O'Brien Creek, but this was the only bull trout population located downstream of Libby Dam that exhibited a significant positive trend. The adjunct Bull Lake population, which spawns in Keeler Creek had only 26 redds in 2009, which was the second lowest count over the period of record (1996-present). Keeler Creek bull trout redd counts have been below the long-term average and the lowest since 2001.

- MFWP attempted to conduct a population estimate for adult bull trout below Libby Dam during April 2010, but a low number of recaptured (marked) fish precluded obtaining an unbiased estimate of adult bull trout were present within this 3.5-mile section of the Kootenai River. We recaptured 27 bull trout in 2010 that were previously marked in 2005, 2006, 2007, 2008 or 2009 below Libby Dam ranging between 79 to 1,819 days prior. The recaptured bull trout grew an average of 142.0 mm (0.22 mm per day), and gained an average of 2293.3g (3.42 g per day).

- MFWP monitored fine sediment (<6.35 mm) levels in eight bull trout spawning tributaries within the Montana portion of the Kootenai Basin using core sampling. In 2010, O'Brien had the highest levels of fine sediment, averaging 31.8%. West Fisher Creek had the lowest mean levels of fine sediment (22.9%). Fine sediment levels on West Fork Quartz Creek have been consistently and relatively low across years, averaging 26.8%. Mean annual fine sediment levels on Pipe Creek were the second highest value of the eight streams we monitored, averaging 30.4% across years. Mean annual fine sediment levels in Bear Creek have been variable, averaging 26.8%, with no apparent trend obvious over the period 2002 to 2010. The two bull trout spawning tributaries located in Montana upstream of Libby Dam had relatively low fine sediment levels. Fine sediment in Grave Creek and the Montana portion of the Wigwam River have both averaged 26.3% from 1998 to 2010. The adjunct bull trout population that resides in Bull Lake and spawns in Keeler Creek had the lowest mean annual levels of fine sediment amongst the eight streams we monitored, averaging 22.2%.

A cooperative mitigation and implementation plan developed by MFWP, the Kootenai Tribe of Idaho and the Confederated Salish and Kootenai Tribes documents hydropower-related losses and mitigation actions attributable to the construction and operation of Libby Dam, as called for by the Northwest Power and Conservation Council's Fish and Wildlife Program (MFWP et al. 1998). A mix of mitigation techniques is necessary to offset losses caused by dam construction and operation. During the 2009 contract period, MFWP implemented riparian vegetation restoration efforts on two restoration projects on Grave Creek, installed a fish screen on an important resident cutthroat and bull trout tributary, and completed monitoring activities to evaluate stream channel response to eight previously completed stream restoration projects. The following points summarize these activities.

- MFWP conducted physical monitoring of the Libby Creek Demonstration Project. The oringal work restoration project constructed one meander length the Libby Creek stream channel (approximately 1,700 feet) which significantly changed the stream channel dimensions, which ultimately resulting in a deeper and narrower channel, which translated into a significantly lower width/depth ratio after project implementation, and increased the quantity and quality of rearing habitat for native salmonids within the project reach. Stream channel dimensions within the project area are similar to the as-built conditions. The project continues to meet the original objectives including limiting instream sediment from two large sources within the project area. Stream channel instability immediately outside the project area has increased, while bank erosion within the project area has remained low.

- MFWP completed physical monitoring on the Upper, Lower Phase I and Phase II Cleveland Restoration Project Areas located on upper Libby Creek. Despite a large rain on snow weather event in fall 2006 created substantial changes in the plan form on these three projects, stream channel dimensions within riffle and pool habitats within these three projects continue to recover from the changes that resulted from this relatively large flood event. The habitat conditions in these three projects are better than existed prior to restoration, and even exceed conditions represented during the as-built surveys in some instances.

- MFWP completed the Young Creek State Lands Restoration Project in the fall of 2003, which changed the stream channel dimensions within this area. The monitoring results presented in this document evaluated whether these physical changes were maintained since construction. The steam channel dimensions within the riffles of this section of Young Creek changed only slightly between years. Pool dimensions and numbers changed little since construction (generally < 10%) within the project area. This project continues to meet the original objectives set forth for this project.

- MFWP partnered with The Kootenai River Network (KRN), the USFWS Partners for Wildlife and the local landowner in 2004 and 2005 to complete the Therriault Creek Restoration Project. This project also doubled the length of stream and created approximately 55 acres of prior converted wetland. Monitoring conducted in 2009 indicates that the planform remains nearly identical that as-built conditions. Stream channel dimensions have also changed little since 2004. MFWP implemented maintenance and supplemental vegetation treatments in the fall of 2009 including maintenance watering, expansion of many of the existing browse protectors, and installation of additional browse protectors on residual shrubs that had never been previously protected. Solarization fabric was an effective method to remove undesirable pasture grasses. Effectiveness monitoring of previous revegetation techniques was also completed, will continue to be used in an adaptive management context. Vegetation effectiveness monitoring at this site indicates that the riparian community is trending toward recovery while creating ecological conditions required to for a sustainable plant community.

- MFWP worked with the landowner of the largest single irrigation diversion on Deep Creek, a tributary to the Tobacco River to develop a cost share project to upgrade the existing system in order to improve ease of operation, eliminate fish entrainment and decrease maintenance at the point of diversion. The system was designed by the Montana FWP Libby staff and was installed in the spring of 2010.

- MFWP treated lower Boulder Lake and Boulder Creek, a tributary to Koocanusa Reservoir, with various commercial formulations of rotenone in September 2009 to remove a hybridized population of cutthroat trout. Monitoring conducted in early 2010 indicated that a single piscicide achieved a complete removal of these fish. MFWP restocked the lake and creek with westslope cutthroat trout fry in the summer of 2010. This project expanded the current distribution of westslope cutthroat trout within the Montana portion of the Kootenai River Subbasin upstream of Libby Dam by about 20%.

Montana FWP designed and implemented a creel survey to estimate fishing effort, catch and harvest of trout in the Kootenai River downstream of Libby Dam during the 2009/2010 fishing season which included the period June 1, 2009 to March 31, 2010, which targeted the rainbow and bull trout fishery, and was conducted during the night and crepuscular hours. We conducted angler interviews to estimate angling success, and we conducted visual counts of boat and bank anglers to estimate fishing effort (pressure). Bank angler effort differed by month, with the highest effort occurring in July, and the lowest effort occurring during November. The total effort for the season was 4,079 hours (1,467 trips). Bank angler catch rates of rainbow trout > 24 inches were low, averaging only 0.007 fish/hour (151 hours/fish). Harvest rates of rainbow trout > 24 inches were similar to catch rates, indicating most fish angled in this size class by bank angler were harvested. Bank angler bull trout catch rates were relatively high, and averaged 0.045 bull trout/hour (22 hours/fish). We estimated that bank anglers caught a total of 27 rainbow trout >24 inches and 185 bull trout during the season. Boat angler effort was substantially lower than bank effort, but generally showed a similar pattern. Boat effort was lowest from September through December, but increased to the highest effort in January to the end of the season in March. Total boat effort for the season was 262 boat hours (411 boat angler hours), which represented 74 boat trips. Boat angler catch rates of rainbow trout > 24 inches averaged 0.020 fish per boat hour (77 hours/fish). The estimated total catch and harvest for the season of rainbow trout > 24 inches was relatively low (5 and 3 fish, respectively). Bull trout catch rate for boats averaged 0.151 fish per boat hour (11 hours/fish). We estimated boats angler caught 39 bull trout during the season.

The Federal Action Agencies conducted a spill test in June 2010 at Libby Dam that lasted seven days which was intended to benefit the Kootenai River white sturgeon. Discharge from the turbines at Libby Dam was held constant at 27,000 cubic feet per second (cfs) throughout the spill test. Spill discharge peaked at 9,000 cfs on June 15, 2010 for two hours at 36,000 cfs total discharge from Libby Dam. Montana FWP conducted monitoring to evaluate the effects of elevated total dissolved gas on resident fish in the Kootenai River immediately downstream of Libby Dam. We conducted day and night visual searches for dead or dying fish, expending a total effort of 103.5 boat-hours (233 man-hours). We did not observe any fish mortality attributable to elevated gas levels. However, we did recover five species of fish, whose deaths using our visual criteria could not be attributed to gas-related injuries. In an effort to estimate search efficiency of dead or morbid fish, we released a total of 39 dead and individually marked bull trout in the Kootenai River. We recovered a total of 12 (30.8%) bull trout during our search efforts. The spatial recovery pattern of the test fish was not randomly distributed, most of the relocated test fish were recovered on the river bottom of the back eddy associated with the pool located near Big Bend (RM 217.4). The visual recovery of test fish was likely biased towards larger individuals during daylight hours. Montana FWP captured fish via jetboat electrofishing on two occasions after spill had ceased in order to determine if fish exhibited symptoms of gas bubble trauma (GBT). The day after spill had ceased, we estimated that 26.5% of the mountain whitefish examined had GBT symptoms. We also captured two rainbow trout, but none of these fish exhibited GBT symptoms. Almost six days after spill activities had ceased at Libby Dam, we captured and examined rainbow trout, bull trout, mountain whitefish, kokanee salmon, and brook trout. However, none of these fish exhibited readily apparent external GBT symptoms. We also present fish population estimates derived from mark recapture electrofishing for rainbow trout on three sections of the river and bull trout from a single section located immediately downstream of Libby Dam.

ACKNOWLEDGEMENTS

We are thankful to the many people that substantially contributed to this project. Mike Hensler, Neil Benson, Ryan Sylvester, and Brian Stephens helped with field data collection, data entry and proofing, and lab processing. Many of the aquatic habitat restoration projects that were accomplishments and summarized in this report were cooperative efforts between Montana Fish, Wildlife & Parks Montana Department of Environmental Quality, the Kootenai River Network, and the U.S. Fish and Wildlife Service Partners for Wildlife Program. This work was funded by the Bonneville Power Administration, and the contract was administered by Cecilia Brown.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 FIGURES

CHAPTER 2 FIGURES

CHAPTER 3 FIGURES

CHAPTER 4 FIGURES

LIST OF TABLES

CHAPTER 1 TABLES

CHAPTER 2 TABLES

CHAPTER 3 TABLES

CHAPTER 4 TABLES

APPENDIX TABLES

APPENDIX EXHIBITS

INTRODUCTION

Libby Reservoir was created under an International Columbia River Treaty between the United States and Canada for cooperative water development of the Columbia River Basin (Columbia River Treaty 1964). Libby Reservoir inundated 109 stream miles of the mainstem Kootenai River in the United States and Canada, and 40 miles of tributary streams in the U.S. that provided habitat for spawning, juvenile rearing, and migratory passage (Figure 1). The authorized purpose of the dam is to provide power (91.5%), flood control (8.3%), and navigation and other benefits (0.2%; Storm et al. 1982).

The Pacific Northwest Power Act of 1980 recognized possible conflicts stemming from hydroelectric projects in the northwest and directed Bonneville Power Administration to "protect, mitigate, and enhance fish and wildlife to the extent affected by the development and operation of any hydroelectric project of the Columbia River and its tributaries..." (4(h)(10)(A)). Under the Act, the Northwest Power Planning Council was created and recommendations for a comprehensive fish and wildlife program were solicited from the region's federal, state, and tribal fish and wildlife agencies. Among Montana's recommendations was the proposal that that initiated to quantify acceptable seasonal minimum pool elevations to maintain or enhance the existing fisheries (Graham et al. 1982).

Research to determine how operations of Libby Dam affect the reservoir and river fishery and to suggest ways to lessen these effects began in May 1983. The framework for the Libby Reservoir Model (LRMOD) was completed in 1989. Development of Integrated Rule Curves (IRCs) for Libby Dam operation was completed in 1996 (Marotz et al. 1996). The Libby Reservoir Model and the IRCs continue to be refined (Marotz et al 1999). Initiation of mitigation projects such as lake rehabilitation and stream restoration began in 1996. The primary focus of the Libby Mitigation project now is to restore the fisheries and fish habitat in basin streams and lakes.

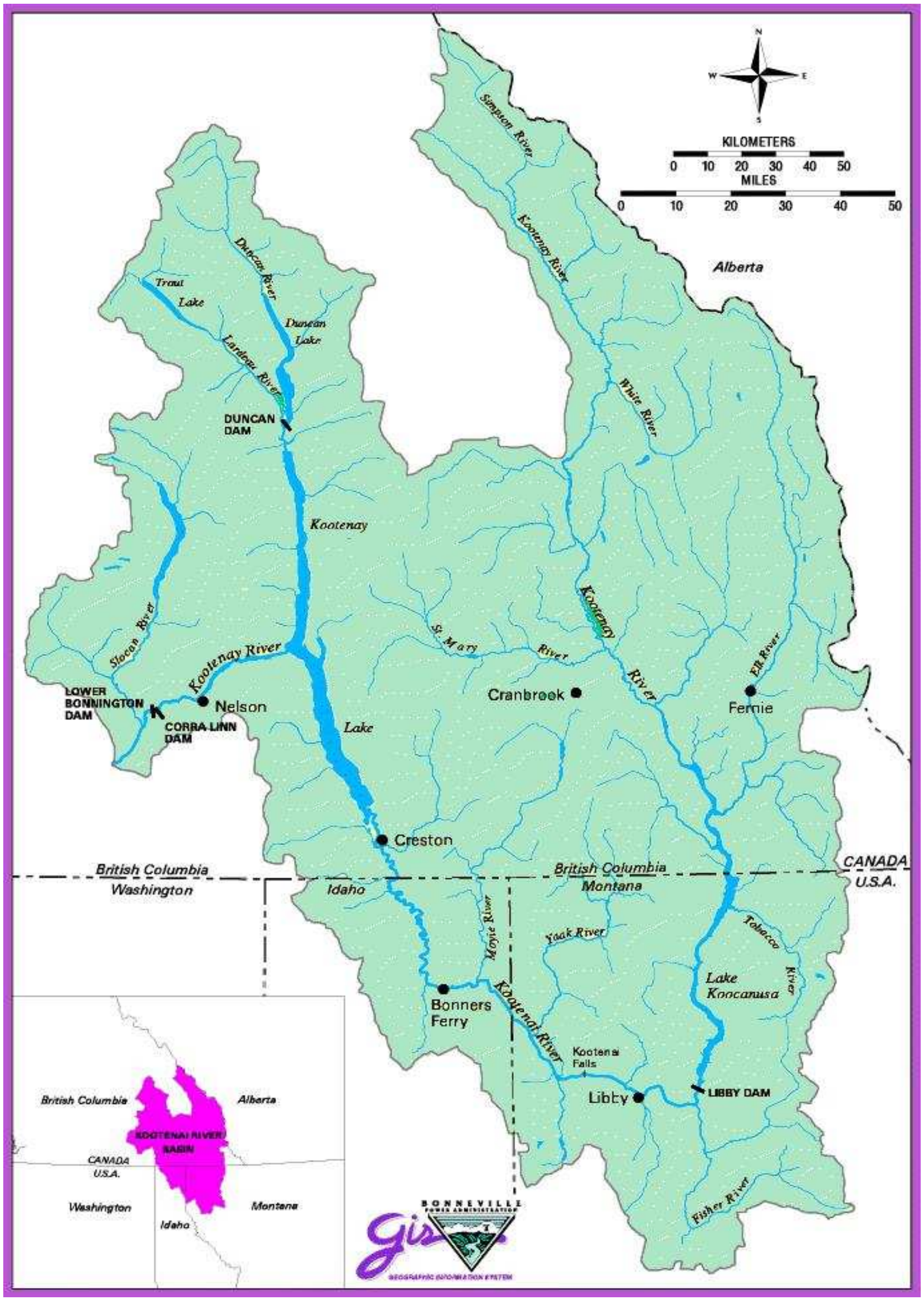


Figure 1. Kootenai River Basin (Montana, Idaho and British Columbia, Canada).

PROJECT HISTORY

Montana Fish, Wildlife and Parks began to assess the effects of Libby Dam operation on fish populations and lower trophic levels in 1982. This project established relationship between reservoir operation and biological productivity, and incorporated the results in the quantitative biological model LRMOD. The models and preliminary IRC's (called Biological Rule Curves) were first published in 1989 (Fraley et al. 1989), and then refined in 1996 (Marotz et al. 1996). Integrated Rule Curves (IRC's) were adopted by NPPC in 1994, and have recently been implemented, to a large degree, in the federal Biological Opinion (BiOp) for white sturgeon and bull trout (USFWS 2000). This project developed a tiered approach for white sturgeon spawning flows balanced with reservoir IRC's and the NOAA-Fisheries BiOp for salmon and steelhead. A tiered flow strategy was adopted by the White Sturgeon Recovery Team in their Kootenai white sturgeon recovery plan (USFWS 1999) and later refined in the USFWS 2000 BiOp.

A long-term database was established for monitoring populations of kokanee, bull trout, westslope cutthroat trout, rainbow trout and burbot and other native fish species. Long-term monitoring of zooplankton and trophic relationships was also established. A model was calibrated to estimate the entrainment of fish and zooplankton through Libby Dam as related to hydro-operations and use of the selective withdrawal, thermal control structure. Research on the entrainment of fish through the Libby Dam penstocks began in 1990, and results were published in 1996 (Skaar et al. 1996). The effects of dam operation on benthic macroinvertebrates in the Kootenai River was also assessed (Hauer et al. 1997) for comparison with conditions measured in the past (Perry and Huston 1983). This study was replicated in 2005 with the addition of examining the effect of a nuisance diatom (*Didymosphenia geminata*) on the benthic community (Marshall 2007). The project identified important spawning and rearing tributaries in the U.S. portion of the reservoir and began genetic inventories of species of special concern. This project developed non-lethal genetic methodologies to differentiate between native redband trout and non-native rainbow trout (Brunelli et al. 2008), and a non-lethal genetic methodology to identify natal tributary origin for bull trout in the upper Kootenai Watershed and quantify bull trout entrainment at Libby Dam (Ardren et al. 2007). Research on the effects of operations on the river fishery using Instream Flow Incremental Methodology (IFIM) techniques was initiated in 1992. Assessment of the effects of river fluctuations on Kootenai River burbot fishery was examined in 1994 and 1995. IFIM studies were also completed in Kootenai River below Bonners Ferry, Idaho, to determine spawning area available to sturgeon at various river flows. Microhabitat data collection specific to species and life-stage of rainbow trout and mountain whitefish has been incorporated into suitability curves. River cross-sectional profiles, velocity patterns and other fisheries habitat attributes were completed in 1997. Hydraulic model calibrations and incorporation of suitability curves and modification of the model code were completed in 1999, and updated by Miller Ecological Consultants, Inc in 2003 (Miller and Geise 2004).

MFWP has completed several on-the-ground projects since beginning mitigation activities since 1997. Highlights of these accomplishments are listed below for each year.

1997 – MFWP chemically rehabilitated Bootjack, Topless and Cibid Lakes (closed-basin lakes) in eastern Lincoln County to remove illegally introduced pumpkinseeds and yellow perch and re-establish rainbow trout and westslope cutthroat trout.

1998 - MFWP rehabilitated 200' of Pipe Creek stream bank in cooperation with a private landowner to prevent further loss of habitat for bull trout and westslope cutthroat trout. Pipe Creek is a primary spawning tributary to the Kootenai River.

1998 through 2000 - MFWP developed an isolation facility for the conservation of native redband trout at the Libby Field Station. Existing ponds were restored and the inlet stream was enhanced for natural outdoor rearing. Natural reproduction may be possible. Activities included chemically rehabilitating the system and constructing a fish migration barrier to prevent fish movement into the reclaimed habitat.

1998 - MFWP chemically rehabilitated Carpenter Lake to remove illegally introduced pike, largemouth bass and bluegills and reestablish westslope cutthroat trout and rainbow trout. Natural reproduction is not expected in this closed basin lake.

1999 - MFWP rehabilitated ~400' of Sinclair Creek to reduce erosion, stabilize highway crossing, and install fisheries habitat for westslope cutthroat trout. Sinclair Creek is a tributary to Libby Reservoir.

2000 - MFWP completed additional work on Sinclair Creek to stabilize a bank slough for westslope cutthroat habitat improvement. Sinclair Creek is now accessible to adfluvial spawners from Libby Reservoir.

2000 - MFWP was a major contributor (financial and in-kind services; primarily surveying) towards completion of Parmenter Creek re-channelization/rehabilitation work (Project Impact). Parmenter Creek has the potential to provide additional spawning and rearing habitat for Kootenai River fish, most likely westslope cutthroat trout.

2000 - MFWP completed stream stabilization and re-channelization project at the mouth of O'Brien Creek to mitigate for delta formation and resulting stream instability, and to ensure bull trout passage in the future. The work was completed in cooperation with private landowners and Plum Creek Timber Company.

2000 - MFWP completed stream stabilization and a water diversion project in cooperation with the city of Troy on O'Brien Creek to ensure bull trout passage in the future. The project removed a head cut and stabilized a section of stream. O'Brien Creek is a core bull trout recovery stream, and this project helped ensure access to spawning areas.

2001 – MFWP designed and reconstructed approximately 1,200 feet of stream channel on Libby Creek to stabilize stream banks, reduce sediment, and improve rearing habitat for salmonids. This project eliminated a mass wasting hill slope that was contributing an estimated 4,560 cubic yards of sediment per year.

2001 – MFWP collaborated with the Kootenai River Network to reconstruct approximately 1,200 feet of stream channel on Grave Creek in order to stabilize stream banks, reduce sediment, and improve rearing habitat for salmonids.

2001 – MFWP chemically rehabilitated Banana Lake in order to remove exotic fish species from this closed basin lake. Banana Lake will be restocked with native fish species for recreational fishing opportunities.

2001 – MFWP worked cooperatively with the city of Troy, MT to construct a community fishing pond in Troy. The pond was completed in 2002 and stocked with fish from Murray Spring Fish Hatchery.

2002 – MFWP collaborated with the Kootenai River Network and 7 other contributors to reconstruct approximately 4,300 feet of stream channel on Grave Creek in order to stabilize stream banks, reduce sediment, improve rearing habitat for salmonids, and restore riparian vegetation. A long-term monitoring plan was also implemented in conjunction with this project to evaluate project effectiveness through time.

2002 – MFWP collaborated with the landowner on upper Libby Creek to reconstruct approximately 4,300 feet of stream channel that was previously impacted by mining activities. The project objectives were to stabilize stream banks, reduce sediment, improve rearing habitat for salmonids, and restore riparian vegetation. Similar to the Grave Creek restoration activities, we also implemented a long-term monitoring plan with this project to evaluate project effectiveness through time. This restoration project was designed to benefit native redband rainbow trout and bull trout.

2003 – Libby Fisheries Mitigation coordinated with the Wildlife Mitigation Trust to complete a conservation easement in the Fisher River corridor. Fisheries mitigation dollars were used to secure riparian habitat along 8.3 km of the Fisher River and important tributaries.

2004 – MFWP collaborated with the Kootenai River Network to reconstruct approximately 3,100 feet of stream channel on Grave Creek (Phase II Restoration Project) in order to stabilize stream banks, reduce sediment, and improve rearing habitat for salmonids.

2005 - MFWP excavated approximately 2,950 feet of new stream channel during fall 2005 to complete the Libby Creek Lower Cleveland Phase I Restoration Project. The resulting stream pattern design increased sinuosity and subsequently increased total stream length from approximately 2,700 to 3,200 feet. This project represented the second phase of restoration activities in the upper Libby Creek Watershed.

2005 – MFWP collaborated with the Kootenai River Network to restore the ecological function to Therriault Creek, a tributary of the Tobacco River by restoring the meander pattern and profile of a 9,300 feet section of stream that had been straightened. This project approximately doubled the stream length within this section of creek.

2006 – MFWP completed the The Libby Creek Lower Cleveland Phase II Project, which started at the downstream boundary of the Phase I project area and restored 3,175 feet of stream to a sustainable planform, profile and channel dimension.

2006 - MFWP chemically rehabilitated Kilbrennan Lake to remove illegally nonnative brook trout, rainbow trout, yellow perch and black bullheads and reestablished redband trout in the lake. We also installed a fish barrier on Kilbrennan Creek, downstream of the lake in order to prevent nonnative fishes from recolonizing the lake.

2006 – MFWP collaborated with the Kootenai River Network to perform maintenance and revegetation efforts on the Grave Creek Phase I and II Restoration Projects.

2006 – MFWP installed a fish screen on an irrigation diversion on lower Libby Creek.

2007 – MFWP completed Phase I of the Therriault Creek Project Revegetation effort.

2007 – MFWP chemically rehabilitated Loon Lake to remove nonnative brook troutand black bullheads and reestablished westslope cutthroat trout in the lake.

2008 – MFWP completed Phase II of the Therriault Creek Project Revegetation effort.

2008 – MFWP installed a fish screen on an irrigation diversion on Young Creek.

2008 – MFWP collaborated on the Grave Creek Phase I Project revegetation effort.

ASSOCIATIONS

The primary goals of the Libby Mitigation project are to implement operational mitigation (Integrated Rule Curve refinement and assessment: measure 10.3B of the Northwest Power Planning Council's Fish and Wildlife Program) and non-operational mitigation (habitat and passage improvements) in the Kootenai drainage. Results complement and extend the Kootenai Focus Watershed Program (Project 199608720) and the Kootenai Subbasin Plan (KTOI and MFWP 2004, see NPCC web page). This project creates new trout habitat by restoring degraded habitat to functional condition through stream restoration and fish passage repairs. The projects compliment each other in the restoration and maintenance of native trout populations in the Kootenai River System.

This project has direct effects on the activities of Idaho Department of Fish and Game (IDFG)-Kootenai River Fisheries Investigations (198806500 – IDFG) and White Sturgeon Experimental Aquaculture (198806400 – Kootenai Tribe of Idaho). The project manager is on the Kootenai white sturgeon recovery team and works closely with project sponsors from IDFG and KTOI. Results and implementation of recommendations derived from the IRCs, sturgeon tiered flow strategy and IFIM models affect white sturgeon recovery activities.

This project uses radio-telemetry to identify migration habits, habitat preferences and spatial distribution of species in the Kootenai system. Information on species habitat selection is shared with the IFIM project in the Flathead Watershed (Project 199101903).

Project personnel are completing activities in the lower Kootenai River in Montana to provide baseline, control information for Kootenai River Ecosystem Improvement Study (19940490 – Kootenai Tribe of Idaho). The intent of their study is to determine if fertilization of the Kootenai River is a viable alternative for increasing primary productivity in the Idaho portion of the river.

We have been cooperating with the efforts of the bull trout recovery project in Canada (2000004 – British Columbia Ministry of Environment) for several years to monitor the status of bull trout in the upper Kootenai River, it's tributaries, and Libby Reservoir. Our cooperative activities have included radio tagging and tracking of adult bull trout, redd counts, sediment and temperature monitoring, and migrant fish trip operations.

MFWP is an active partner with the Kootenai River Network (KRN). KRN is a non-profit organization created to foster communication and implement collaborative processes among private and public interests in the watershed. These cooperative programs improve resource management practices and the restoration of water quality and aquatic resources in the Kootenai basin. KRN is an alliance of diverse citizen's groups, individuals, business and industry, and tribal and government water resource management agencies in Montana, Idaho, and British Columbia. KRN enables all interested parties to collaborate in natural resource management in the basin. MFWP serves on the KRN Executive Board. Formal participation in the KRN helps MFWP achieve our goals and objectives toward watershed restoration activities in the Kootenai Basin.

DESCRIPTION OF STUDY AREA

Subbasin Description

The Kootenai River Subbasin is an international watershed that encompasses parts of British Columbia (B.C.), Montana, and Idaho (Figure 1). The headwaters of the Kootenai River originate in Kootenay National Park, B.C. The river flows south within the Rocky Mountain Trench into the reservoir created by Libby Dam, which is located near Libby, Montana. From the reservoir, the river turns west, passes through a gap between the Purcell and Cabinet Mountains, enters Idaho, and then loops north where it flows into Kootenay Lake, B.C. The waters leave the lake's West Arm and flow south to join the Columbia River at Castlegar, B.C. The annual runoff volume makes the Kootenai the second largest Columbia River tributary. The Kootenai ranks third in watershed area (36,000 km^2 or 8.96 million acres; Knudson 1994). The climate, topography, geology, soils and land use characteristics of the Kootenai Basin were previously described in Dunnigan et al. (2003).

Drainage Area

Nearly two-thirds of the river's 485-mile-long channel, and almost three-fourths of its watershed area, is located within the province of British Columbia. Roughly twenty-one percent of the watershed lies within the state of Montana (Figure 2), and six percent falls within Idaho (Knudson 1994). The Continental Divide forms much of the eastern boundary, the Selkirk Mountains the western boundary, and the Cabinet Range the southern. The Purcell Mountains fill the center of the river's J-shaped course to Kootenay Lake. Throughout, the subbasin is mountainous and heavily forested.

Hydrology

The headwaters of the Kootenay River in British Columbia consist primarily of the main fork of the Kootenay River and Elk River. High channel gradients are present throughout headwater reaches and tributaries.

Libby Reservoir (Lake Koocanusa) and its tributaries receive runoff from 47 percent of the Kootenai River drainage basin. The reservoir has an annual average inflow of 10,615 cfs. Three Canadian rivers, the Kootenay, Elk, and Bull, supply 87 percent of the inflow (Chisholm et al. 1989). The Tobacco River and numerous small tributaries flow into the reservoir south of the International Border.

Major tributaries to the Kootenai River below Libby Dam include the Fisher River (838 sq. mi.; 485 average cfs), the Yaak River (766 sq. mi. and 888 average cfs) and the Moyie River (755 sq. mi.; 698 average cfs). Kootenai River tributaries are characteristically high-gradient mountain streams with bed material consisting of various mixtures of sand, gravel, rubble, boulders, and drifting amounts of clay and silt, predominantly of glacio-lacustrine origin. Fine materials, due to their instability during periods of high stream discharge, are continually abraded and redeposited as gravel bars, forming braided channels with alternating riffles and pools. Stream flow in unregulated tributaries generally peaks in late-May or early June after the onset of snow melt, then declines to low flows from November through March. Flows also peak with rain-on-snow events. Kootenai Falls, a 200-foot-high waterfall and a natural impediment to fish migrations, is located eleven miles downstream of Libby, Montana.

The river drops in elevation from 3618 m at the headwaters to 532 m at the confluence of Kootenay Lake. It leaves the Kootenay Lake through the western arm to a confluence with the Columbia River at Castlegar. A natural barrier at Bonnington Falls, and now a series of four dams isolate fish from other populations in the Columbia River basin. The natural barrier has isolated sturgeon for approximately 10,000 years (Northcote 1973). At its mouth, the Kootenay River has an average annual discharge of 868 m^3/s (30,650 cfs).

Fish Species

Eighteen species of fish are present in Libby Reservoir and the Kootenai River (Table 1). The reservoir currently supports an important fishery for kokanee *Oncorhynchus nerka* and rainbow trout *Oncorhynchus mykiss*, with annual fishing pressure over 500,000 hours (Chisholm and Hamlin 1987). Burbot *Lota lota* are also important game fish, providing a popular fishery during winter and spring. The Kootenai River below Libby Dam is a "blue ribbon" trout fishery, and the state record rainbow trout was harvested there in 1997 (over 33 pounds). Although bull trout *Salvelinus confluentus* fishing was banned in the Kootenai River, "incidental captures" provide a unique seasonal fishery.

Table 1. Current relative abundance (A=abundant, C=common, R=rare) and abundance trend from 1975 to 2000 (I=increasing, S = stable , D = decreasing, U = unknown) of fish species present in Libby Reservoir.

Common Name	**Scientific name**	**Relative abundance**	**Abundance trend**	**Native***
Game fish species				
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	C	D	Y
Rainbow trout	*Oncorhynchus mykiss*	C	D	Y
Bull trout	*Salvelinus confluentus*	C	I	Y
Brook trout	*Salvelinus fontinalis*	R	U	N
Lake trout	*Salvelinus namaycush*	R	U	N
Kokanee salmon	*Oncorhynchus nerka*	A	U	N
Mountain whitefish	*Prosopium williamsoni*	R	D	Y
Burbot	*Lota lota*	C	D	Y
Largemouth bass	*Micropterus salmoides*	R	U	N
Northern pike	*Esox lucius*	R	U	N
Nongame fish species				
Pumpkinseed	*Lepomis gibbosus*	R	U	N
Yellow perch	*Perca flavescens*	C	I	N
Redside shiner	*Richardsonius balteatus*	R	D	Y
Peamouth	*Mylocheilus caurinus*	A	I	Y
Northern pikeminnow	*Ptychocheilus oregonensis*	A	I	Y
Largescale sucker	*Catostomus macrocheilus*	A	S	Y
Longnose sucker	*Catostomus catostomus*	C	D	Y

* Native species are designated Y, and nonnatives N

Reservoir Operation

Libby Dam is a 113-m (370-ft) high concrete gravity structure with three types of outlets: sluiceways (3), operational penstock intakes (5, 8 possible), and a gated spillway. The dam crest is 931 m long (3,055 ft), and the widths at the crest and base are 16 m (54 ft) and 94 m (310 ft), respectively. A selective withdrawal system was installed on Libby Dam in 1972 to control water temperatures in the dam discharge by selecting of water various strata in the reservoir forebay.

Completion of Libby Dam in 1972 created the 109-mile Libby Reservoir. Specific morphometric data for Libby Reservoir are presented in Table 2. Filling Libby Reservoir inundated and eliminated 109 miles of the mainstem Kootenai River and 40 miles of critical, low-gradient tributary habitat. This conversion of a large segment of the Kootenai River from a lotic to lentic environment changed the aquatic community (Paragamian 1994). Replacement of the inundated habitat and the community of life it supported are not possible. However, mitigation efforts are underway to protect, reopen, or reconstruct the remaining tributary habitat to partially offset the loss. Fortunately, in the highlands of the Kootenai Basin, tributary habitat quality is high. The headwaters are relatively undeveloped and retain a high percentage of their original wild attributes and native species complexes. Protection of these remaining pristine areas and reconnection of fragmented habitats are high priorities.

Between 1977 and 2000, reservoir drawdowns averaged 111 feet, but were as extreme as 154 feet (Figure 3). Reservoir drawdown affects all biological trophic levels and influences the probability of subsequent refill during spring runoff. Refill failures are especially harmful to biological production during warm months. Annual drawdowns impede revegetation of the reservoir varial zone and result in a littoral zone of nondescript cobble/mud/sand bottom with limited habitat structure.

Table 2. Morphometric data for Libby Reservoir.

Surface elevation	
maximum pool	749.5 m (2,459 ft)
minimum operational pool	697.1 m (2,287 ft)
minimum pool (dead storage)	671.2 m (2,222 ft)
Area	
maximum pool	188 sq. km (46,500 acres)
minimum operational pool	58.6 sq. km (14,487 acres)
Volume	
maximum pool	7.24 km^3 (5,869,400 acre-ft)
minimum operational pool	1.10 km^3 (890,000 acre-ft)
Maximum length	145 km (90 mi)
Maximum depth	107 m (350 ft)
Mean depth	38 m (126 ft)
Shoreline length	360 km (224 mi)
Shoreline development	7.4 km (4.6 mi)
Storage ratio	0.68 yr
Drainage area	23,271 sq. km (8,985 sq. mi)
Drainage area:surface area	124:1
Average daily discharge	
pre-dam (1911-1972)	11,774 cfs
post-dam (1974-2000)	10,991 cfs

Similar impacts have been observed in the tailwater below Libby Dam. The zone of water fluctuation or *varial zone* has been enlarged by daily changes in water-flow and stage caused by power operations. The resulting rapid fluctuations in dam discharges (as great as 400 percent) are inconsistent with the normative river concept (ISAB 1997). The varial zone is neither a terrestrial nor aquatic environment, so is biologically unproductive. Daily and weekly differences in discharge from Libby Dam have an enormous impact on the stability of the riverbanks. Water logged banks are heavy and unstable; when the flow drops in magnitude, banks calve off, causing serious erosion in the riparian zone. These impacts are common during winter but go unnoticed until spring. In addition, widely fluctuating flows can give false migration cues to burbot and white sturgeon spawners (Paragamian 2000 and Paragamian and Kruse 2001).

Also, barriers have been deposited in critical spawning tributaries to the Kootenai River through the annual deposition of bedload materials (sand, gravel, and boulders) at their confluence with the river (MFWP et al. 1998). During periods of low stream flow, the enlarged deltas and excessive deposition of bedload substrate in the low gradient reaches of tributaries impedes or blocks fall-spawning migrations. During late spring and summer, when redband and cutthroat trout are out-migrating from nursery streams, the streams may flow subsurface through the porous deltas (Paragamian V., IDFG, personal communication 2000). As a result, many potential recruits are stranded. Prior to impoundment, the Kootenai River contained sufficient hydraulic energy to annually remove these deltas, but since the dam was installed, peak flows have been limited to maximum turbine capacity (roughly 27 kcfs). Hydraulic energy is now insufficient to remove deltaic deposits. Changing and regulating the Kootenai River annual hydrograph for power and flood control and altering the annual temperature regime have caused impacts typical of dam tailwaters.

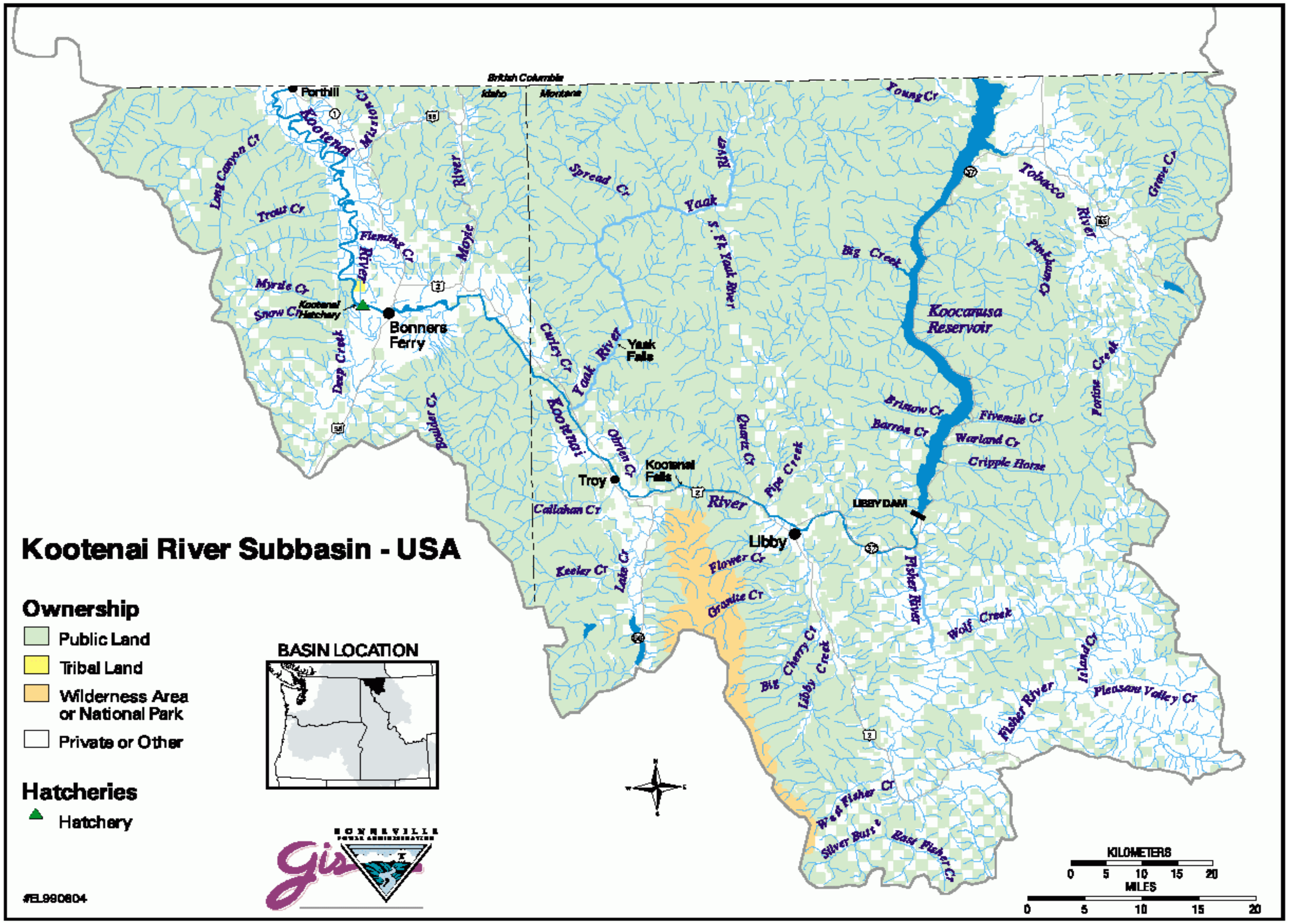


Figure 2. Kootenai River Basin, Montana.

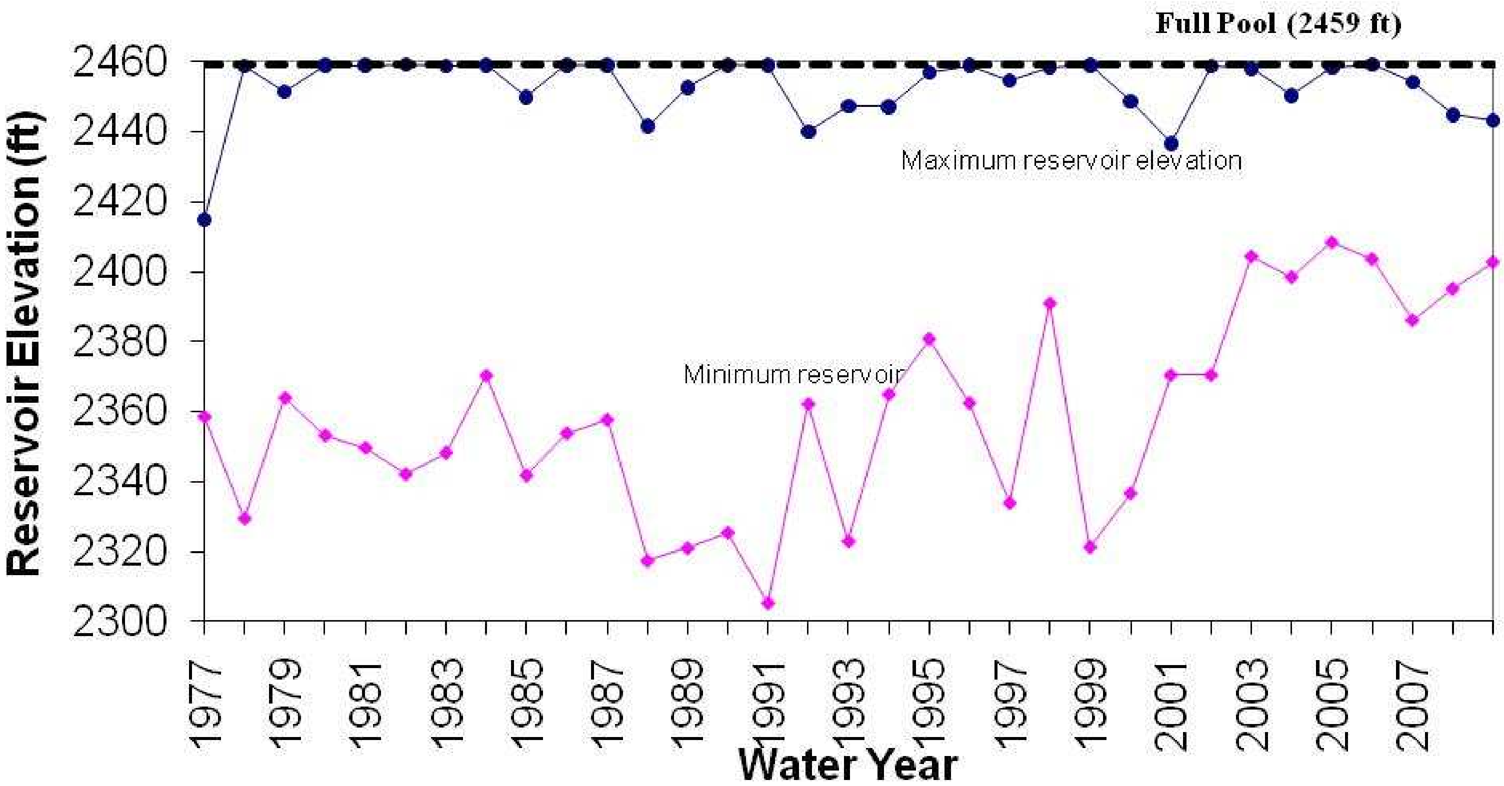


Figure 3. Libby Reservoir elevations (minimum, maximum), water years (October 1 – Sept. 30), 1976 through 2009.

REFERENCES

Ardren, W, P. DeHaan, J. Dunnigan. 2007. Genetic analysis of bull trout in the Kootenai River Basin: Final Report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Brunelli, J.P., R.F. Leary, J.L. Dunnigan, and G.H. Thorgaard. Single nucleotide polymorphisms associated with allozyme differences between inland and coastal rainbow trout. Prepared for, Montana Fish, Wildlife & Parks, Kalispell, Montana.

Chisholm, I.M. and P.D. Hamlin. 1987. 1985 Libby Reservoir angler census. Prepared for Bonneville Power Administration, Project No. 83-467 by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Chisholm, I.M., M.E. Hensler, B. Hansen, D. Skaar. 1989. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries. Methods and Data Summary 1983-1987. Prepared for Bonneville Power Administration by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Dunnigan, J.L, B. Marotz, J. DeShazer, L. Garrow, and T. Ostrowski. 2003. Mitigation for the construction and operation of Libby Dam: Annual report 2001-2002. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Fraley, J., B. Marotz, J. Decker-Hess, W. Beattie, and R. Zubic,. 1989. Mitigation, compensation, and future protection for fish populations affected by hydropower development in the Upper Columbia System, Montana. USA Regulated Rivers: Research and Management (3):3-18.

Graham, P.J., P.W. Fredenberg, and J. Huston. 1982. Supplements to recommendations for a fish and wildlife program. Submitted to: Pacific Northwest Power Planning Council by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Hauer, R., J.T. Gangemi and J. Stanford. 1997. Long-term influence of Libby Dam Operation on the ecology of macrozoobenthos of the Kootenai River, Montana and Idaho. Flathead Lake Biological Station. Yellow Bay, MT; Prepared for Montana Fish, Wildlife and Parks. Helena, MT. 61 pp.

ISAB. 1997. Ecological impacts of the flow provisions of the Biological Opinion for endangered Snake River salmon on resident fishes in the Hungry Horse, and Libby systems in Montana, Idaho, and British Columbia. Independent Scientific Advisory Board.

Knudson, K. 1994. Water quality status report: Kootenay (Kootenai) River Basin British Columbia, Montana and Idaho. Kootenai River Network. Libby, MT. and Ecological

Resource Consulting, Helena, MT. 57 pp.

Kootenai Tribe of Idaho and Montana Fish, Wildlife & Parks. 2004. Kootenai Subbasin Plan. Available on CD from the Kootenai Tribe of Idaho, Bonners Ferry, ID and Montana Fish, Wildlife & Parks, Kalispell. Also available at: http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan/

Marotz, B.L., D. Gustafson, C. Althen and B. Lonnen. 1996. Model development to establish integrated operational rule curves for Hungry Horse and Libby Reservoirs-Montana. Report to Bonneville Power Administration by Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana. 114pp.

Marotz, B.L., D. Gustafson, C.L. Althen, and W. Lonon. 1999. Integrated operational rule curves for Montana reservoirs and application for other Columbia River storage projects. Pages 329-352 In Ecosystem Approaches for Fisheries Management. Alaska Sea Grant College Program. AK-SG-99-01, 1999.

Marshall, B.D. 2007. Effects of Libby Dam, Habitat, and an invasive diatom, Didymosphenia geminate, on the benthic macroinvertebrate assemblages of the Kootenai River, Montana. Prepared for Montana, Fish, Wildlife & Parks, Kalispell, Montana.

Miller, W.J., and D. Geise. 2004. Kootenai River instream flow analysis. Prepared for, Montana Fish, Wildlife & Parks, Kalispell, Montana.

Montana Fish, Wildlife & Parks, Confederated Salish Kootenai Tribes, and the Kootenai Tribe of Idaho. 1998. Fisheries mitigation and implementation plan for losses attributable to the construction and operation of Libby Dam. Montana Fish, Wildlife and Parks, Kalispell, MT., Confederated Salish and Kootenai Tribes, Pablo, Montana, and Kootenai Tribe of Idaho, Bonners Ferry, Idaho.

Northcote, T. G. 1973. Some impacts of man on Kootenay Lake and its salmonids. Great Lakes Fishery Commission, Technical Report Number 25, Ann Arbor, Michigan.

Paragamian, V. L. 1994. Kootenai River fisheries inventory: stock status of burbot and rainbow trout and fisheries inventory. Idaho Department of Fish and Game, Bonneville Power Administration, Project 88-65. Boise, ID.

Paragamian, V. L. 2000. The effect of variable flows on burbot spawning migrations in the Kootenai River, Idaho, USA, and Kootenay Lake, British Columbia, Canada, after construction of the Libby Dam. Pages 111-123 i*n* V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda.

Paragamian, V. L., and G. Kruse. 2001. Kootenai River White Sturgeon Spawning Migration Behavior and a Predictive Model North American Journal of Fisheries Management. 21:10-21.

Perry, S. J. Huston. 1983. Aquatic insect study: October 1979 through June, 1982. In: Kootenai River Fisheries Investigations. Final Completion Report. 1983. US Army Corps of Engineers.

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski and B. Thornberg. 1996. Quantification of Libby Reservoir levels needed to enhance reservoir fisheries. Investigations of fish entrainment through Libby dam, 1990-1994. Final Report. Montana Department of Fish, Wildlife and Parks - Region 1. Prepared for Bonneville Power Administration. Project Number 83-467.

Storm, P.C. et al. 1982. Limnological investigations: Lake Koocanusa, Montana, Part 3 basic data, post impoundment, 1972-1978. U.S. Arm Corps of Engineers, Seattle District, Seattle, Washington.

U.S. Fish and Wildlife Service. 1999. Recovery Plan for the white sturgeon (*Acipenser transmontanus*): Kootenai River population. U.S. Fish and Wildlife Service. Portland, OR. 96 pp. Plus appendices.

U.S. Fish and Wildlife Service. 2000. Biological Opinion on Federal Columbia River Power System Operations. U.S. Fish and Wildlife Service. Portland, OR. 97 pp. Plus appendices

Chapter 1

Biological Monitoring in the Montana Portion of the Kootenai River Basin

Abstract

MFWP has monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994, but catch rates have declined precipitously since. During the 2009/2010 trapping season we caught four burbot below Libby Dam after fishing a total of 362 trap days, for an equivalent catch rate of 0.011 burbot/trap/day. This catch represents the highest catch rate since 2005.

We conducted juvenile salmonid population estimates within reference reaches on Therriault, Grave, Young, Libby, and Pipe creeks in order to evaluate fish population response to habitat work. Trend analyses and before/after/control analyses related to stream restoration projects are presented for Therriault, Young, Grave and Libby creeks.

MFWP has documented the changes in fish species composition, and species size and abundance within Libby Reservoir since the construction of Libby Dam. We continued monitoring fish populations within the reservoir using spring and fall gill netting and present the results and trend analyses for 11 fish species. Average length and weight of kokanee in 2009 was 276.8 mm and 201.1 g, respectively. Kokanee mean length has varied relatively little since 1995, but is significantly negatively correlated to catch rate in the fall nets. Rainbow and westslope cutthroat trout and mountain whitefish catch declined precipitously following impoundment. The catch rates of cutthroat trout and mountain whitefish during the past several years has remained low and not differed significantly from a stable population, but rainbow trout catch rates have exhibited a significantly increasing trend since 1994. The mean spring gill net catch of bull trout in 2010 was 4.4 bull trout per net, which was slightly higher than the previous year, but lower than the rolling ten year average. Bull trout catch rates on Libby Reservoir peaked in 2000 at 6.71 bull trout per net, and have generally exhibited a declining trend since. The spring gill net catch of bull trout is significantly and positively correlated to the bull trout redd counts in the Wigwam River and Grave. We were able to improve trend analyses using an adjusted catch of bull trout that accounted for differing reservoir levels at the time of netting. Catch rates for inland rainbow trout in fall gillnets has been low since 1996, averaging only 0.07 fish per gillnet. The catch rate in 2009 at the Rexford site was about double the mean. The catch rate of inland rainbow trout in fall floating gillnets was significantly and positively correlated with the number of hatchery Inland rainbow trout stocked in the reservoir the previous year, especially yearling fish releases from 1989 through 2009.

MFWP has monitored zooplankton species composition, abundance and size of zooplankton within the reservoir since the construction and filling of Libby Dam. Zooplankton abundance, species composition, and size distribution have also all been similar during the second half of the reservoir's history. *Cyclops* has been the most abundant genera of zooplankton present in the reservoir since 1997, and *Daphnia* was the second most

abundant genera of zooplankton within the reservoir in most years, including 2009. Zooplankton abundance within the reservoir varies by month, with the monthly abundance peaks over the past ten years remaining relatively consistent. Area differences existed for all genera except *Bosmina, Diaptomus, and Diaphanosoma*.

Bull trout redd counts in Grave Creek and the Wigwam River have both exhibited significant positive trends since the mid 1990s. There were a total of 1,575 bull trout redds within the index portion of the Wigwam River, which was approximately an order of magnitude higher than any other tributary within the Kootenai Basin. Bull trout core areas in the Kootenai River downstream of Libby Dam include Quartz, Pipe, Bear (Libby Creek drainage), O'Brien creeks and the West Fisher Creek. Bull trout redd counts within these individual core streams have been variable over the past several years, and have not increased in proportion to bull trout redd counts upstream of Libby Dam. Three of the four populations between Libby Dam and Kootenai Falls were below average over the period of record. West Fisher Creek was the only stream in this group that was approximately equal to the average. We observed the lowest redd counts in ten years in O'Brien Creek, but this was the only bull trout population located downstream of Libby Dam that exhibited a significant positive trend. The adjunct Bull Lake population, which spawns in Keeler Creek had only 26 redds in 2009, which was the second lowest count over the period of record (1996-present). Keeler Creek bull trout redd counts have been below the long-term average and the lowest since 2001.

MFWP attempted to conduct a population estimate for adult bull trout below Libby Dam during April 2010, but a low number of recaptured (marked) fish precluded obtaining an unbiased estimate of adult bull trout were present within this 3.5-mile section of the Kootenai River. We recaptured 27 bull trout in 2010 that were previously marked in 2005, 2006, 2007, 2008 or 2009 below Libby Dam ranging between 79 to 1,819 days prior. The recaptured bull trout grew an average of 142.0 mm (0.22 mm per day), and gained an average of 2293.3g (3.42 g per day).

MFWP monitored fine sediment (<6.35 mm) levels in eight bull trout spawning tributaries within the Montana portion of the Kootenai Basin using core sampling. In 2010, O'Brien had the highest levels of fine sediment, averaging 31.8%. West Fisher Creek had the lowest mean levels of fine sediment (22.9%), but has only been monitored for four years. Fine sediment levels on West Fork Quartz Creek have been consistently and relatively low across years, averaging 26.8%. Mean annual fine sediment levels on Pipe Creek were the second highest value of the eight streams we monitored, averaging 30.4% across years. Mean annual fine sediment levels in Bear Creek have been variable, averaging 26.8%, with no apparent trend obvious over the period 2002 to 2010. The two bull trout spawning tributaries located in Montana upstream of Libby Dam had relatively low fine sediment levels. Fine sediment in Grave Creek and the Montana portion of the Wigwam River have both averaged 26.3% from 1998 to 2010. The adjunct bull trout population that resides in Bull Lake and spawns in Keeler Creek had the lowest mean annual levels of fine sediment amongst the eight streams we monitored, averaging 22.2%.

Introduction

The primary objectives of the Libby Mitigation Project are to 1) Correct deleterious effects caused by hydropower operations and mitigate for fisheries losses attributed to the construction and operation of Libby Dam using watershed-based, habitat enhancement, fish passage improvements, and offsite fish recovery actions, 2) Integrate computer models into a watershed framework using MFWP's quantitative reservoir model (LRMOD), Integrated Rule Curves (IRC), Instream Flow Incremental Methodology (IFIM) and Libby Dam fish entrainment model (ENTRAIN), to improve biological production by modifying dam operation, and 3) Recover native fish species including the endangered Kootenai River white sturgeon, threatened bull trout, westslope cutthroat trout, interior redband rainbow trout, and burbot. A loss statement, site-specific mitigation actions and monitoring strategies were documented in the Libby Mitigation and Implementation Plan (MFWP et al. 1998) and Kootenai Subbasin Plan (KTOI and MFWP 2004).

Biological monitoring data was critical for empirically calibrating computer models used in management of water resources and operation of Libby Dam. The quantitative biological model LRMOD was calibrated using field data collected by project personnel from 1983 through 1990. Field data from 1991 through 1995 were used to refine and correct uncertainties in the model and add a white sturgeon component (Marotz et al. 1996 and 1999). These models include Integrated Rule Curves (IRC's), the Libby Reservoir model (LRMOD) and an alternate flood control strategy called VARQ, which stands for variable discharge (Q). The ultimate result has been the integration of fisheries operations with power production and flood control to reduce the economic impact of basin-wide fisheries recovery actions.

Investigations into the factors limiting native fish populations require a combination of field evaluation techniques. Characteristics evaluated include population densities, species assemblages and composition, fish length-at-age (otolith and scale aging), growth, condition factors, indices of abundance and biomass estimates. In this chapter we describe the results of the field activities required to gather this information.

In addition, habitat enhancement and fish passage improvement measures may be the most promising methods for recovering native resident stocks. This project has embraced this approach and implemented several restoration projects on a basin wide priority basis using a step-wise, adaptive management approach to correct limiting factors for bull trout, burbot, cutthroat trout, and redband trout in the Kootenai Basin (see chapter 2). Biological and physical monitoring is critical to assess the effectiveness of restoration or management actions designed to restore native fishes and their habitats. Evaluation of restoration actions will continue to determine the most cost-effective methods for enhancing these diverse populations. This chapter describes the physical and biological monitoring activities necessary to evaluate habitat restoration and passage improvements.

The bull trout that inhabit Libby Reservoir and Kootenai River represent geographically and genetically distinct and important populations within their range (USFWS

1999; Ardren et al. 2007). MFWP list bull trout as a species of special concern and in 1996 the United States Fish and The US Wildlife Service (USFWS), through the Endangered Species Act, listed bull trout as threatened throughout their range in 1998 (USFWS 1999).

Libby Dam, constructed on the mainstem Kootenai River in 1972, represents a major limiting factor affecting bull trout in the Kootenai River (USFWS 2002; Montana Bull Trout Scientific Group 1996a). Presently no fish passage facilities exist at Libby Dam and migration only occurs downstream through the dam. Previous studies have documented the passage of bull trout (Dunnigan et al. 2005; Skaar et al. 1996) downstream through Libby Dam, and a recent study funded by this project has indicated that at least half of the bull trout in the three mile section of river downstream of the dam between 2004 and 2007 were entrained (DeHaan et al. 2008). Dam operations represent a direct threat to bull trout in the middle Kootenai because of the biological effects associated with unnatural flow fluctuations and potential gas supersaturation problems arising from spill operations. The dam is a fish barrier, generally restricting a portion of this migratory population to 29 miles of river between Libby Dam and Kootenai Falls. Although MFWP has documented upstream bull trout passage at Kootenai Falls, the falls represent a substantial fish barrier at most current flow regimes. The Kootenai River is nodal habitat containing critical over-wintering areas, migratory corridors, and habitat required for reproduction and early rearing. Land use practices also constitute a high risk to bull trout in the middle Kootenai (Libby Dam to Kootenai Falls) due impacts on spawning and rearing habitat. These risks are accentuated due to the low number of spawning streams (Quartz, Pipe, O'Brien, Callahan and Libby Creek drainages) available; a direct result of habitat fragmentation caused by Libby Dam.

In the upper Kootenai (above Libby Dam), the threats to bull trout habitat include non-native fish introductions, rural residential development, and forestry practices. Additional risks come from mining, agriculture, water diversions, and illegal harvest (Montana Bull Trout Scientific Group 1996b). Critical spawning streams include the Grave Creek drainage in the U.S. and the Wigwam drainage in British Columbia. Beginning in 2004, MFWP opened a recreational bull trout fishery on Libby Reservoir for the first time since 1993. The fishery was established as an experimental exception to the Federally Listed threatened status of bull trout within the Columbia River Subbasin through negotiations with the US Fish and Wildlife Service. This fishery was established due to the relatively high abundance of bull trout in Libby Reservoir.

Bull trout are found below Kootenai Falls in O'Brien Creek, Callahan Creek and in Bull Lake. The latter is a disjunct population that migrates out of Bull Lake, downstream to Lake Creek then upstream in Keeler Creek. These fish inhabit areas in the lower Kootenai River and Kootenay Lake during most of the year.

MFWP conducts annual monitoring to assess bull trout trends in abundance and critical spawning and rearing habitat. We monitor annual escapement in eight critical tributaries used for spawning by conducting redd counts within index reaches of each stream, and within these stream we monitor fin sediment levels in order to evaluate the potential impact of sediment on egg survival. We also monitor bull trout abundance within the Libby Dam tailrace and conduct genetic assessments to estimate annual entrainment (DeHann et al. 2008). In 2007, we also assessed the impact of non-native brook trout on hybridization with bull trout in four tributaries in the Kootenai Basin.

Methods

Burbot Monitoring Below Libby Dam

Baited hoop traps are an effective gear to capture burbot (Bernard et al. 1991), and MFWP has monitored burbot densities directly downstream of Libby Dam since 1994, using baited hoop traps during December and February to capture burbot in or near spawning condition. The trapping effort in 2003 was expanded to include the month of January because a modified flood control strategy (VARQ) was implemented beginning in January 2003. Two hoop traps measuring 2-feet diameter, approximately 6-8 feet in length with ¾ inch net mesh were baited with cut bait (usually kokanee, depending upon availability) and lowered in the stilling basin downstream of Libby Dam at depths ranging from 20-55 feet (Figure 1). Sash weights attached to the cod end of each hoop trap securely positioned the trap on the bottom. Traps were generally checked twice per week unless catches substantially increased between periods. Captured burbot were enumerated, examined for a PIT (passive integrated transponder) tag, measured, PIT tagged with a 125 or 134.2 KHz PIT tag if not previously tagged, and released. Fish less than approximately 350 mm total length were not tagged. PIT tags were inserted with an 8 or 12-gauge hypodermic needle into the musculature of the left operculum. We standardized the catch in terms of the average catch per trap day, in order to compare burbot catch rates among years.

Figure 1. An aerial photograph of Libby Dam, looking downstream. The red symbols represent typical locations that hoop traps are positioned below Libby Dam for burbot monitoring.

Juvenile Salmonid Population Estimates

MFWP conducted juvenile salmonid population estimates on Sinclair, Therriault, Young, Libby, Grave, and Pipe creeks in 2006, as part of an effort to monitor long-term trends in juvenile salmonid abundance, size distribution and species composition associated with past or future stream restoration efforts. We conducted estimates on each stream with mobile electrofishing gear using DC current for multiple pass depletions similar to Shepard and Graham et al. (1982). We placed a block net at the lower end of each section and electrofished from the upper end of the section towards the lower end. After two such passes were completed, we estimated the probability of capture (P) using the following formula.

$$P = C1 - C2 / C1$$

Where: C1 = number of fish >75 mm total length captured during first catch and
C2 = number of fish > 75 mm total length captured during second catch.

Based on captures made during the first two passes, if P was $\geq$ 0.7, a third pass was conducted. Population estimates were performed for fish $\geq$ 75 mm, consistency with historic data collected prior to 1997. Population estimates and associated 95% confidence intervals were estimated using *Microfish 2.2* (Van Deventer and Platts 1983). We evaluated trends in abundance using multiple regression. We compared fish abundance at sites where we performed stream restoration efforts using student's t-test to evaluate differences in abundance before and after restoration was completed. We also previously established control sections in Young, Therriault, and Libby creeks, which enabled us to utilize the more powerful Before/After/Control (BACI) design at these restoration sites. A description of reach sampled within each tributary is presented below.

Therriault Creek

We established three monitoring sections in Therriault Creek for juvenile salmonid trend analyses (Hoffman et al. 2002). Section one began at the Highway 93 culvert and extended 82 m upstream, and is located 0.61 miles downstream of the lower project boundary of the Therriault Creek Restoration Project. The upstream boundary of section two began at the upper end of the Therriault Creek Restoration Project that was finalized in the spring of 2005 and is located approximately 3.4 miles upstream from the Therriault Creek confluence. Section three is located 0.23 miles upstream of the upper boundary of the restoration project, and this section is moderately stable. Sections one and three are intended as control sites.

Grave Creek

We established a representative sampling reach on Grave Creek to perform population estimates. The shocking section begins at the Vukonich Bridge, which is located 3.5 miles upstream of the Grave Creek confluence, and extends downstream 1,000 feet to the lower boundary of the Demonstration Project. Baseline fish population data for Grave Creek prior to the completion of the demonstration project were collected in 2000 and 2001.

Due to the high volume of water in lower Grave Creek, a CPUE was conducted rather than the usual depletion population estimate in 2000 and 2001. We used a Coleman canoe electrofishing boat with a mobile electrode to sample this section. The system consisted of a Cofelt model VVP-15 rectifier powered by a 4000 watt generator. Our estimates are for fish ≥ 75 mm long (total length, TL) for consistency with data previously collected on other Kootenai River tributaries. This section of Grave Creek was sampled via electrofishing in 2003-2008. However, sampling in 2002 was limited to snorkel observations due to the presence of >2,000 adult kokanee salmon in the monitoring section. Two observers moved slowly upstream enumerating trout estimated to be ≥ 75 mm total length.

Young Creek

MFWP previously established five monitoring sections in Young Creek to assess trends in juvenile salmonid abundance within the Young Creek watershed (Huston et al. 1984). However, MFWP has curtailed monitoring to include only three sections; including the following:

- Section 1: Tooley Lake Section. This section is located 0.65 miles upstream of Koocanusa Reservoir (at full pool), 2.73 miles downstream of the Young Creek State Lands Restoration Project, and is intended to serve as a control site.
- Section 4: Dodge Creek Road #303. This section is located 2.42 miles upstream from Young Creek State Lands Restoration Project, 5.8 miles upstream of Koocanusa Reservoir (at full pool), and is intended to serve as a control site.
- Section 5: State Lands Restoration Project. This section is located at the upper boundary of the restoration project, and is located 3.38 miles upstream of Koocanusa Reservoir (at full pool).

Libby Creek

MFWP personnel collected fish population information in six sites on Libby. We sampled Sections 1, 4 and 6 using a Coleman canoe outfitted with a mobile electrode. The system consisted of a Cofelt model VVP-15 rectifier powered by a 4000 watt generator. The other sections were sampled with a two Smith Root backpack electrofishers. The section locations are as follows:

- Section 1: is approximately 1,000 feet long, begins at the upper end of the Libby Creek Demonstration Project area and is located 0.79 miles downstream of the Highway 2 bridge. This section is located at approximately river mile 12.3.
- Section 2: is a 171 m long reach located ~100 m upstream of the Highway 2 bridge at approximately river mile 13.1

- Section 3: is a 171 m long reach located on the upper Cleveland Restoration Project, and is the upper most section in the watershed sampled. This section is located at approximately river mile 22.3.
- Section 4: is a 201 m long reach located downstream of the lower Cleveland property, is intended to serve as a control site for the lower Cleveland Stream Restoration Project, and is located at approximately river mile 19.7.
- Section 5: is a 143 m long reach located upstream of the lower Cleveland property upstream of the bridge on Forest Rd. number 231, and is intended to serve as a control site for the lower Cleveland Stream Restoration Project. This section is located at approximately river mile 20.5.
- Section 6: is a 172 m long reach near the confluence of Midas Creek located within the lower Cleveland Phase II Stream Restoration Project, and is located at approximately river mile 20.2.

Pipe Creek

MFWP established a single monitoring section on lower Pipe Creek in 2001 below the Bothman Road Bridge at approximately 0.25 miles upstream of the confluence with the Kootenai River. This section was established to collect baseline biological data prior to a scheduled stream restoration project on lower Pipe Creek. This section has been sampled annually since 2001.

Libby Reservoir Gillnet Monitoring

MFWP has used gillnets since 1975 to assess annual trends in fish populations and species composition. These yearly sampling series were accomplished using criteria established by Huston et al. (1984). This report focuses on the period 1988 through 2006, but the entire database (1975 through 2006) was occasionally used to show long-term catch trends.

Netting methods remained similar to those reported in Chisholm et al. (1989). Netting effort has continually been reduced since it was first initiated in 1975. During the period 1975-1987 a total of 128 ganged (coupled) nets were fished. This was reduced to 56 in 1988-1990, and reduced again to 28 ganged floating and 28 single sinking nets in 1991-1999. Effort was further reduced to 14 ganged nets from 2000 to present. Furthermore, netting effort occurred in the spring and fall, rather than the year round effort prior to 1988. Only fish exhibiting morphometric characteristics of pure cutthroat (scale size, presence of basibranchial teeth, spotting pattern and presence of a red slash on each side of the jaw along the dentary) were identified as westslope cutthroat trout; all others were identified as rainbow trout (Leary et al. 1983). Inland rainbow trout (Gerrard and Duncan strain) were distinguished from wild rainbow trout by eroded fins (pectoral, dorsal and caudal) and/or presence of hatchery adipose clip.

Species abbreviations used throughout this report are: rainbow trout (RBT), inland rainbow trout (IRB), westslope cutthroat trout (WCT), rainbow X cutthroat hybrids (HB), bull trout (BT), kokanee salmon (KOK), mountain whitefish (MWF), burbot (LING), peamouth chub (CRC), northern pikeminnow (NPM), redside shiner (RSS), largescale sucker (CSU), longnose sucker (FSU), and yellow perch (YP).

The year was stratified into two gillnetting seasons based on reservoir operation and surface water temperature criteria:

1) Spring (April - June): The reservoir was being refilled, surface water temperatures increased to 9 - 13^{o}C.

2) Fall (September - October): Drafting of the reservoir began, surface water temperature decreased to 13 - 17^{o}C.

Seasonal and annual changes in fish abundance within the nearshore zone were assessed using floating and sinking horizontal gillnets. These nets were 38.1 m long and 1.8 m deep and consisted of five equal panels of 19-, 25-, 32-, 38-, and 51-mm mesh.

Fourteen to twenty-eight floating (ganged) and one or two single, sinking nets were set in the fall in the Rexford and Canada portions of the reservoir. Spring netting series consisted of 20 to 111 (standardized to 28 in 1991) sinking nets and an occasional floating net set only in the Rexford area. Spring floating, and fall sinking, net data were not included in this report because net placement was not standardized. Nets were set perpendicular from the shoreline in the afternoon and were retrieved before noon the following day. All fish were removed from the nets and identified, followed by collection of length, weight, sex and maturity data. Scales and a limited number of otoliths were collected for age and growth analysis. When large gamefish (Kamloops rainbow, cutthroat, bull trout or burbot) were captured alive, only a length was recorded prior to release.

We calculated catch per unit effort (CPUE) for all species of fish captured during each fall and spring sampling event by dividing the total number of fish captured by the total number of nets fished. We used multiple regression to evaluate trends in catch per unit effort through time.

Libby Reservoir Zooplankton Monitoring

MFWP has collected zooplankton from Libby Reservoir since 1983 in an attempt to relate changes in density and structure of the community to parameters of other aquatic communities, and to collect data indicative of reservoir processes, including aging and the effects of reservoir operation. We performed monthly vertical zooplankton tows using a 0.3 m, 153µ Wisconsin net in each of three reservoir areas (Tenmile, Rexford and Canada) from 1983 to 1996. However, beginning in 1997, we reduced sampling effort to the period April through November, after a rigorous analysis indicated we would not compromise our ability to identify trends (Hoffman et al. 2002). In an effort to further standardize sampling methodologies, we experimented with the effects of sample depth on the resulting analyses. When we excluded samples of greater than 20 m, the results were statistically similar (Kruska-Wallis $p = 0.05$; Hoffman et al. 2002) relative to analyses including depths of 30 m with regards to total zooplankton abundance. These results corroborate previous results from Schindler trap sampling that found that approximately 90% of all zooplankton captured were from depths of 20 m or less (Skaar et al. 1996). Therefore, beginning in 1997, we conducted 20 m sampling tows when depth permitted, and when depth was between 10 and 20 m we sampled the entire water column. We did not collect samples when depth was less than 10 m. This differed from sampling protocols used from 1983 through 1989, where one sample was taken from a permanent station and two samples were taken randomly in each area, regardless of water depth. However, we made two sampling protocol changes in 1990, 1) We only collected zooplankton samples when depth was at least 10 m, and 2) all sampling locations (reservoir mile) and bank (east, west or middle) were randomly selected. All samples were pulled at a rate of 1 m/second to minimize backwash (Leathe and Graham 1982).

Zooplankton samples were preserved in a water / methyl alcohol / formalin / acetic acid solution from September 1986 to November 1986. After December 1986, all samples were preserved in 95% ethyl alcohol to enhance egg retention in Cladocerans.

Low density samples (<500 organisms total) were counted in their entirety. High-density samples were diluted to a density of 80 to 100 organisms in each of five, five ml aliquots. The average of the five aliquots was used to determine density. We randomly subsampled and measured the length of approximately 30 *Daphnia*, *Diaptomus*, *Epischura* and *Diaphanosoma* to estimate abundance within 0.5 mm length classes, and to estimate mean length of each genera. We used analysis of variance, and subsequent Tukey multiple comparisons to assess whether zooplankton abundance differed by month and sampling area.

Bull Trout Redd Counts

Redd surveys were conducted in October after bull trout spawned in the Wigwam and West Fisher Creeks and Grave, Quartz, Bear (a tributary to Libby Creek), Keeler, Pipe, and O'Brien creeks. Personnel from the British Columbia Ministry of Water, Land, and Air Protection conducted redd counts on the Wigwam River and associated tributaries. Observers enumerated "positive" and "possible" redds. "Possible" redds were those that did not have fully developed pits and egg mounds. Since 1993, only "positive" redds have been counted, and are included in tables and figures for this report. In addition to counting redds, size and location of redds were also noted. Surveyors recorded suitable habitat and barriers to spawning bull trout when a stream was surveyed for the first time. We used linear regression of redd counts to assess population trends through time.

Kootenai River Adult Bull Trout Population Estimate

We collected adult bull trout using nighttime electrofishing by jet boat to perform a mark-recapture population estimate of bull trout in the Kootenai River from Libby Dam (River mile [RM] 221.7) downstream to the confluence of the Fisher River (RM 218.2). We marked bull trout on the evenings of April 9 and 10, 2008, and performed recapture sessions on April 16 and 17, 2008. We operated two jet boat electrofishing crews during each of the other two sampling events. Each boat contained a driver and two netters. Our electrofishing unit on each boat consisted of a Coffelt model Mark 22 electrofishing unit operating with an electrical output ranging from 200-350 volts at 5-8 amps powered by a 5,000 watt gasoline powered generator. In order to thoroughly electrofish the entire 3.5 miles of Kootenai River, we divided the sample area into 2 sections, and conducted electrofishing on each section on a single evening. Section 1 was from Libby Dam downstream to the Alexander Creek confluence (RM 220.5), and was 1.2 miles long, and was sampled on April 9 and 16, respectively. Section 2 was from the Alexander Creek confluence downstream to the Fisher River Confluence, and was 2.3 miles long, and was sampled on April 10 and 17.

We recorded the total time (minutes) electrical current was generated in the water as a measure of effort. We measured total length (mm), weighed (g), examined all fish for marks, collected scale samples, and released all bull trout captured near their capture location. All bull trout were marked with individually numbered 134.2 (ISO) KHz passive integrated transponder (PIT) tags and an adipose fin clip was removed to evaluate PIT tag retention. PIT tags were inserted with an 8 or 12-gauge hypodermic needle into the musculature behind the dorsal fin.

We estimated bull trout abundance using a mark-recapture population estimation technique which assumes the population of bull trout is “closed”, suggesting no births, deaths or migrations occurred during sampling periods (Ricker 1958). Additional assumptions were that marked and unmarked fish have equal mortality rates, marked fish were randomly distributed throughout the study area, marks were not lost, and all marked fish captured were recognized and counted (Lagler 1956). We used the Petersen Estimator as modified by Chapman (Ricker 1958) to estimate absolute abundance of bull trout where:

$$N = \frac{(M + 1) \bullet (C + 1)}{R + 1} - 1 + Morts \qquad [1]$$

Where:
- N = population estimate,
- C = total fish captured in the recapture sample(s),
- M = number of marked fish at the start of recapture sample period and
- R = number of marked fish in the recapture sample(s)
- Morts = number unmarked mortalities captured during the marking sessions.

We used the following formula to calculate bounds (B) for 95% confidence intervals for N:

$$B = 1.96 \times \sqrt{\frac{N^2 \bullet (C - R)}{(C + 1) \bullet (R + 2)}} \qquad [2]$$

We compared the mean length of bull trout captured during our 2009 sampling to the mean length of bull trout captured during similar sampling conducted annually from 2004 to 2008 using ANOVA and subsequent Tukey multiple comparisons. For all PIT tagged bull trout that were captured from previous marking sessions, we calculated the average total length and weight gain since time of original capture.

Bull Trout Spawning Substrate Surveys

Sample Collection and Processing

We used a standard 15.2 cm hollow core sampler (McNeil and Ahnell 1964) to collect four samples across each of three transects from each fluvial or adfluvial bull trout tributary in the Montana portion of the Kootenai watershed in order to assess potential trends in bull trout emergence success. We located coring sites within each stream using a stratified random selection process during the winter months (generally February through March). The total width of stream having suitable depth, velocity, and substrate for spawning was visually divided into four equal cells. We randomly took one core sample in each cell. In some study areas we deviated from this procedure due to limited or discontinuous areas of suitable spawning habitat. We selected study areas based on observations of natural spawning. We only sampled in spawning areas used by adfluvial and fluvial bull trout. During the period of study, these fish spawned in the same general areas, so sampling locations remained similar.

Sampling involved working the corer into the streambed to a depth of 15.2 cm. We removed all material inside the sampler and placed it in a heavy duty plastic bags. We labeled the bags and transported them to the Kootenai National Forest Soils Laboratory in Libby, Montana, for gravimetric analysis. We sampled the material suspended in water inside the corer using an Imhoff settling cone (Shepard and Graham 1982). We allowed the cone to settle for 20 minutes before recording the amount of sediment per liter of water. After taking the Imhoff cone sample, we determined total volume of the turbid water inside the corer by measuring the depth and referring to a depth to volume conversion table (Shepard and Graham 1982).

The product of the cone reading (ml of sediment per liter) and the total volume of turbid water inside the corer (liters) yields an approximation of the amount of fine sediment suspended inside the corer after sample removal. We than applied a wet to dry conversion factor developed for Flathead tributaries by Shepard and Graham (1982), yielding an estimated dry weight (g) for the suspended material.

We oven dried the bagged samples and sieve separated them into 13 size classes ranging from >76.1 mm to <0.063 mm in diameter (Table 1). We weighed the material retained on each sieve and calculated the percent dry weight in each size class. The estimated dry weight of the suspended fine material (Imhoff cone results) was added to the weight observed in the pan, to determine the percentage of material <0.063 mm. We refer to each set of samples by using the mean percentage <6.35 mm in diameter. This size class is commonly used to describe spawning gravel quality, and it includes the size range typically generated during land management activities. We examined the range of median values for this size class observed throughout the survey area.

Analyses

We pooled up to 12 substrate samples from each stream within a given year and performed an arcsine transformation on the percentage on the <6.35 mm in diameter within each sample. We re-transformed all data back for graphical display purposes. We performed an analysis of variance to test for differences between years within a given stream. Post hoc multiple comparisons (Tukey's HSD) were performed if yearly differences existed ($p < 0.05$). All statistical analyses were performed using SPSS 7.5 Software.

Table 1. Mesh size of sieves used to gravimetrically analyze hollow core streambed substrate samples collected from Kootenai River basin tributaries.

Mesh Size (mm)	Mesh Size (inches)
76.1 mm	3.00 inch
50.8 mm	2.00 inch
25.4 mm	1.00 inch
18.8 mm	0.74 inch
12.7 mm	0.50 inch
9.52 mm	0.38 inch
6.35 mm (Pan)	0.25 inch

Results and Discussion

Burbot Monitoring Below Libby Dam

The burbot catch in our hoop traps below Libby Dam has declined precipitously since 1996/1997 (Figure 2). During the 2009/2010 trapping season we caught four burbot below Libby Dam after fishing a total of 362 trap days, for an equivalent catch rate of 0.011 burbot/trap/day. This catch represents the highest catch rate since 2005. The highest catch rates occurred in 1995-96 and 1996-97. The mean annual catch rate since the 1994/1995 trapping season was 0.421 burbot per trap day. However, the catch rates since then have exhibited a significant negative trend ($r^2 = 0.391$; $p = 0.001$; Figure 2). The mean annual catch rate for the 1990s (1.20 fish/trap day) is significantly higher than the catch rate for the 2000s (0.07 fish/trap day; $p = 0.003$ two tailed t-test).

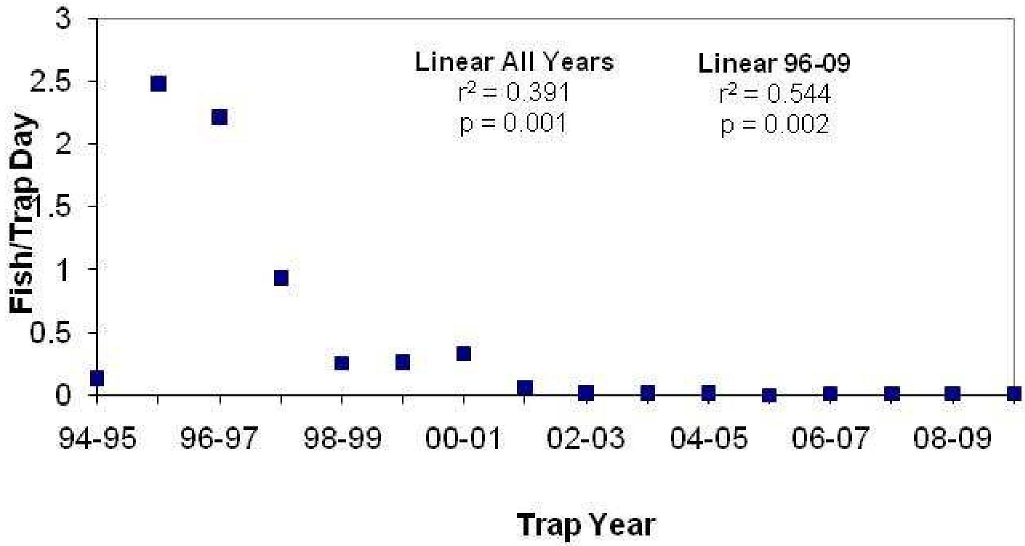


Figure 2. Total catch per effort (burbot per trap day) of baited hoop traps in the stilling basin downstream of Libby Dam 1994/1995 through 2009/2010. The traps were baited with kokanee salmon and fished during December through February.

Juvenile Salmonid Population Estimates

Therriault Creek

Section 1 on Therriault Creek is located downstream of the Therriault Creek Restoration Project Area, and is used as a control site to compare pre- and post-restoration fish populations. MFWP has sampled this site annually since 1997, with the exception that this site was not sampled in 2000-2002. Rainbow and brook trout have been observed at this site every year it has been sampled. Rainbow trout abundance in Section 1 of Therriault has not differed significantly from a stable population ($r^2 = 0.01$; $p = 0.84$; Figure 3; Table A1). The mean abundance of rainbow trout during the period of record was 102.7 fish per 1,000 feet, with the observed abundance in 2009 (113.4 fish per 1,000 feet) 10.5% higher than the annual mean. The trend in brook trout abundance for this section has shown a nearly significant increasing trend ($r^2 = 0.31$; $p = 0.095$; Figure 3; Table A1), and has averaged 68.4 brook trout per 1,000 feet, with the observed abundance of brook trout in 2009 (134 brook trout per 1,000 feet) almost twice as high as the average of record. Juvenile bull trout have been detected annually at this site since 2003, with abundance being highest in 2004 (92.1 bull trout per 1,000 feet). In 2009, we estimated 34.4 bull trout per 1,000 feet were present in this section of Therriault Creek, which was about 52% higher than the mean over the observation period (22.7 bull trout per 1,000 feet). The high variability in catch of bull trout at this site precluded detecting a significant trend in abundance ($r^2 = 0.16$; $p = 0.25$; Figure 3). We did not observe any cutthroat trout at this site in 2009. The only year during the period of record that we observed any cutthroat trout at this site was in 2008.

Section 2 on Therriault Creek lies within the Therriault Creek Restoration Project area and was sampled in 1997-1999, 2001, and 2003-2009. The data we collected in 2009 represented the fifth year after project completion, and was used to compare to data collected prior to project implementation (1997-2004). We observed rainbow, brook and bull trout at this site every year we sampled this site. (Table A1). We used linear regression to evaluate population trends for each of these three species. Rainbow and brook trout abundance at this site both showed nearly significant declines in abundance over the period of record ($r^2 = 0.26$; $p = 0.11$ and $r^2 = 0.28$; $p = 0.10$, respectively). Bull trout abundance at this site also exhibited a negative trend, but not significantly ($r^2 = 0.14$; $p = 0.25$; Figure 4). We estimated 28.8, 54.1, and 6.8 rainbow, brook, and bull trout, respectively per 1,000 feet within the project area in 2009, which was 48.7, 14.5, and 57.6% lower than each of the annual mean over the period of record. The mean abundance of rainbow trout we observed within this section after implementation (2005-2009) was 29.3 rainbow trout per 1,000 feet, which was 62.7% lower than the mean abundance prior to project completion (Figure 5; pre-project mean = 78.4 fish per 1,000 feet). Brook trout abundance at the restoration site also decreased after project implementation by an average of 19.7% (Figure 6). Brook trout abundance slightly decreased within the project area (Section 2) after project completion decreasing from 69.5 to 55.8 fish per 1,000 feet after the project completion. The variation in bull trout abundance over time was higher than the variation in rainbow or brook trout abundance at all three sections (Figure 6). Bull trout abundance within the project reach after implementation decreased compared to the pre-project levels by 84.3%. Given the variability in bull trout abundance in the pre-implementation years (1997-2004) detecting a significant difference as a result of the restoration project is difficult (see below).

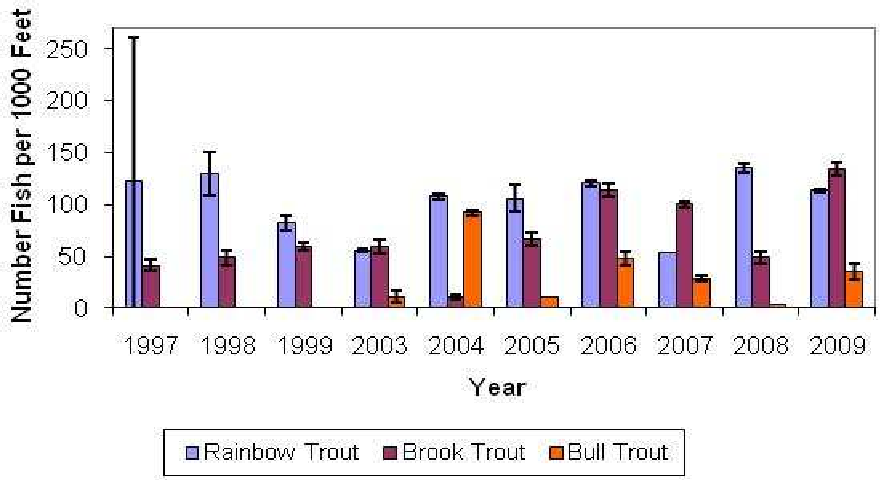


Figure 3. Rainbow trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 1 monitoring site from 1997-1999 and 2003-2009 collected by backpack electrofishing. The error bars represent 95% confidence intervals.

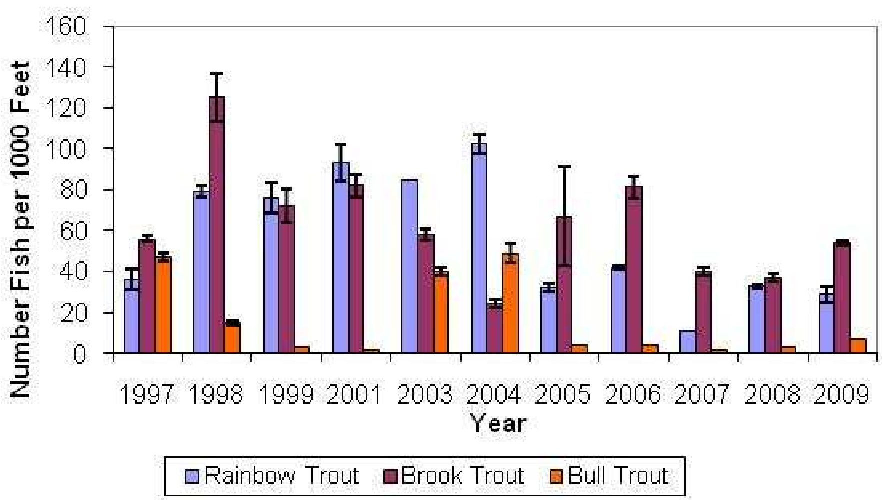


Figure 4. Rainbow trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 2 monitoring site from 1997-1999, 2001 and 2003-2009 collected by backpack electrofishing. The error bars represent 95% confidence intervals.

Section 3 on Therriault Creek is located upstream of the Therriault Creek Restoration Project area and was sampled in 1997-1999, and 2003-2008 (Table A1), and is used as a control site to compare pre- and post-restoration fish populations. We observed rainbow and brook trout at this site each year, but bull trout were only observed in 2003-2009. The trend of rainbow trout abundance has exhibited a nearly significant decline since 1997 ($r^2 = 0.39$; $p = 0.056$; Figure 5; Table A1), and the trend in brook trout abundance has also significantly decreased ($r^2 = 0.43$; $p = 0.039$). However, bull trout abundance at this site has significantly increased since 1997 ($r^2 = 0.432$; $p = 0.039$; Figure 5). These trends were also consistent when we compared estimated abundances at this site in 2009 to the annual mean, with rainbow trout decreasing by 33.8%, brook trout decreasing by 11.4% and bull trout increasing by over 200%.

We compared the abundance of rainbow, brook and bull trout within the restoration project area (Section 2) to control sites located below and above the restoration project (Sections 1 and 3, respectively), using the Before/After/Control/Impact (BACI) statistical design. This design uses a paired t-test to assess differences between the Control and Treatment (impact) sites before and after project implementation. Because the test is only capable of using a single control site, we conducted the test for each of the control sites (Sites 1 and 3) and for each species of fish (rainbow, brook and bull trout), for a total of six individual tests (Tables 2 and 2). The mean difference (Control - Treatment) in rainbow, brook and bull trout abundance between Sections 1 and 2 decreased in each comparison, suggesting that the abundance of each species within the project area decreased after project implementation (Table 2). Comparisons were significant using the more conservative two-tailed test for rainbow trout ($p = 0.048$), and brook trout ($p = 0.018$), but not significant for bull trout ($p = 0.110$; Table 2). This trend was nearly the opposite scenario when we used Section 3 as a control and compared it to Section 2 for rainbow and brook trout abundance (Table 3). However, these comparisons were not significant ($p > 0.05$; Table 3). The results of a student's t-test for rainbow trout abundance within the restoration project area, support the hypothesis that rainbow trout abundance decreased at this site after the project was completed (mean prior = 78.4, mean after = 29.3; $p = 0.002$ for a two tailed test). Bull trout abundance in Section 2 relative to Section 3 significantly decreased the five years following project completion ($p = 0.005$; Table 3). The results of a student's t-test for bull trout abundance within the project area support this observation also (mean prior = 26.0, mean after = 4.1; $p = 0.054$ for a two tailed test).

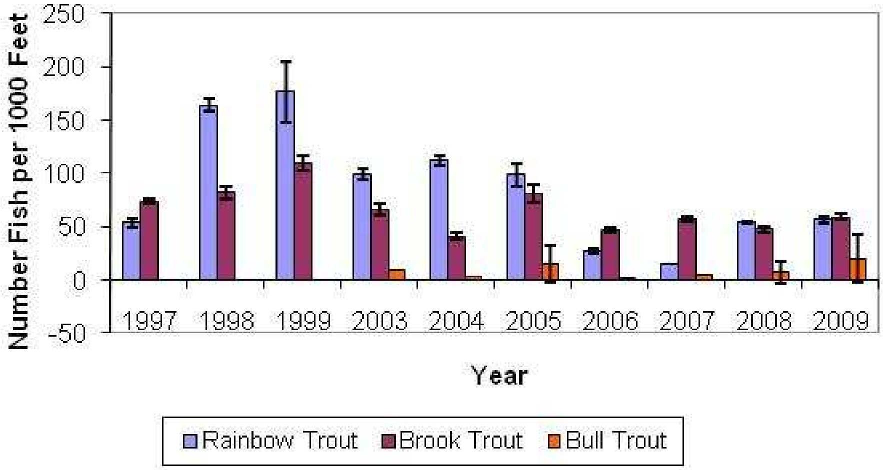


Figure 5. Rainbow trout, bull trout and brook trout densities (fish per 1,000 feet) within the Therriault Creek Section 3 monitoring site from 1997-1999 and 2003-2009 collected by backpack electrofishing. The error bars represent 95% confidence intervals.

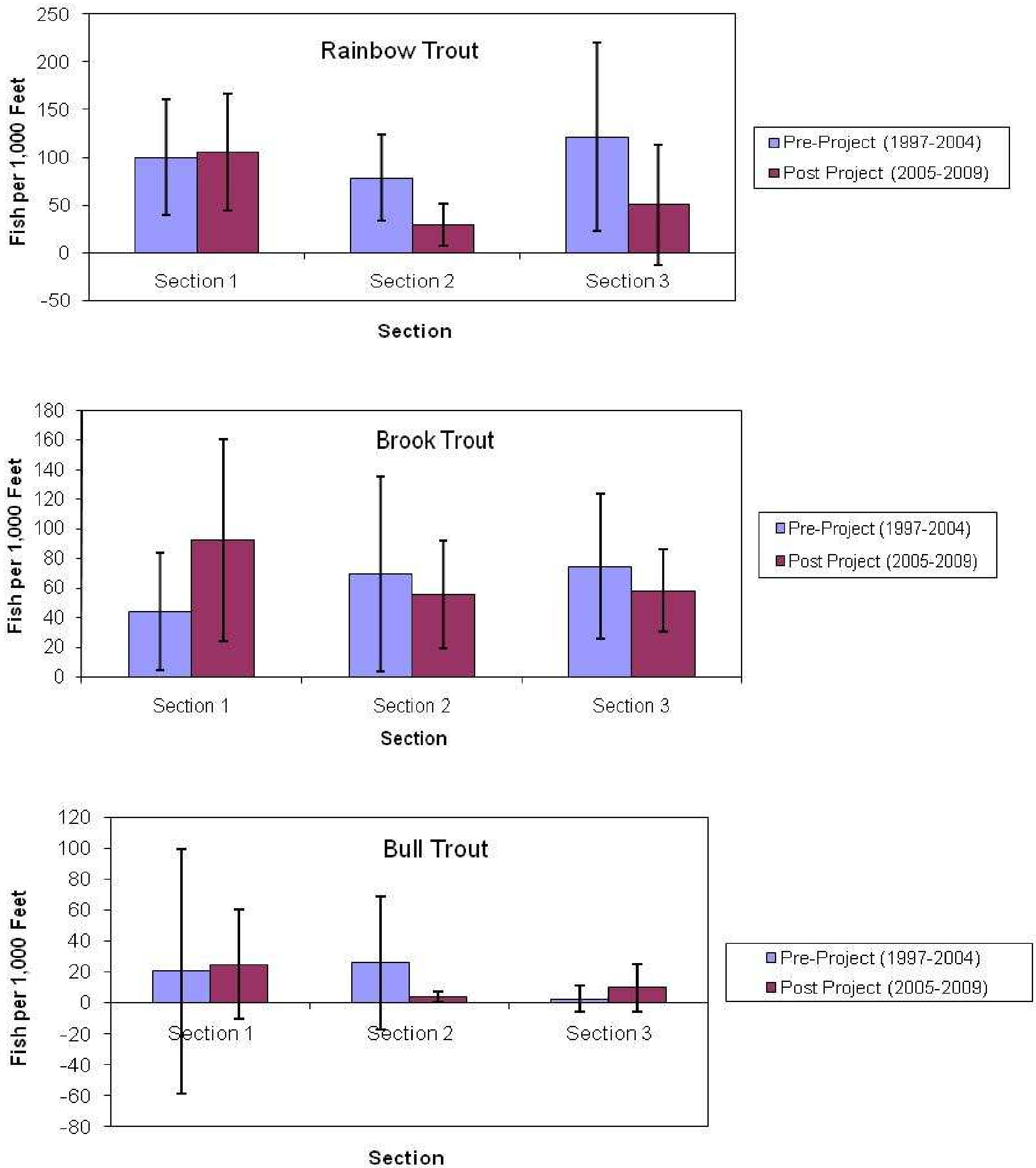


Figure 6. Rainbow (upper), brook (mid), and bull (lower) trout densities (fish per 1,000 feet) within the Therriault Creek Sections 1 and 3 represent control sites located downstream and upstream, respectively of the treatment section (Section 2). Data that was collected from 1997-2004 represents pre-project, and data collected in 2005-2009 represents post-project results. Depletion estimates were calculated from backpack electrofishing. The error bars represent 95% confidence intervals.

Table 2. Results from a paired t-test (BACI) of the differences between control (Section 1) and treatment (Section 2) on Therriault Creek before and after the restoration project was completed in 2005.

	Rainbow Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	24.2	76.5	-23.1	37.0	-10.1	20.7
Variance	2038.8	484.9	918.9	1112.7	1157.9	311.8
Sample size (n)	5	5	5	5	5	5
P-value (1-tailed)		0.024		0.010		0.055
P-value (2-tailed)		0.048		0.018		0.110

Table 3. Results from a paired t-test (BACI) of the differences between control (Section 3) and treatment (Section 2) on Therriault Creek before and after the restoration project was completed in 2005.

	Rainbow Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	45.5	21.0	7.8	2.5	-28.1	14.6
Variance	1916.9	910.9	920.3	459.1	365.9	260.9
Sample size (n)	5	5	5	5	5	5
P-value (1-tailed)		0.166		0.380		0.003
P-value (2-tailed)		0.332		0.760		0.005

Grave Creek

Juvenile salmonid monitoring within the Grave Creek Demonstration Project had two primary objectives, to determine fish population trends through time and to evaluate the fish community response to the restoration activities completed during the fall of 2001 (Grave Creek Demonstration Project). Bull trout were the most abundant fish species present at this site for the sixth consecutive year (Table A2). We compared mean fish abundance (by species) for pre (2000-2001) and post (2002-2009) restoration projects using t-tests (two-tailed tests; Figure 7). Bull trout and rainbow trout were the two most abundant species at this site, and mean abundance of each species was higher after the project was implemented. However, variability in pre- and post-project fish abundance estimates is high (Figure 7 and 8), and sampling methodology differed between years. These factors reduced our ability to distinguish statistical differences in abundance before and after project completion. Rainbow trout abundance increased substantially from 9.0 to 25.6 (184%) rainbow trout per 1,000 feet after project construction. However, this difference was not significant (Figure 7; $p = 0.18$; two-tailed test), and the observed power of the test was very low (0.18). Despite the increase in abundance of rainbow trout after project completion, we were not able to detect a significant trend over time ($r^2 = 0.002$; $p = 0.89$). Bull trout abundance after project completion also increased over 3.5 fold from 17.0 to 59.9 bull trout per 1,000 feet after project completion, which represented a nearly significant increase ($p = 0.068$; two tailed test), but the power of this test was also low (0.46). Bull trout abundance was the only species we were able to detect a significant trend over the period of record ($r^2 = 0.44$; $p = 0.03$). The linear fit for all other species was poor and did not differ significantly from stable populations (Figure 8). Brook trout and westslope cutthroat trout abundance were nearly identical before and after project completion, with the mean differences less than 2.0 fish per 1,000 feet ($p > 0.68$; Figure 7). We were unable to use the more powerful Before/After/Control/Impact (BACI) statistical design to compare fish abundances at this site due the lack of an adequate control site nearby in Grave Creek. Annual variability of fish abundance within this restoration site is relatively large, and likely limits our ability to detect changes that result from restoration efforts. Given the lack of a control site, additional years of fish population monitoring prior to restoration may have also improved the statistical power of most of our tests to detect change relative to the restoration activities.

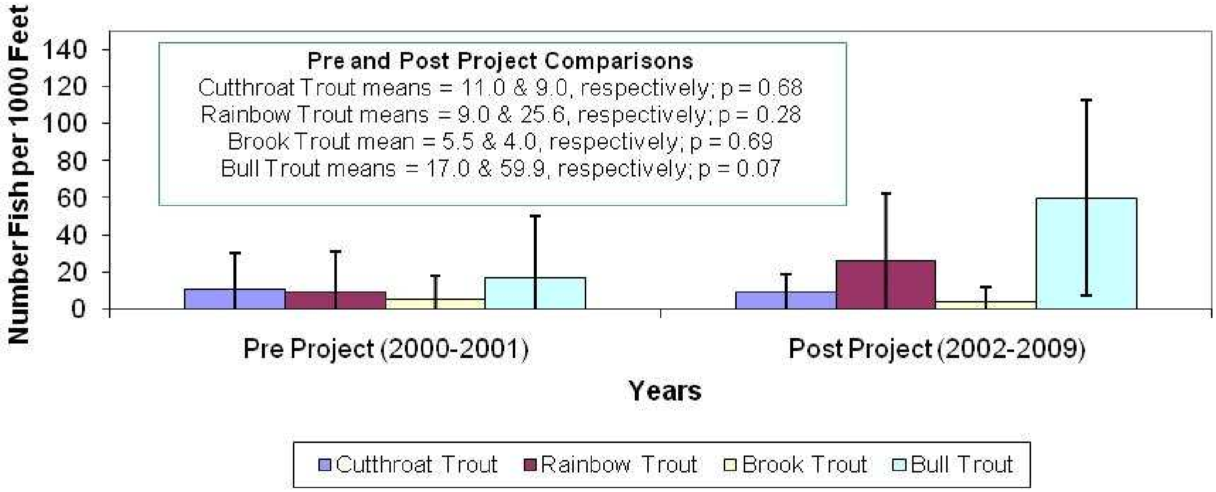


Figure 7. Mean cutthroat, rainbow, brook, and bull trout densities (fish per 1,000 feet) within the Grave Creek Demonstration Project area prior to (2002-2001) and after (2002-2009) the completion of the Grave Creek Demonstration Restoration Project. Data collected during 2000 and 2001 represent pre-project implementation fish abundances and were collected using single pass electrofishing. Fish abundance data collected in 2002 represents post-project implementation fish abundances and was collected via snorkel counts. All other data were collected using multiple pass depletion electrofishing. Error bars represent 95% confidence intervals.

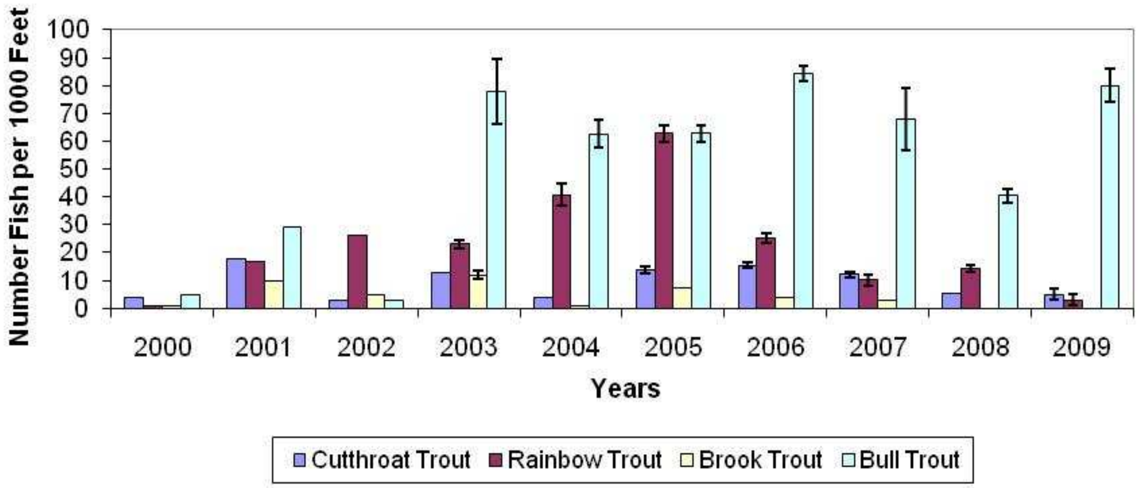


Figure 8. Cutthroat, rainbow, brook, and bull trout abundance estimates (fish per 1,000 feet) and linear regression trend analyses within the Grave Creek Demonstration Project monitoring site from 2000-2006 collected by backpack electrofishing. The 2000 and 2001 data were collected using single pass electrofishing, the data collected in 2002 was collected via snorkel counts, and the 2003- 2009 data was collected using multiple pass electrofishing. Error bars represent 95% confidence intervals.

Young Creek

The Young Creek Section 1 juvenile monitoring site was sampled consecutively from 1997-2009, with the exception of 2000 and 2003 (Table A3), and is intended to serve as a control section relative to the restoration project area (Section 5). There was no evidence of linear trends in abundance for cutthroat, rainbow, or brook trout from 1997-2009 ($p > 0.05$; Figure 9). Cutthroat trout have been the most abundant species of fish at this site since 1997, with the exception of 2005 and 2009, when brook trout were slightly more abundant (Figure 9). Cutthroat trout abundance peaked at this site in 1999 when we observed 139 cutthroat trout per 1,000 feet. In 2009, we observed an estimated 38.3cutthroat trout per 1,000 feet, which was 39% lower than the average over the observation period of 62.5 fish per 1,000 feet (Figure 9). In 2009, brook trout were slightly more abundant as cutthroat trout at this site, with an estimated abundance of 44.7 brook trout per 1,000 feet (Figure 9), which was slightly lower (6.7)% than the long-term average since 1996 (47.9 fish per 1,000 feet). Bull trout were first observed at Section 1 in 2004-2006, and a in 2009, we observed an estimated 27.7 bull trout per 1,000 feet, which was the highest abundance over the period of record, and was nearly six fold the annual average of 4.0 fish per 1,000 feet. Bull trout abundance trend exhibited a nearly significant increase ($r^2 = 0.31$; $p = 0.078$; Figure 9). The juvenile bull trout we observed in this section may have immigrated from the reservoir since no bull trout spawning is known to occur in Young Creek.

The Young Creek Section 4 juvenile monitoring site was sampled consecutively from 1996-2009, with the exception of 2000 and 2003 (Table A3). Westslope cutthroat trout dominated the fish community at this sampling location during all years, including 2009, when we observed an estimated 339 fish per 1,000 feet. This was 29% higher than the annual average of 262 fish per 1,000 feet (Figure 10). Despite the increases in cutthroat trout abundance in recent years, we were not able to distinguish this trend from a stable population ($r^2 = 0.1$; $p = 0.32$). However, brook trout abundance at this site has significantly increased over time ($r^2 = 0.67$; $p = 0.001$). We observed an estimated 32.5 fish per 1,000 feet in 2009, which was the second highest abundance observed during our sampling. Brook trout are increasing an average of 2.4 fish per 1,000 feet per year at this site since 1996. We did not observe any bull trout at this site in 2009. The only year bull trout were observed at this site was in 2007 (Figure 10).

The Young Creek Section 5 lies entirely within the stream restoration project completed on State land in the fall of 2003. Therefore, all data collected through 2003 represents data gathered prior to the restoration project completion. Cutthroat trout have dominated the catch at this site since we began sampling in 1998. In 2009 we observed an estimated 90.2 and 63.4 cutthroat and brook trout per 1,000 feet, respectively at this site (Figure 11). However, cutthroat trout abundance at this site has significantly decreased since 1998 ($r^2 = 0.38$; $p =0.032$) by an estimated 10.9 fish per 1,000 feet per year. The trend of brook trout abundance at this site has not differed from a stable population ($r^2 = 0.18$; $p = 0.17$). We did not observe any bull trout at this site in Young Creek in 2008. The brook trout observed estimated abundance at this site in 2009 was slightly higher than the annual average since 1998. Bull trout remained at low abundance at this site in 2009, with an estimated abundance of 1.6 fish per 1,000 feet. Annual mean abundance estimates for cutthroat, brook and bull trout have averaged 159.9, 60.4 and 1.0 fish per 1,000 feet for each species respectively (Table A3).

We compared mean fish abundance (by species) for pre (1998-2003) and post (2004-2009) restoration projects using t-tests (two-tailed tests; Figure 12). Abundance estimates for cutthroat trout significantly ($p = 0.02$) decreased after project completion from an average of 199.5 fish per 1,000 feet prior to restoration to 120.4 fish per 1,000 feet in 2004-2009 (Figure 12). Brook trout and bull trout both increased after the restoration. The abundance of brook trout significantly increased from a mean of 39.8 fish per 1,000 feet before the project to 81.0 fish per 1,000 feet after the project ($p = 0.021$, for a 2-tailed test; Figure 12). Bull trout abundance significantly increased after the project, from a mean of 0.3 to 1.7 bull trout per 1,000 feet after the project ($p = 0.02$, for a 2-tailed test; Figure 12).

We compared the abundance of cutthroat and brook trout within the restoration project area (Section 5) to control sites located below (Section 1) and above (Section 4) the restoration project, using the Before/After/Control/Impact (BACI) statistical design. This design uses a paired t-test to assess differences between the Control and Treatment (impact) sites before and after project implementation. Because the test is only capable of using a single control site, we conducted the test for each of the control sites (Sections 1 and 4) and for each species of fish (cutthroat, brook and bull trout), for a total of six individual tests (Tables 4 and 5). The mean difference (Control minus Treatment) in cutthroat trout abundance between Sections 1 and 5 significantly ($p = 0.006$) decreased by 58.8% five years after project completion (Table 4). An opposite trend was observed for brook trout at these two sites. The mean difference in brook trout abundance between Sections 1 and 5 significantly ($p = 0.004$) increased by 2.7 fold before and after project completion (Table 4). The mean difference in bull trout abundance between Sections 1 and 5 decreased after the restoration work in Section 5, but this difference was not significant ($p = 0.30$; Table 4). When we repeated the tests using Section 4 as the control section, the trends were similar for cutthroat and brook trout. However, we weren't able to declare these differences significant ($p > 0.05$; Table 5). The trend for bull trout abundance was opposite the trend we observed when we compared Section 1 and Section 5. The mean difference in bull trout abundance between Sections 4 and 5 increased by a factor of about 3 after the restoration work in Section 5, but the difference was not significant ($p = 0.24$; Table 5).

We also used a factorial analysis of variance to assess differences between sections and treatments within Young Creek. In this analysis we used three sections (Sections 1, 4 and 5) and four treatments. The treatments included; pre-restoration within the two control sections (Sections 1 and 4 combined), post-restoration within the two control sections combined, pre-restoration within the treatment section, and post-restoration within the treatment section. We conducted a separate analysis for cutthroat, brook and bull trout. At the overall Section level, brook trout abundance was significantly higher in Sections 1 and 5 than Section 4 ($p < 0.05$; Table 6), but brook trout abundance did not differ between Sections 1 and 5 ($p = 0.353$). The interaction term for brook trout abundance between section and treatment was significant ($p=0.036$; Table 6). Brook trout abundance in Section 5 after the restoration was significantly higher than Section 5 before restoration (p = 0.037). Brook trout abundance in Section 5 after restoration was significantly higher than brook trout abundance in Sections 1 and 4 (combined) before or after restoration (p < 0.05; Table 6), but brook trout abundance within Section 5 before restoration was not significantly higher than brook trout abundance in Sections 1 and 4 (combined) before restoration (Table 6). Cutthroat trout abundance differed significantly between sections (p <0.001; Table 7). Cutthroat trout abundance was highest in Sections 4, 5, and 1, respectively, with all comparisons being significant (p<0.05; Table 7). None of the treatment comparisons differed significantly (p > 0.05; Table 7). However, the power of this post hoc test was only 0.392. Although the results of the ANOVA indicated that bull trout abundance differed between sections, none of the multiple comparisons were significant (p > 0.05; Table 8). Bull trout abundance within the three sections of Young Creek did not differ between treatments (p = 0.099; Table 8). The interaction term for bull trout abundance between section and treatment was significant (p = 0.049; Table 8).

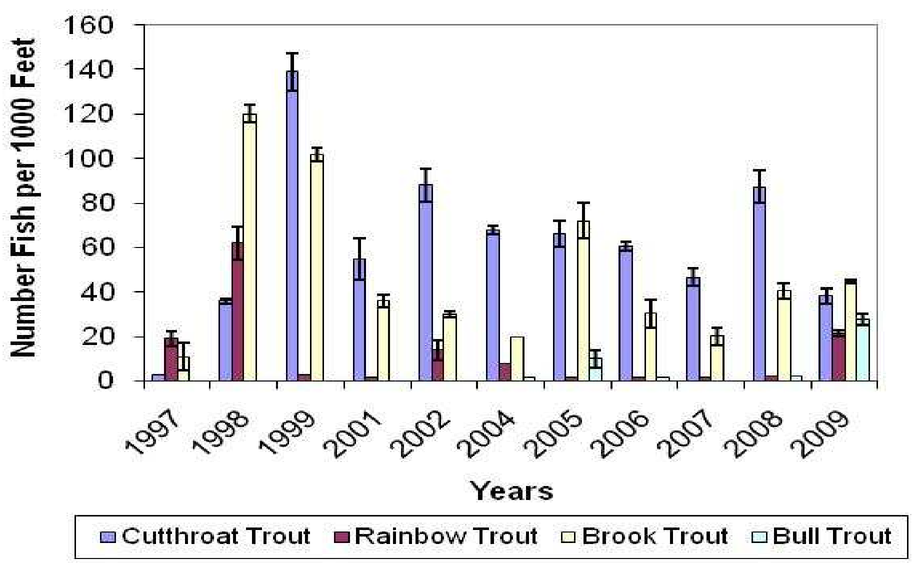


Figure 9. Cutthroat, rainbow, brook and bull trout densities (fish per 1,000 feet) within the Young Creek Section 1 monitoring site from 1997-2009, with the exception of 2003. Data was collected by backpack electrofishing. Error bars represent 95% confidence intervals.

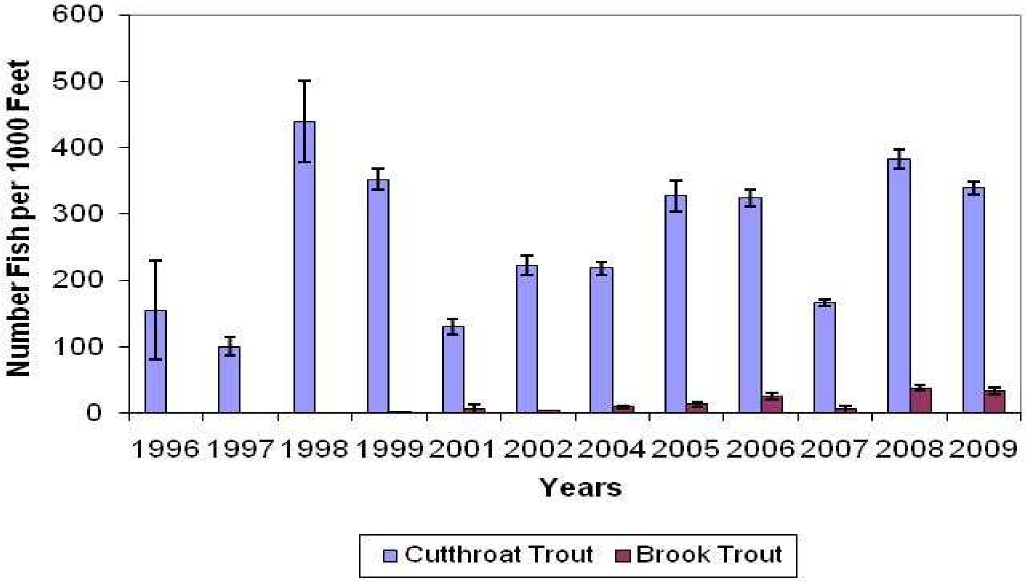


Figure 10. Cutthroat trout and brook trout densities (fish per 1,000 feet) within the Young Creek Section 4 monitoring site from 1996-2009, with the exception of 2000 and 2003. Data was collected by backpack electrofishing. Error bars represent 95% confidence intervals.

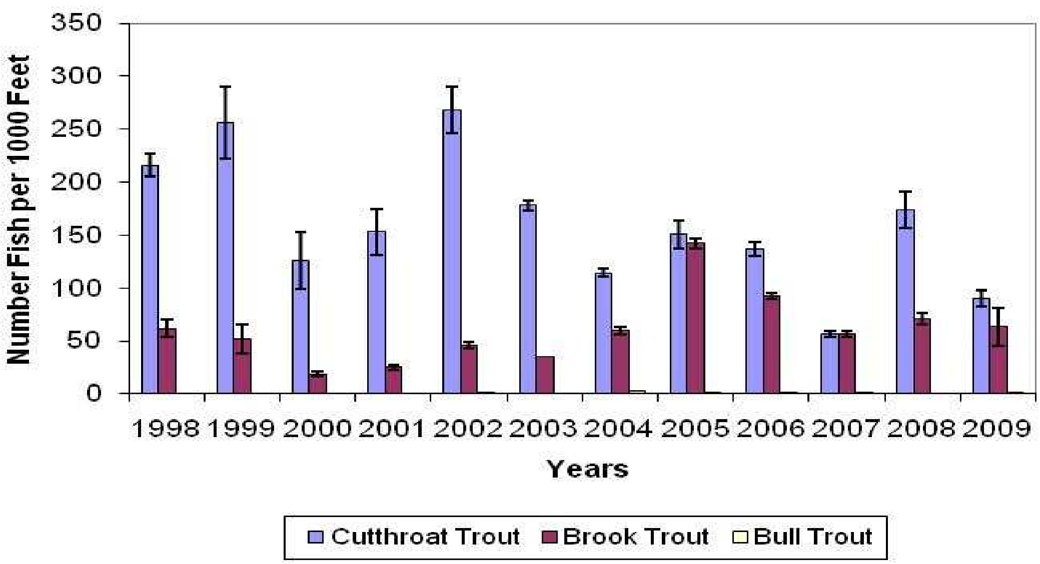


Figure 11. Cutthroat, brook and bull trout densities (fish per 1,000 feet) within the Young Creek Section 5 monitoring site from 1997-2009 collected by backpack electrofishing. The data presented for 2004-2009 represent post restoration data. The error bars represent 95% confidence intervals.

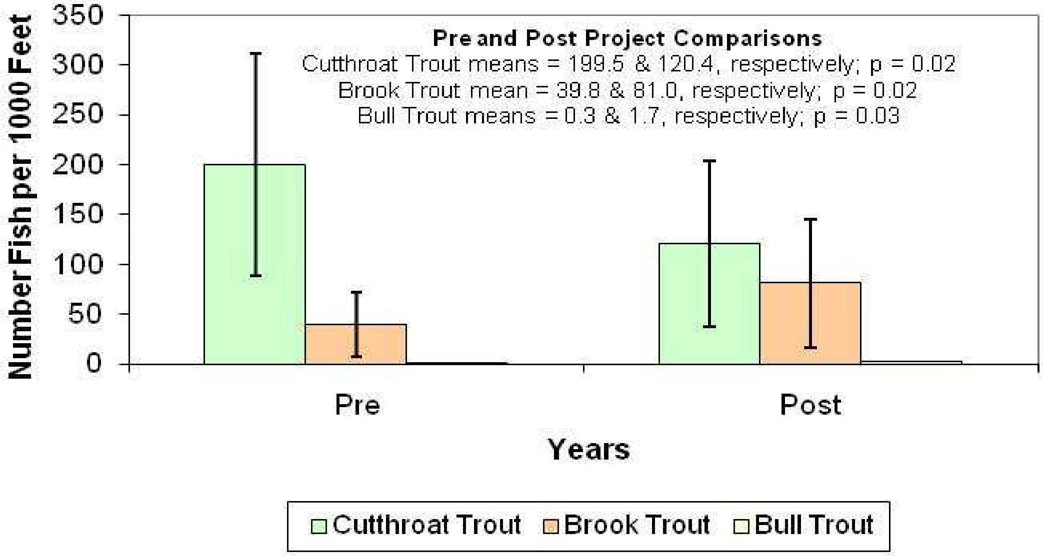


Figure 12. Cutthroat, brook and bull trout densities (fish per 1,000 feet) within the Young Creek Section 5 (State Lands Restoration Project Area), comparing annual mean pre-project (1998-2003) data and post-project (2004-2009) using mobile electrofishing gear. Comparisons were made using a 2-tailed t-test. Error bars represent 95% confidence intervals.

Table 4. Results from a paired t-test (BACI) of the differences between control (Section 1) and treatment (Section 5) on Young Creek before and after the restoration project was completed in 2003.

	Cutthroat Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	-143.8	-59.3	25.8	-43.1	-0.5	5.63
Variance	1812.3	3234.9	1196.3	383.1	1.0	113.0
Sample size (n)	5	6	4	6	4	6
P-value (1-tailed)	0.003		0.002		0.15	
P-value (2-tailed)	0.006		0.004		0.30	

Table 5. Results from a paired t-test (BACI) of the differences between control (Section 4) and treatment (Section 5) on Young Creek before and after the restoration project was completed in 2003.

	Cutthroat Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	62.5	172.1	-43.0	-60.4	-0.5	-1.4
Variance	15321.7	3234.9	324.7	1320.3	1.0	1.5
Sample size (n)	4	6	4	6	4	6
P-value (1-tailed)	0.045		0.20		0.12	
P-value (2-tailed)	0.090		0.40		0.24	

Table 6. Results from a factorial analysis of variance of brook trout abundance in Young Creek for the two control sites (Sections 1 and 4) and the treatment site (Section 5) before and after the stream restoration project was completed in 2004. Multiple comparisons for each Section and Treatment comparisons are also presented. The overall R^2 for this model was 0.572.

Source	**Comparison**	**Mean Difference (First – Second)**	**Significance**	**Power**
Overall Model			<0.001	0.996
Intercept			<0.001	1.0
Section			0.003	0.870
	Section 1 and 4	34.1	0.009	
	Section 1 and 5	-15.0	0.353	
	Section 4 and 5	-49.0	<0.001	
Treatment			0.025	0.693
	Section 5 Before/Sections 1 and 4 Before	11.4	0.802	
	Section 5 Before/After	-41.3	0.037	
	Section 5 Before/Sections 1 and 4 After	14.4	0.669	
	Section 5 After/Sections 1 and 4 After	55.7	0.001	
	Section 5 After/Sections 1 and 4 Before	52.7	0.001	
	Sections 1 and 4 Before/Sections 1 and 4 After	3.0	0.992	
Section*Treatment Interaction			0.036	0.568

Table 7. Results from a factorial analysis of variance of cutthroat trout abundance in Young Creek for the two control sites (Sections 1 and 4) and the treatment site (Section 5) before and after the stream restoration project was completed in 2004. Multiple comparisons for each Section and Treatment comparisons are also presented. The overall R^2 for this model was 0.615.

Source	**Comparison**	**Mean Difference (First – Second)**	**Significance**	**Power**
Overall Model			<0.001	0.996
Intercept			<0.001	1.0
Section			<0.001	0.870
	Section 1 and 4	-206.2	<0.001	
	Section 1 and 5	-97.4	0.011	
	Section 4 and 5	102.8	0.006	
Treatment			0.143	0.392
	Section 5 Before/Sections 1 and 4 Before	43.2	0.670	
	Section 5 Before/After	79.0	0.281	
	Section 5 Before/Sections 1 and 4 After	22.6	0.930	
	Section 5 After/Sections 1 and 4 After	-56.4	0.447	
	Section 5 After/Sections 1 and 4 Before	-35.8	0.782	
	Sections 1 and 4 Before/Sections 1 and 4 After	-20.6	0.912	
Section*Treatment Interaction			0.326	0.162

Table 8. Results from a factorial analysis of variance of bull trout abundance in Young Creek for the two control sites (Sections 1 and 4) and the treatment site (Section 5) before and after the stream restoration project was completed in 2004. Multiple comparisons for each Section and Treatment comparisons are also presented. The overall R^2 for this model was 0.625.

Source	**Comparison**	**Mean Difference (First – Second)**	**Significance**	**Power**
Overall Model			0.046	0.716
Intercept			0.038	0.559
Section			0.049	0.512
	Section 1 and 4	3.8	0.116	
	Section 1 and 5	2.9	0.270	
	Section 4 and 5	-0.9	0.870	
Treatment			0.099	
	Section 5 Before/Sections 1 and 4 Before	0.3	0.999	
	Section 5 Before/After	-1.3	0.951	
	Section 5 Before/Sections 1 and 4 After	-3.3	0.435	
	Section 5 After/Sections 1 and 4 After	-2.0	0.792	
	Section 5 After/Sections 1 and 4 Before	1.6	0.873	
	Sections 1 and 4 Before/Sections 1 and 4 After	-3.7	0.212	
Section*Treatment Interaction			0.049	0.512

Libby Creek

Section 1 of Libby Creek lies within the Libby Creek Demonstration Restoration Project Area, which was completed in the fall of 2001. This site has been sampled each consecutive year since 1998. Fish monitoring data collected from 1998 to 2001 represents the fish community prior to project implementation. Electrofishing conducted in 1999 and 2000 were limited to single pass catch estimates. We used three statistical methods to evaluate the fish community response to the restoration activities at this site. We used linear regression to investigate temporal trends for each species at this section. We also compared abundances before and after restoration at this site using a student's t-test, and finally, we compared species abundance within the restoration project area to a control site located upstream of the restoration project (Sections 2, see below), using the Before/After/Control/Impact (BACI) statistical design. This design uses a paired t-test to assess differences between the Control and Treatment (impact) sites before and after project implementation and has greater statistical power to detect changes over time than the student's t-test. Rainbow trout have been the most abundant fish species within this section during all years, but have not exhibited a significant trend in abundance ($r^2 = 0.18$; $p = 0.17$; Figure 13). We observed an estimated 87 rainbow trout per 1,000 feet at this site in 2009, which was 36.4% lower than the average since the project was completed (136.8 fish per 1,000 feet). The abundance of rainbow trout at this section was approximately twice as high after the restoration as before (Figure 14), with the relatively large difference nearly significant (69.5 and 136.8 fish per 1,000 feet, respectively) ($p = 0.095$). However, using the BACI statistical design, we were able to detect a significant increase in rainbow trout abundance since the project was completed (Table 9). The difference in rainbow trout abundance between the control (Section 2) and the project area approximately doubled after the project was completed (Table 9).

Brook trout were also observed within this section every year, but at lower abundance than rainbow trout. Brook trout abundance has ranged from 5 fish per 1,000 feet in 2003 to 57.5 fish per 1,000 feet in 2005. We estimated brook trout abundance at 39 fish per 1,000 feet in 2009. Brook trout abundance has exhibited a significant increasing trend in abundance since 1998 ($r^2 = 0.38$; $p = 0.03$), increasing on average by 2.6 fish per 1,000 feet per year. Similarly, mean brook trout abundance at this site increased by approximately three fold after project completion (8.8 and 25.8 fish per 1,000 feet, respectively; $p = 0.067$; Figure 14). The results were similar when we used the BACI statistical design to evaluate changes in brook trout abundance at this site before and after restoration. Brook trout abundance almost tripled the control and treatment sections after the restoration activities, but we were not able to declare this difference significant (Table 9).

Prior to 2009, juvenile bull trout were only observed in this section in 2002 and 2005, with an estimated abundance of 3 and 0.9 fish per 1,000 feet, respectively. However, in 2009, we estimated 11 juvenile bull trout per 1,000 feet were present at this site, which was the highest density we've observed over the period of record, and many fold increase over the annual mean bull trout abundance of 1.9 fish per 1,000 feet. However, although the difference in bull trout abundance before and after the restoration work was striking, it was not significant using either the student's t-test ($p = 0.37$; two tailed test) or the BACI design ($p = 0.472$; two tailed test; Table 9). Our lack of power with BACI tests for brook and bull trout was likely limited by the fact that the control section was not sampled consecutively since 1998, as was the case with the Demonstration Section which resulted in eliminating corresponding years from the dataset from the Demonstration Section.

Section 2 of Libby Creek was established and sampled primarily as a control site for the Libby Creek Demonstration Project. This site was sampled in 1998, 2001, and 2003-2009 (Table A4). Rainbow trout were substantially more abundant at this section than brook trout and bull trout during all years (Figure 15; Table A4). Rainbow trout abundance at this site has ranged from 203 fish per 1,000 feet in 1998 to a low of 76 fish per 1,000 feet in 2005. We observed an estimated 78 fish per 1,000 feet in 2009. There was a significant negative trend in rainbow trout abundance through time at this site ($r^2 = 0.57$; $p = 0.018$), for an average decline of approximately 8.5 fish per 1,000 feet per year. Due to this negative trend in abundance, rainbow trout abundance significantly decreased when compared over the pre and post implementation period of the Libby Creek Demonstration Project ($p = 0.008$). We found no evidence of a trend in brook trout abundance at Section 2 ($r^2 = 0.20$; $p = 0.23$; Figure 15) despite the fact that brook trout abundance increased nearly four fold when compared over the pre and post implementation period for the Libby Creek Demonstration Project. However, we were not able to declare the pre and post differences significant ($p = 0.11$; two-tailed test). Bull trout were observed in this section during most years (67%; Figure 15; Table A4), but we found no evidence of a significant trend or difference between pre and post restoration periods for the Demonstration Project area.

Section 3 on Libby Creek is located within the upper Cleveland's Stream Restoration Project area. Redband trout dominate the catch in Section 3 of Libby Creek. We were unable to determine a trend in redband trout abundance at this site since we began sampling the site in 2000 ($r^2 < 0.01$; $p =0.87$; Figure 16). Mean annual redband trout abundance decreased after project implementation, but the difference was not significant (mean abundance 115.0 and 168.3 fish per 1,000 feet, respectively; $p = 0.21$; two-tailed test; Figure 17). However, redband abundance at this site during the past two years has been the highest observed during the period of record. No brook trout were observed at this site during the past ten years. We observed an estimated 10 juvenile bull trout per 1,000 feet at this site in 2009, which represented the second highest since we began monitoring this site. However, estimates of juvenile bull trout abundance before and after project implementation were similar (means = 6.0 and 3.9 fish per 1000 feet, respectively), and did not differ significantly ($p = 0.48$; two-tailed test; Figure 17). Similarly, we found no evidence of a trend in bull trout abundance through time at this site for the period of record ($r^2 = 0.06$; $p = 0.61$; Figure 16).

We established juvenile monitoring Sections 4, 5, and 6 on upper Libby Creek in 2004 to monitor the fish community response to the lower Cleveland Stream Restoration Project that we began implementing in the fall of 2005. Sections 4 and 5 serve as control sites and are located downstream and upstream of the proposed restoration project area, respectively. Section 6 is located within the Phase II project area implemented in the fall of 2006. Fish population data collected from 2004 through 2006 provide the baseline data for comparison after project implementation, and data collected in 2007-2009 represent post-implementation conditions. Redband trout dominated the fish community at all three sampling locations during all years (Table A4). However, redband trout abundance at each of the sections in 2007 decreased substantially in each of the sections compared to the three years previous (see Dunnigan et al. 2009). The decrease in abundance is presumably due to the rain-on-snow event that occurred in November 2006 within the upper Libby Creek watershed. We were unable to detect a significant trend in abundance for either redband, brook or bull trout in any of the three sections in upper Libby Creek ($p > 0.05$; Figures 18-20). Statistical comparisons between pre and post restoration were performed on each of the three sections for each of the three fish species. We were unable to detect any significant changes over the pre and post periods ($p > 0.10$). We compared the abundance of rainbow, brook and bull trout within the restoration project area (Section 6) to control sites located below (Section 4) and above (Section 5) the restoration project, using the BACI statistical design. This design uses a paired t-test to assess differences between the Control and Treatment (impact) sites before and after project implementation. Because the test is only capable of using a single control site, we conducted the test for each of the control sites (Sections 1 and 4) and for each species of fish (rainbow, brook and bull trout), for a total of six individual tests (Tables 10 and 11). The results were similar to the student's t-test we completed, and did not show any significant changes in abundance within the restoration project area relative to the control sections ($p > 0.05$; two tailed test; Tables 10 and 11). The lack of statistical power for both the student's t-test and the BACI tests is primarily due to the limited number of observations prior to and after restoration.

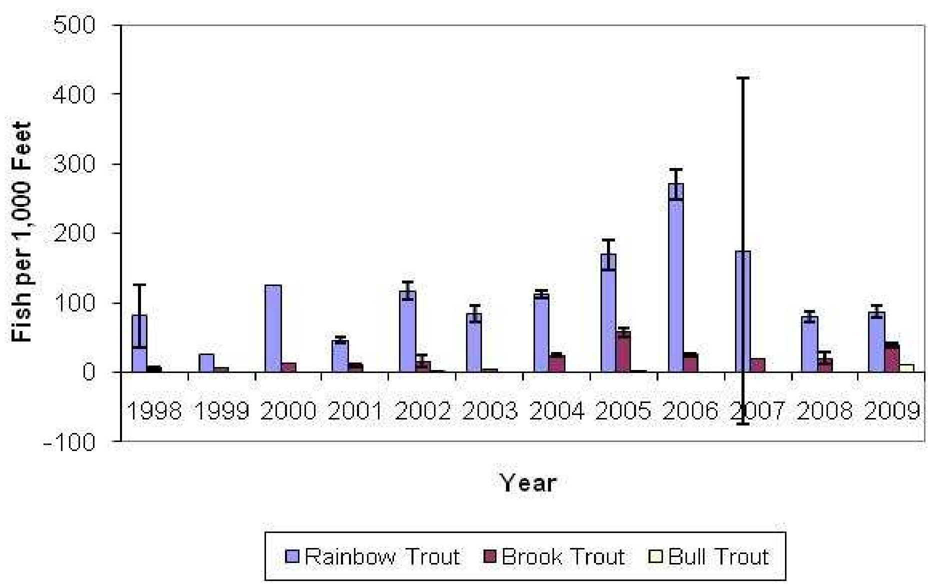


Figure 13. Rainbow trout, brook trout, and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 1 monitoring site 1998 through 2009 using mobile electrofishing gear. Upper 95% confidence intervals are represented by the error bars. The site was sampled using single pass electrofishing in 1999 and 2000.

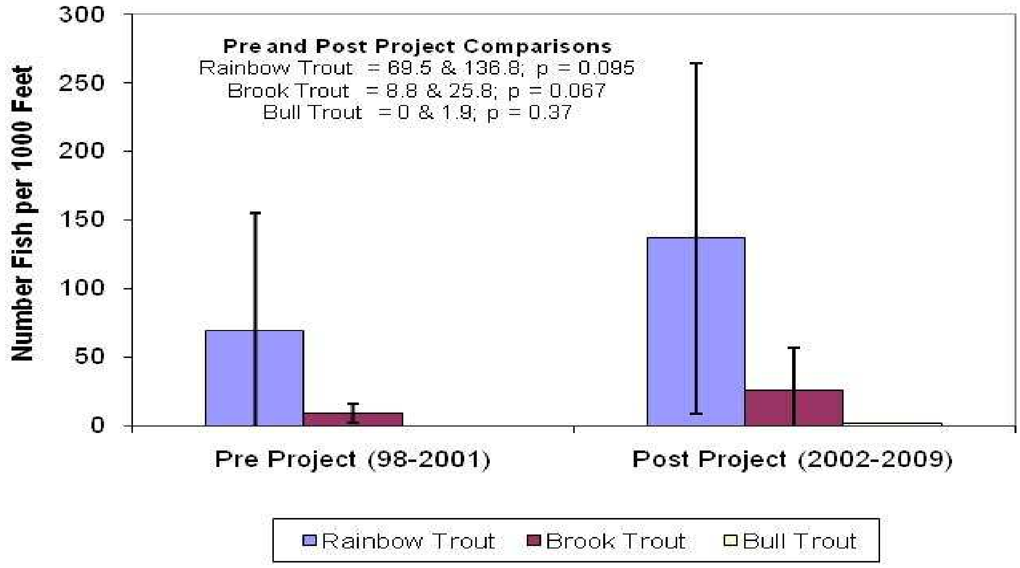


Figure 14. Rainbow trout and brook trout densities (fish per 1,000 feet) within the Libby Creek Demonstration Project area, comparing annual mean pre-project (1998-2001) data and post-project (2002-2009) using mobile electrofishing gear. The error bars represent 95% confidence intervals.

Table 9. Results from a paired t-test (BACI) of the differences between control (Section 2) and treatment (Section 1) on Libby Creek before and after the Libby Creek Demonstration Restoration Project was completed in 2001.

	Rainbow Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	112.0	-35.6	-3.5	-9.3	2.5	-0.004
Variance	200.0	5300.0	40.5	196.3	12.5	17.6
Sample size (n)	2	7	2	7	2	7
P-value (1-tailed)	0.014		0.299		0.236	
P-value (2-tailed)	0.029		0.600		0.472	

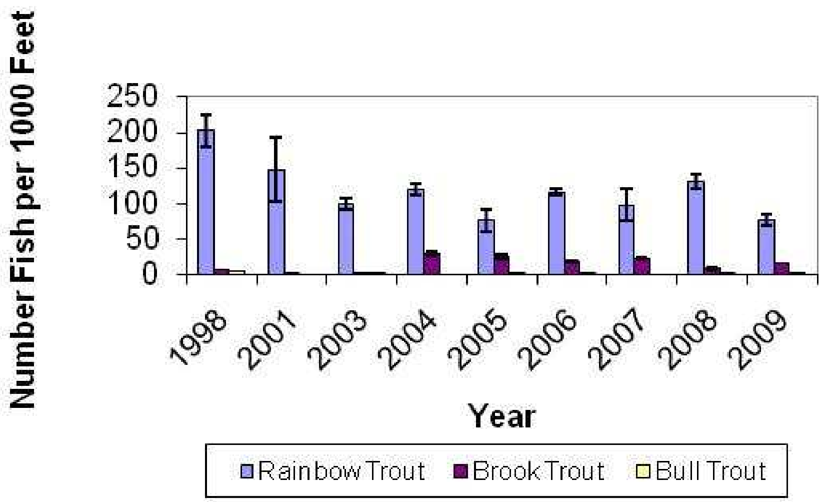


Figure 15. Rainbow trout, brook trout, and bull trout densities (fish per 1000 feet) within the Libby Creek Section 2 monitoring site sampled in 1998, 2001, 2003-2009 using a backpack electrofisher. The error bars represent 95% confidence intervals.

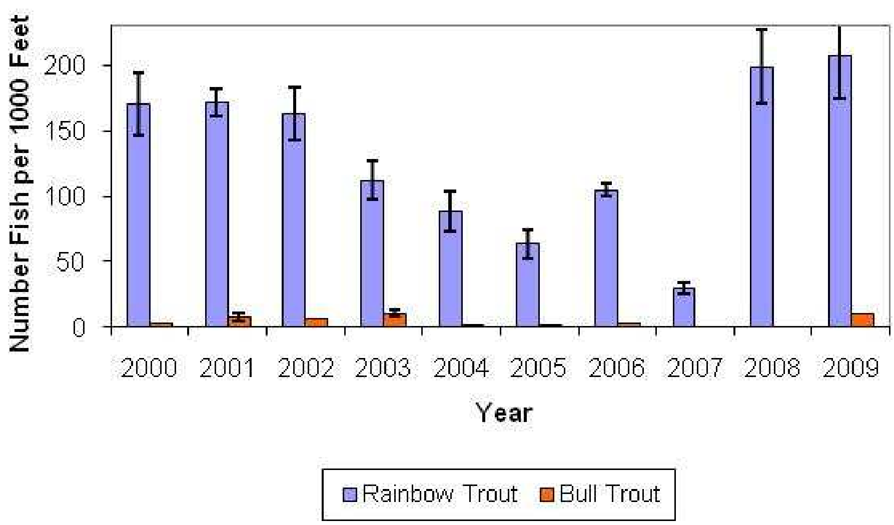


Figure 16. Rainbow trout and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 3 monitoring site in 2000-2008 using a backpack electrofisher. The error bars represent 95% confidence intervals. This site is located within the upper Libby Creek restoration project area. The data from 2000-2002 represent pre-project trends of fish abundance, and the 2003-2009 data represent data after project completion.

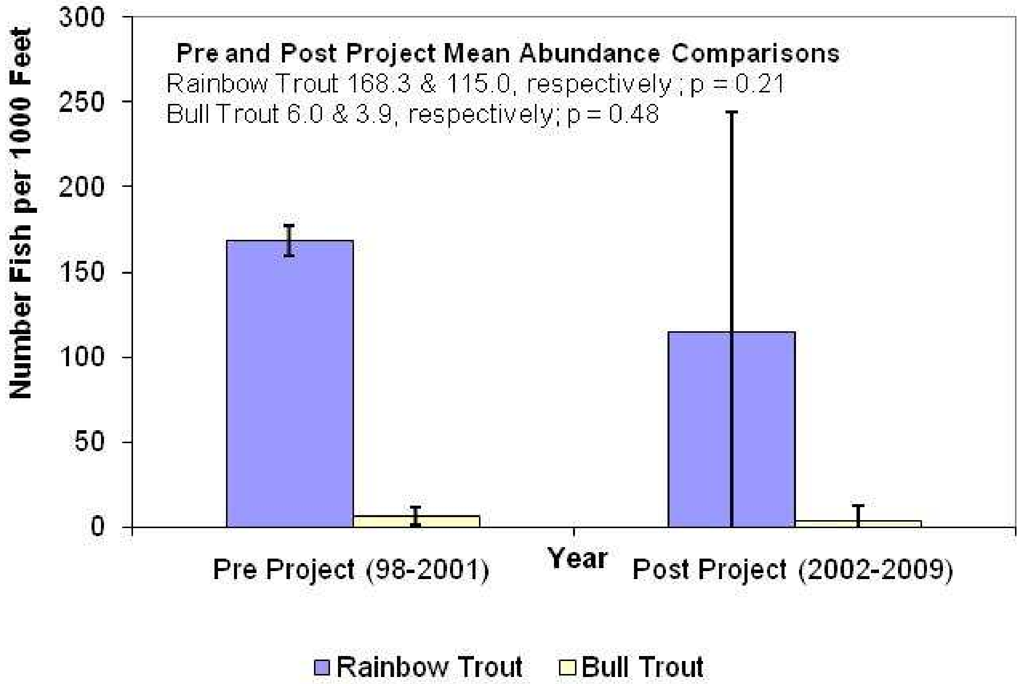


Figure 17. Rainbow trout and bull trout densities (fish per 1,000 feet) within the Libby Creek Upper Cleveland's Stream Restoration Project area (Section 3), comparing annual mean pre-project (2000-2002) data and post-project (2003-2009) using mobile electrofishing gear. The error bars represent 95% confidence intervals.

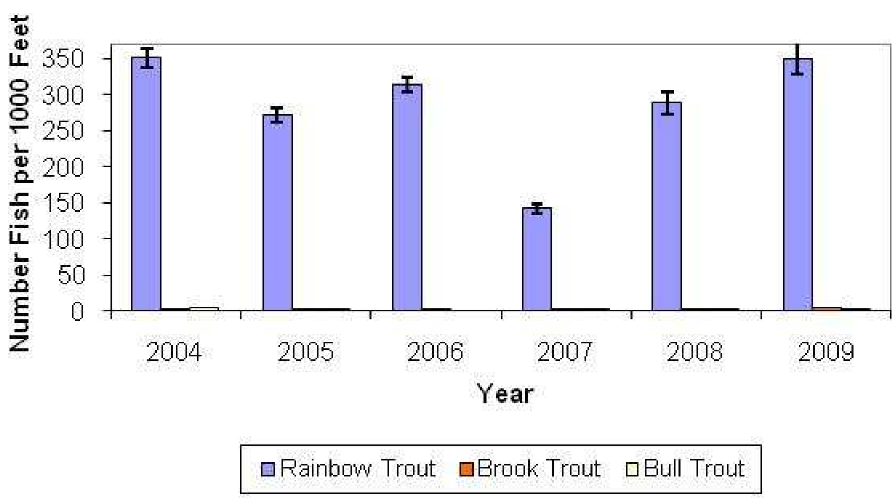


Figure 18. Rainbow, brook and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 4 in 2004 – 2009. This site was sampled using a backpack electrofisher. The Error bars represent the 95% confidence intervals.

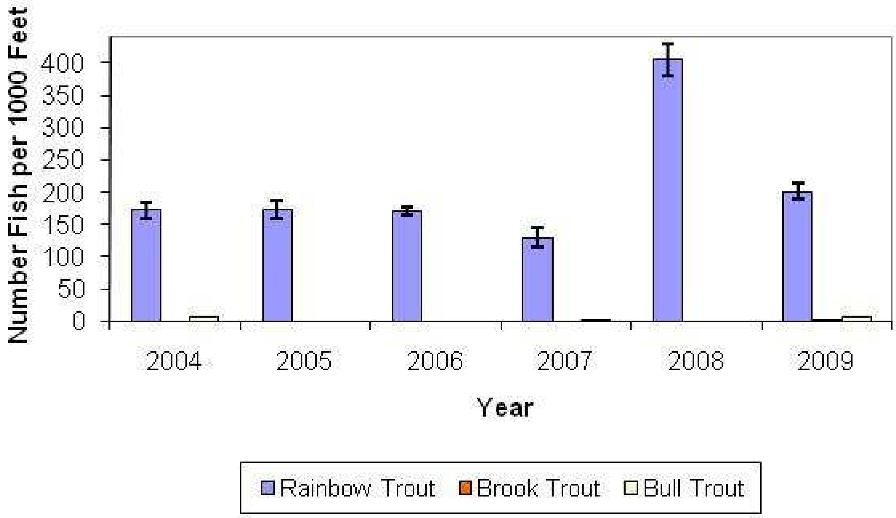


Figure 19. Rainbow, brook and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 5 in 2004 – 2009. This site was sampled using a backpack electrofisher. The Error bars represent the 95% confidence intervals.

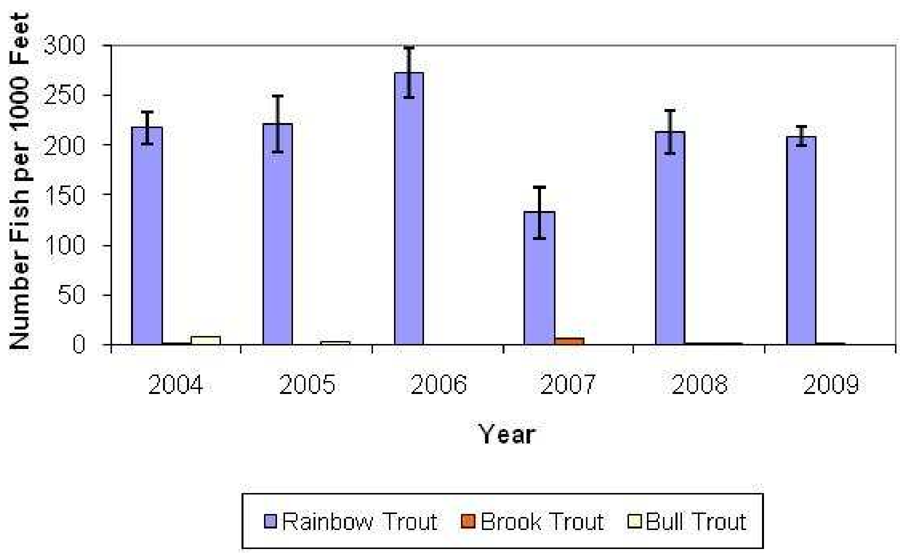


Figure 20. Rainbow, brook and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 6 in 2004 – 2006 (pre restoration), and 2007-2009 (post restoration). This site was sampled using a backpack electrofisher. The Error bars represent the 95% confidence intervals.

Table 10. Results from a paired t-test (BACI) of the differences between control (Section 4) and treatment (Section 6) on Libby Creek before and after the Libby Lower Cleveland's Restoration Project was completed in fall 2006.

	Rainbow Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	75.6	75.7	1.5	-0.5	-1.5	1.0
Variance	2265.8	4411.4	0.1	16.0	1.7	1.3
Sample size (n)	3	3	3	3	3	3
P-value (1-tailed)	0.499		0.213		0.033	
P-value (2-tailed)	0.998		0.425		0.067	

Table 11. Results from a paired t-test (BACI) of the differences between control (Section 5) and treatment (Section 6) on Libby Creek before and after the Libby Lower Cleveland's Restoration Project was completed in fall 2006.

	Rainbow Trout		Brook Trout		Bull Trout	
	Before	After	Before	After	Before	After
Mean Difference (Control-Treatment)	-65.5	60.5	-5.9	-2.9	-1.4	2.0
Variance	1049.4	13173.9	1.0	10.7	3.5	16.8
Sample size (n)	3	3	3	3	3	3
P-value (1-tailed)	0.071		0.156		0.132	
P-value (2-tailed)	0.141		0.312		0.263	

Pipe Creek

Rainbow trout were the most abundant fish species at the lower Pipe Creek Section during all years sampled (Table A5), but in 2009 we observed the highest density since we began sampling this site in 2001 (118.8 fish per 1,000 feet). The trend in rainbow trout abundance has not differed significantly from a stable population since 2001 ($r^2 = 0.31$; $p = 0.12$; Figure 21). Rainbow trout abundance at this site has averaged 56.7 fish per 1,000 feet since 2001. Brook trout were relatively scarce at this site in 2009 (4.8 fish per 1,000 feet), which was nearly identical to the mean abundance since 2001 (4.9). Brook trout abundance also has not differed substantially from a stable population through time ($r^2 = 0.03$; $p = 0.64$). Bull trout were first observed at this site in 2006, at an estimated 2.1 fish per 1,000 feet, and not observed since.

Restoration efforts on this section of Pipe Creek began in the fall of 2010, and completed approximately half of the project area. The project will be implemented in two phases due to funding constraints. The upper section was completed in October 2010 and did not include the section of stream that encompasses the monitoring site.

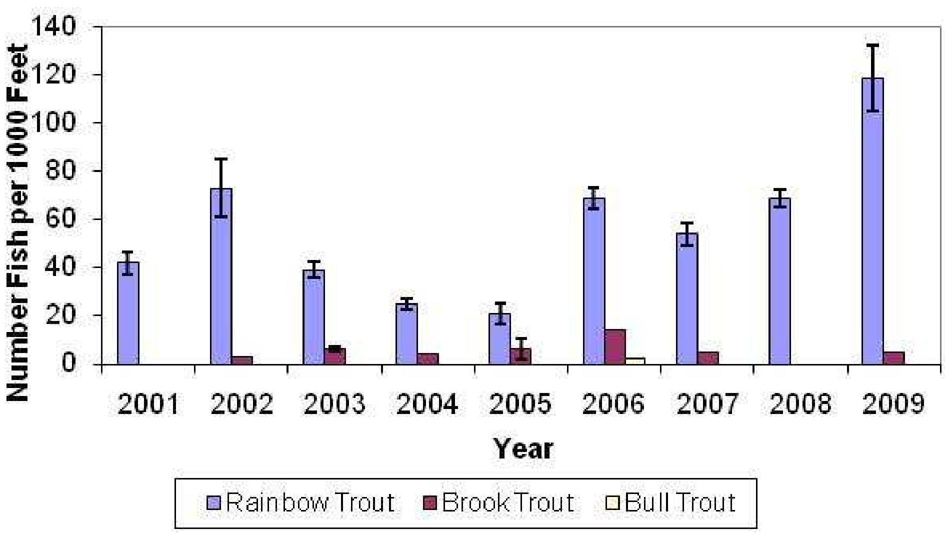


Figure 21. Rainbow, brook and bull trout densities (fish per 1,000 feet) within the Pipe Creek monitoring site from 2001-2009. Fish were collected using a backpack electrofishing. The error bars represent 95% confidence intervals.

Libby Reservoir Gillnet Monitoring

We documented changes in the assemblage of fish species sampled in Libby Reservoir since impoundment, but have species composition, and relative abundance has relatively stabilized during the previous 13-20 years. Kokanee salmon, Kamloops rainbow trout and yellow perch did not occur in the Kootenai River prior to impoundment but are now present. Kokanee were released into the reservoir from the Kootenay Trout Hatchery in British Columbia (Huston et al. 1984). Yellow perch may have dispersed into the reservoir from Murphy Lake (Huston et al. 1984). The British Columbia Ministry of Environment (BCMOE) first introduced Kamloops rainbow trout in 1985, and since 1988, MFWP annually stocked between 11,000 to 73,000 Duncan strain Kamloops rainbow trout directly into the reservoir (see below). Eastern brook trout are not native to the Kootenai Drainage, but were present in the river before impoundment and continue to be rarely captured in gillnets within the reservoir. Peamouth and northern pikeminnow were rare in the Kootenai River before impoundment, but have increased in abundance since the reservoir filled. Mountain whitefish, rainbow trout and westslope cutthroat trout abundance all exhibited dramatic decreases in abundance following the first ten years after reservoir filling, but have stabilized at much lower levels of abundance than the pre-dam period (see below). Fish species composition also shifted during the first 10 years after reservoir construction, but has also stabilized, with the exception of bull trout, which has increased in abundance during the past several years, but appears to perhaps to be beginning to stabilize. We attribute these trends toward trophic equilibrium due to the aging process of the reservoir (Kimmel and Groeger 1986) and the operational history of Libby Dam during the past 20 years. The following sections present specific trend information for several species of fish currently present in the reservoir.

Kokanee

Since the unintended introduction of fry from the Kootenay Trout Hatchery in British Columbia into Libby Reservoir in the early 1980s, kokanee have become the second or third most abundant fish captured during fall gillnetting. Catch rates in both the spring and fall nets have been variable, with no apparent continuous trend in abundance (Figure 22). However, Skaar et al. (1996) suggested that kokanee in Libby Reservoir exhibit density dependent growth. When we examined the relationship between catch of kokanee and total length in the fall nets over the past fifteen years, a significant negative relationship is evident (Figure 23), but when we include data from 1988 to 2009, the relationship is no longer significant ($r^2 = 0.01$; $p = 0.649$). Catch rates of kokanee in the past four years has varied relatively little, ranging from 4.6 to 6.4 fish per net. Over the period of record, average length of kokanee has varied among years, ranging from a 350 mm in 1992 to 232 mm in 2005 (Table 12). Average length and weight of kokanee in 2009 was 276.8 mm and 201.1 g, respectively, which were slightly less than the average over the period of record (284 mm and 221 g, respectively; Table 12).

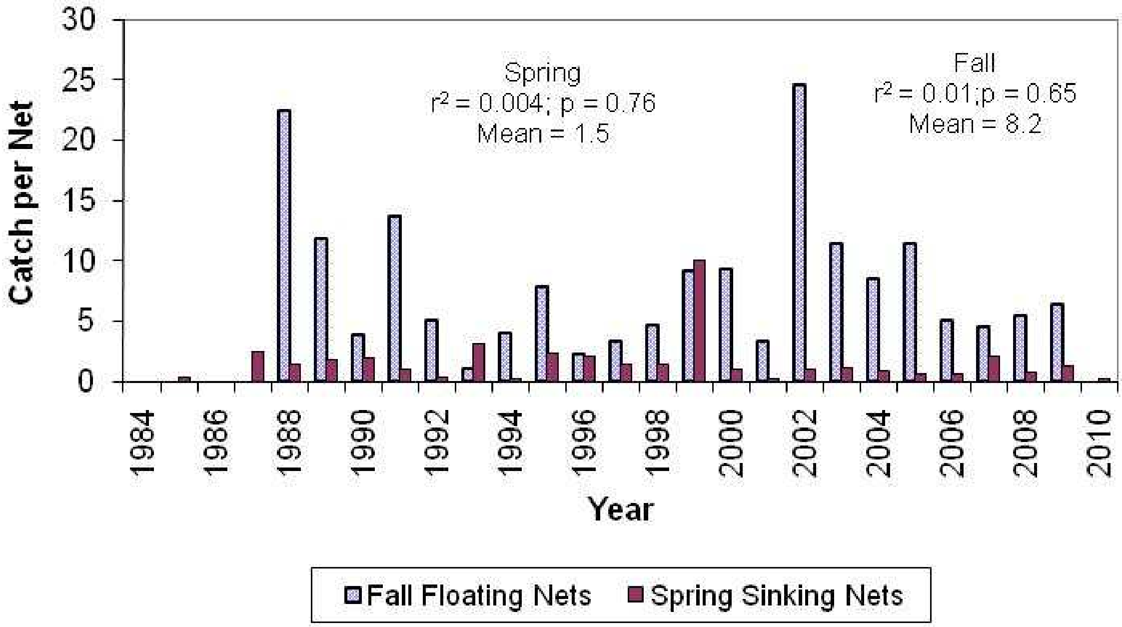


Figure 22. Average catch per net of kokanee for fall floating (1988-2009) and spring sinking (1984-2010) gill nets in Libby Reservoir.

Table 12. Average length and weight of kokanee salmon captured in fall floating gillnets (Rexford and Canada Sites) in Libby Reservoir, 1988 through 2009.

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996
Sample size (n)	2150	1259	517	624	250	111	291	380	132
Length (mm)	315.5	275	257.3	315.8	350	262.7	270.2	300.2	293.7
Weight (g)	289.1	137.2	158.4	327.3	411.3	162.3	191.7	261.6	234.5

Table 12. Continued

YEAR	1997	1998	1999	2000	2001	2002	2003	2004	2005
Sample size (n)	88	76	200	342	120	357	263	194	320
Length (mm)	329.6	333.9	291.6	271.3	261.6	251.3	264.9	261.0	232.2
Weight (g)	363.2	322.0	229.6	185.6	161.6	152.2	175.5	159.2	117.4

Table 12. Continued

YEAR	2006	2007	2008	2009	AVG.
Sample size (n)	163	118	206	141	377
Length (mm)	276.3	290.2	273.9	276.8	284
Weight (g)	202.5	237	187	201.1	221

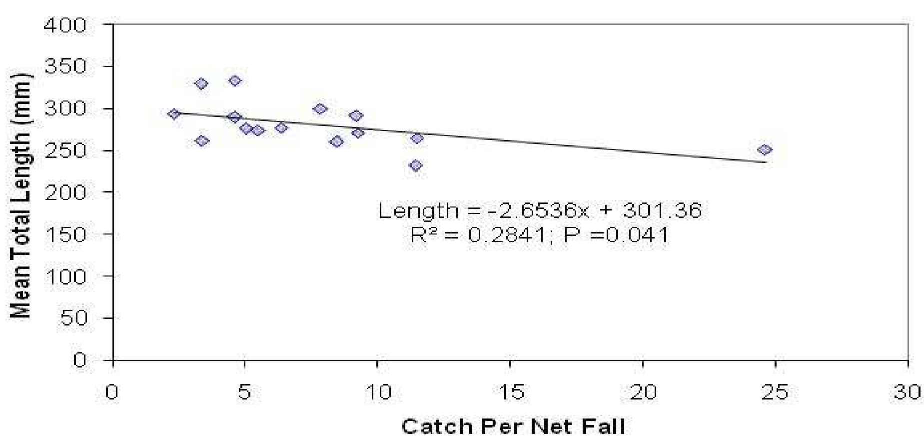


Figure 23. Relationship between kokanee length and catch per net in fall gillnets in Libby Reservoir over the period 1995-2009.

Mountain Whitefish

Mountain whitefish are one of three native species that have exhibited the most significant decline in abundance since impoundment of the Kootenai River (Huston et al. 1984; Figure 24). A linear model provided the best fit to the sinking gillnet mountain whitefish catch data for the period 1975 to 2009 (Figure 24; $r^2 = 0.44$, $p < 0.0001$). Mountain whitefish catch exhibited a significant negative trend during the first 13 years after reservoir impoundment (1975-1988) decreasing by approximately 0.38 fish/net/year, until it reached a significantly lower ($p < 0.001$; two-tailed test) equilibrium. However, since 1989 mountain whitefish catch rates have averaged 0.74 fish per net, with no evidence of an apparent trend ($r^2 < 0.01$; $p = 0.93$). We attribute the initial (1975-1988) mountain whitefish decline in Libby Reservoir to the loss of spawning habitat and rearing habitat that resulted from a conversion from a lotic to lentic environment through reservoir construction. Since the initial decline, it appears that mountain whitefish exist at a much lower, but stable equilibrium.

Rainbow and Westslope Cutthroat Trout

Rainbow trout and westslope cutthroat trout catch have both significantly declined since the impoundment of Libby Reservoir (Figure 24). Rainbow trout have exhibited two general trends since impoundment. The first trend showed a significant decline in abundance from 1975 to 1988 (Figure 24), followed by a period of very slight increase in catch rates from 1989 to 2009 ($r^2 = 0.25$; $p = 0.03$; Figure 24). Gill net catch of cutthroat trout in Libby Reservoir exhibit a similar pattern, with the exception that that cutthroat trout catch rates exhibit 3 general trends through the same period. The first is a significant and precipitous decline during the early years of impoundment from 1975 to 1986 (Figure 24), where mean catch rates decreased on average 0.15 fish per net per year. The second trend showed reduced abundance (0.38 fish per net), but at a level of stability from 1987 to 1993 ($r^2 = 0.337$; $p = 0.172$). The third trend occurred from 1994 to 2009, characterized by a significantly lower level of abundance (0.14 fish per net; $p < 0.001$), at a somewhat stable level ($r^2 = 0.01$; $p = 0.96$). We believe that the period of general equilibrium during the period 1987-1993 may have been artificially elevated by the presence of hatchery cutthroat trout that were extensively stocked in the reservoir during this period (Table 13). Hatchery cutthroat trout were last stocked in the reservoir in 1994.

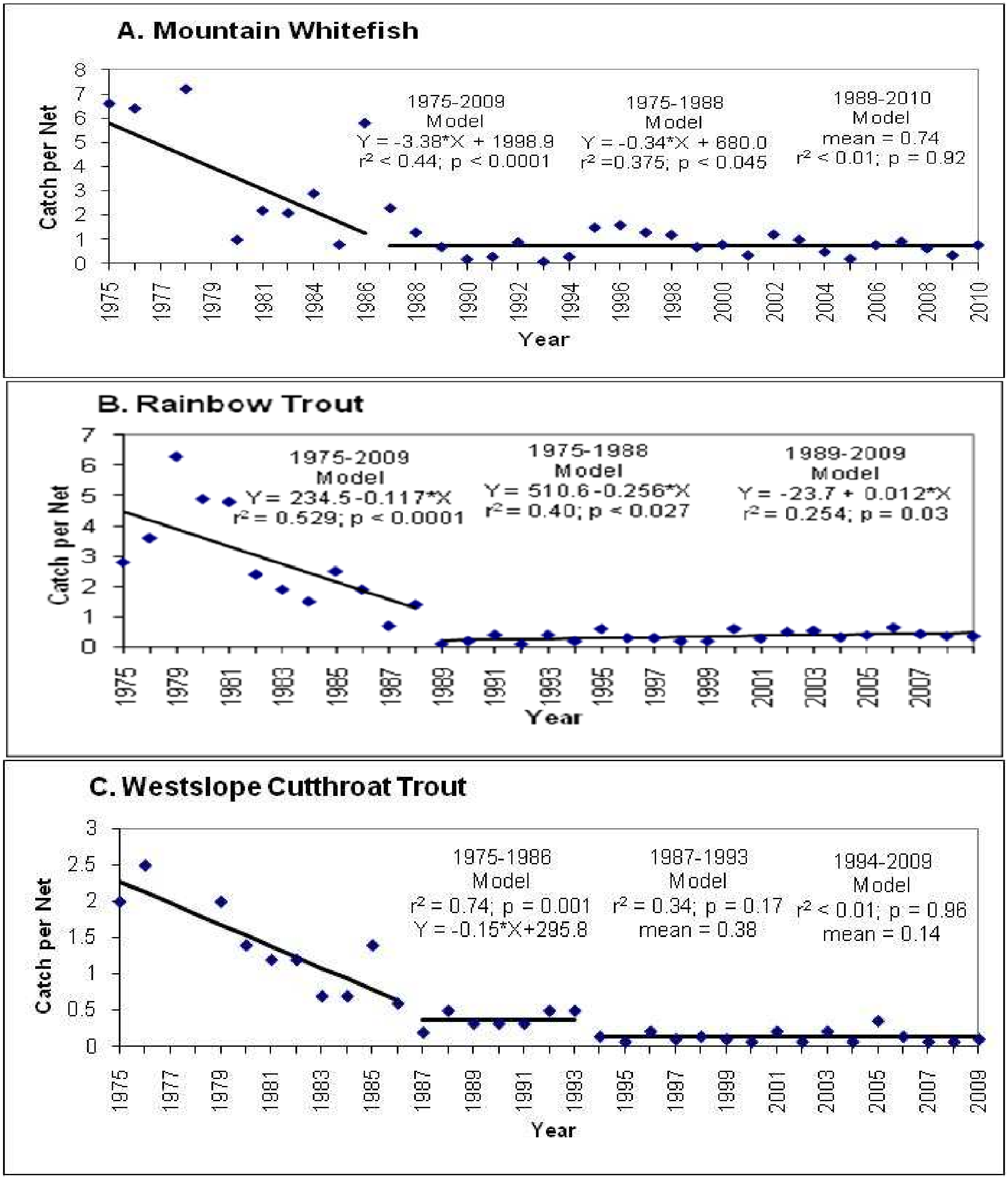


Figure 24. Mean catch rates (fish per net) of three native species (mountain whitefish (a) in spring sinking gillnets in the Rexford area (1975-2010), rainbow (b) and westslope cutthroat trout (c) in fall floating gillnets (1975-2009) from Tenmile and Rexford areas in Libby Reservoir. The Tenmile area was not sampled from 2001-2009.

Table 13. Average catch rate (fish per net) of westslope cutthroat trout per floating gill net caught in the Rexford and Tenmile areas during the fall, average length, average weight, number stocked directly into Libby Reservoir, and corresponding size of stocked fish between 1988 and 2009. The Tenmile location was not sampled in 2000-2009.

	Year													
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**
Catch Rate	0.50	0.32	0.32	0.32	0.50	0.50	0.14	0.07	0.21	0.11	0.14	0.11	0.07	0.21
Avg. Length (mm)	295	264	238	261	275	260	251	314	252	225	267	305	302	259
Avg. Weight (gm)	249	196	146	191	211	191	156	316	161	128	228	296	271	175
No. Stocked	none	5,779	40,376	67,387	72,376	72,367	1,360	none	none	none	none	none	none	none
Length (mm)	n/a		33	104	216	190	287	n/a	n/a	n/a	n/a	n/a	n/a	n/a

	Year							
	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Catch Rate	0.07	0.21	0.07	0.36	0.14	0.07	0.18	0.11
Avg. Length (mm)	305	270	196	215	286	205	279	286
Avg. Weight (gm)	256	206	76	132	243	91	246	243
No. Stocked	none	none	none	none	none	none	none	none
Length (mm)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Inland Rainbow Trout

Inland rainbow trout were first introduced to Libby Reservoir in 1985 by BCMOE. The BCMOE continued stocking approximately 5,000 fingerling fish (Gerrard strain) annually into Kikomun Creek (a tributary to the Kootenai River) from 1988-1998 (L. Siemens, BCMOE, personal communication). From 1988-1999, MFWP acquired inland rainbow (Duncan Strain) from Ennis National Fish Hatchery, and stocked 10,831-73,386 age one fish into the reservoir (Table 14). However, at the latter end of this period, Ennis National Fish Hatchery decided to discontinue the broodstock that produced these fish. In 1997, MFWP decided to start a broodstock at Murray Springs Fish Hatchery in Eureka, MT using eggs that were collected from Luce Reservoir, Wyoming (J. Lord, MT FWP, personal communication). The fish in Luce Reservoir were also originally a result of fish plants from the Ennis NFH broodstock (Duncan Strain). Murray Springs brood fish were first released into Libby Reservoir in 2002, with approximately 30,000 age 0 fish released. Releases continued through 2009, with the annual stocking program consisting of approximately 30,000 age 0 fish and 15,000 age one fish (Table 14). MFWP evaluated this program through gillnet catch rates, creel surveys on the reservoir, and genetic analysis (Leary 2005), and concluded that the Murray Springs brood fish were not contributing to the trophy fishery in the reservoir. In 2005, MFWP obtained triploid (3N) eggs from Wardner Hatchery in British Columbia (Gerrard strain), and in 2006, stocked these fish into Libby Reservoir as age one fish (Table 14). The Murray Springs broodstock was discontinued in 2008, with the last release of age one fish occurring in 2009 (Table 14). MFWP has only released triploid (3N) fish in Libby Reservoir since 2005. Catch rates for inland rainbow trout in fall gillnets has been low since 1996, averaging only 0.07 fish per gillnet. The catch rate in 2009 at the Rexford site was about double the mean, capturing two hatchery trout per 14 nets (0.14 fish/net; Figure 25). The catch rate of inland rainbow trout in fall floating gillnets (fish per net) was significantly and positively correlated with the number of hatchery Inland rainbow trout stocked in the reservoir the previous year ($p = 0.08$; $r^2 = 0.15$) for 1989 through 2009. This relationship is even further strengthened when we regressed the number of age 1 Inland rainbow trout released the previous year to gillnet catch rates ($p = 0.0002$; $r^2 = 0.52$). However, there was no suggestion of a relationship between number of age 0 hatchery Inland rainbow trout released the year before and gillnet catch rates ($r^2 = 0.06$; $p = 0.31$).

Table 14. Inland rainbow trout captured in fall floating gillnets in the Rexford and Tenmile areas of Libby Reservoir, 1988 through 2009. The Tenmile site was not sampled in 2001-2009.

	Year							
	1988	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
No. Caught	3	0	18	6	3	4	0	12
Avg. Length mm)	289	n/a	301	383	313	460	N/A	313
Avg. Weight (gm)	216	n/a	243	589	289	373	N/A	311
Age 0 Stocked	0	0	0	0	0	0	0	0
Age 1 Stocked	26,756[1]	73,386[1]	39,683[1]	15,004[1]	12,918[1]	10,831[1]	16,364[1]	15,844[1]
Total Stocked	26,756	73,386	39,683	15,004	12,918	10,831	16,364	15,844

	Year							
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
No. Caught	2	1	2	3	3	0	0	5
Avg. Length (mm)	460	395	376	378	395	N/A	N/A	260.8
Avg. Weight (gm)	1192	518	450	504	555	N/A	N/A	159.2
Age 0 Stocked	3,165[1]	0	0	0	0	0	29,564[2]	31,039[2]
Age 1 Stocked	9,396[1]	22,610[1]	16,368[1]	13,123[1]	0	0	0	13,721[2]
Total Stocked	12,561	22,610	16,368	13,123	0	0	29,564	44,760

	Year					
	2004	**2005**	**2006**	**2007**	**2008**	**2009**
No. Caught	0	0	1	1	1	2
Avg. Length (mm)	N/A	N/A	256	277	252	283
Avg. Weight (gm)	N/A	N/A	174	220	181	196
Age 0 Stocked	46,944[2]	33,265[2,4,5]	28,578[2,4,5]	32,240[2,4]	38,712[2,4]	0
Age 1 Stocked	16,110[2]	14,933[2,4,5]	22,638[3,4,5]	16,091[2,4]	18,042[2,4]	16,757[2,4]
Total Stocked	63,054	48,198	51,216	48,331	56,754	16,757

[1]Ennis National Fish Hatchery (Duncan Strain)
[2]Murray Springs Hatchery (Duncan Strain)
[3]Wardner Hatchery B.C (Gerrard Strain)
[4]Triploid Fish
[5]Adipose Clip marked

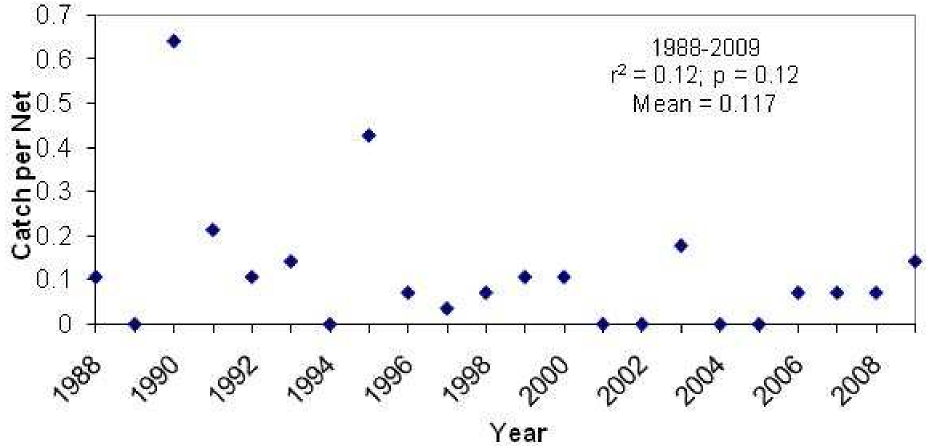


Figure 25. Average catch (fish per net) of Inland rainbow trout in fall floating gill nets in Libby Reservoir at the Rexford and Tenmile sites 1988-2009. The Tenmile site was not sampled in 2001-2009.

Bull Trout

Spring gill net catch of bull trout during the period 1975-1989 appeared to exist at an equilibrium with a slope (0.0091) that was not significantly different than zero (r^2 = 0.011; p = 0.751). Bull trout catch rates on Libby Reservoir began increasing in1990 and peaked in 2000 at 6.71 bull trout per net, but have generally exhibited a declining trend since. Nevertheless, bull trout catch per net in Libby Reservoir during the period 1990-2010 still exhibit a significant positive trend (Figure 26; r^2 = 0.495; p = 0.0003). The mean catch rate we observed in 2010 was 4.4 bull trout per net, which was slightly higher than the previous year, but lower than the rolling ten year average (5.03 fish/net). We attempted to account for differing reservoir levels during the gillnetting activities between years by multiplying the mean bull trout catch per net by reservoir volume at the time the nets were fished each year. This adjustment substantially improved the regression model's fit for both the overall (all years) and 1990-2010 data sets (Figure 27). However, the largest improvement was observed when the adjustment was applied over the time period 1990-2010 (Figures 26 and 27, respectively), where we observed an improvement in the model's r^2 by 0.115, versus an improvement of only 0.023 when the adjustment was applied to overall dataset. Bull trout redd counts in both the Wigwam River and Grave Creek (see below) are both significantly and positively correlated to the spring gill net catch rates for bull trout (Figure 28; r^2 = 0.370; p = 0.01). The adjustment we made using reservoir volume was also applied to the previous model, which improved the overall model fit by increasing the r^2 by 0.094 (Figure 29).

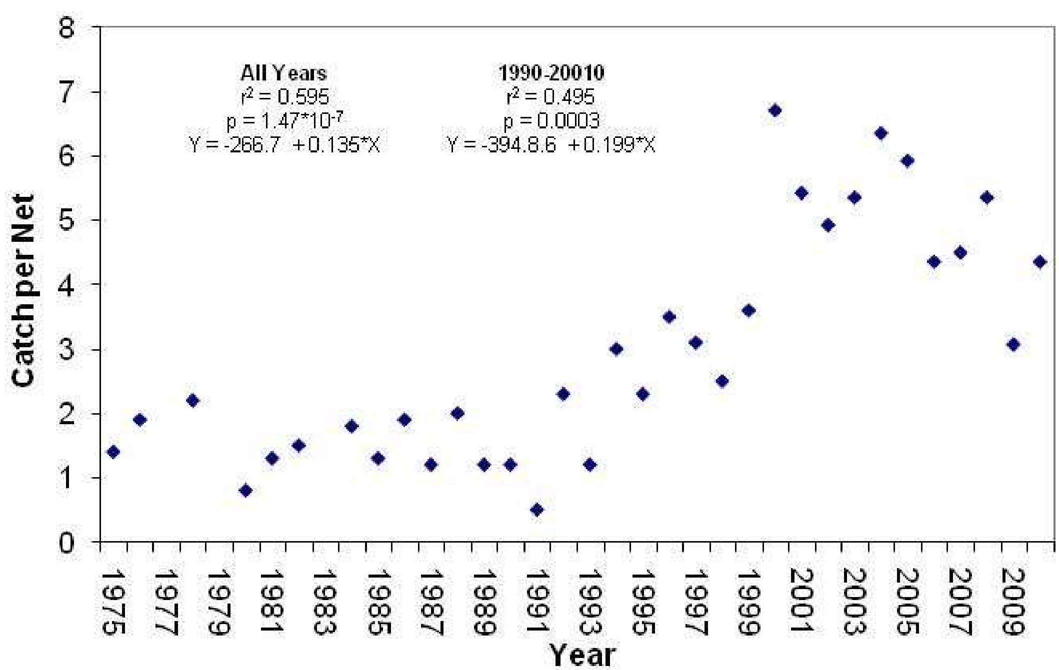


Figure 26. Average catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir 1975-2010.

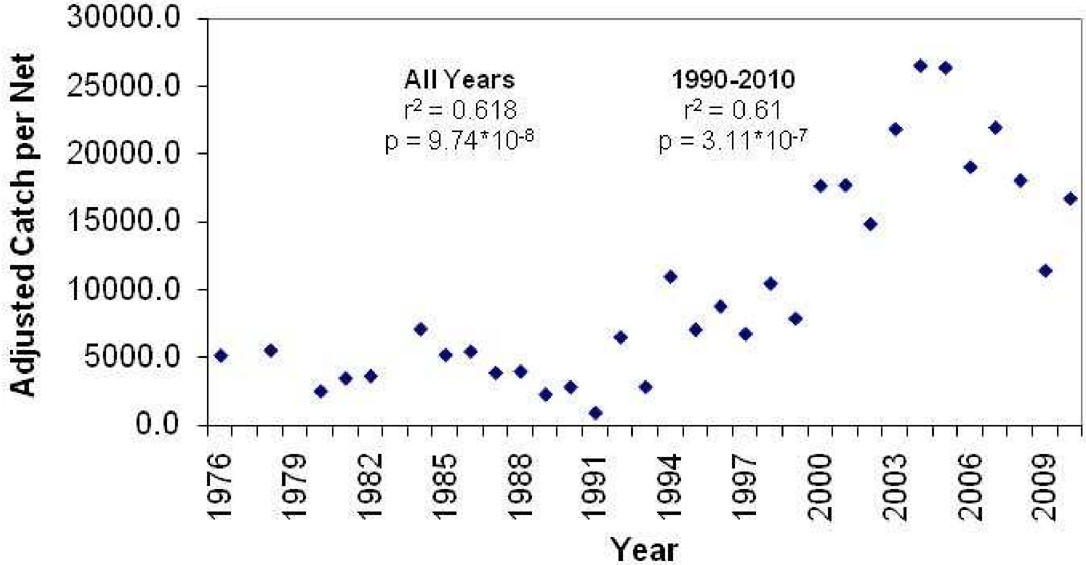


Figure 27. Average adjusted catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir. Average annual bull trout catch per net was adjusted by multiplying catch by reservoir volume at the time of gillnetting.

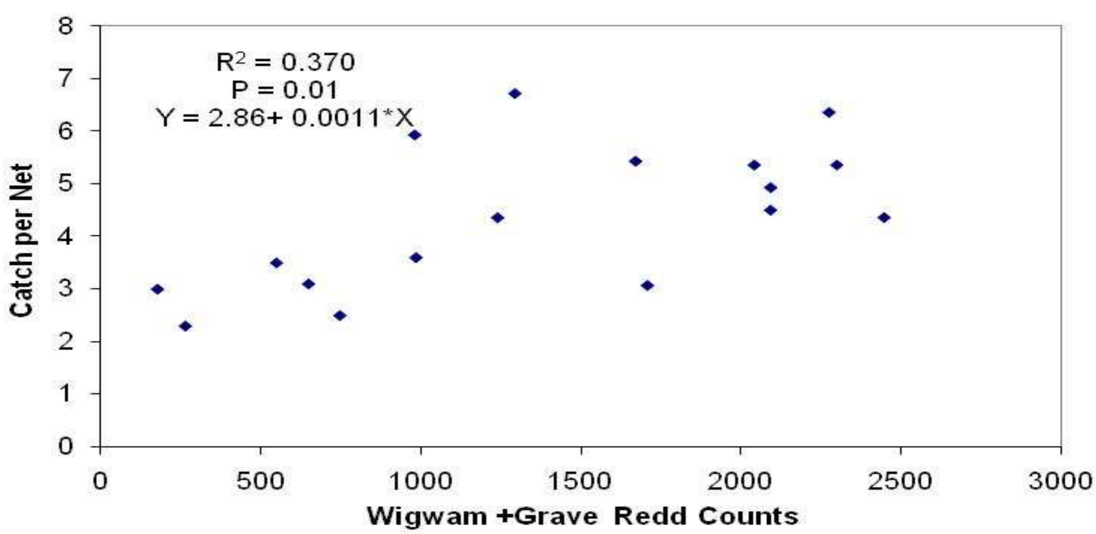


Figure 28. Average catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir related to total annual bull trout redd counts for the Wigwam River and Grave Creek during the period 1994-2010.

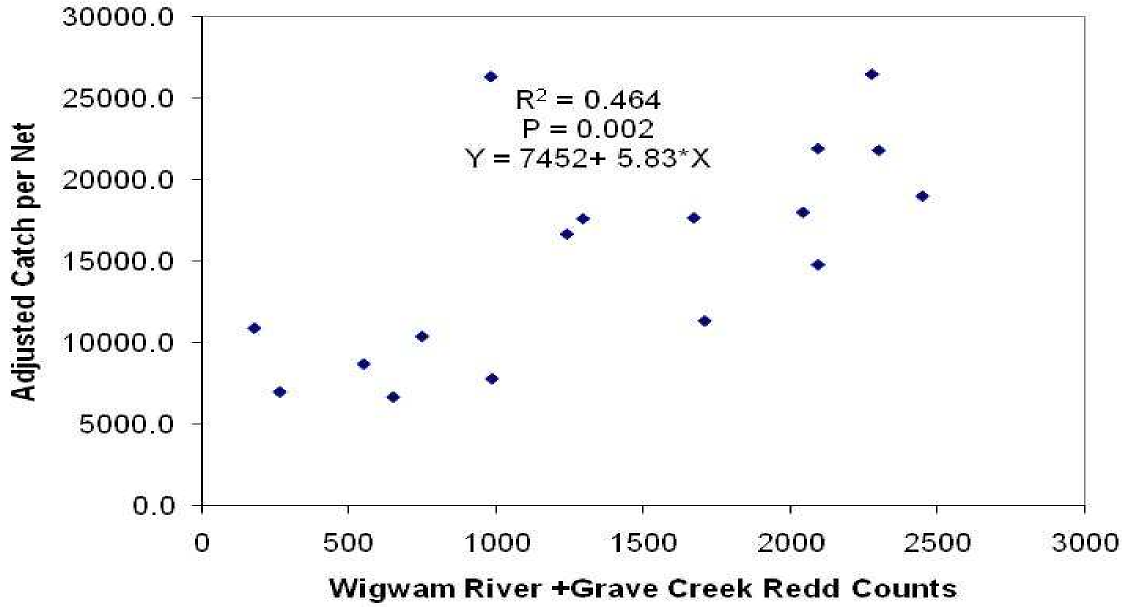


Figure 29. Average adjusted catch per net of bull trout in spring gill nets at the Rexford site related to total annual bull trout redd counts for the Wigwam River and Grave Creek during the period 1994-2010.

Burbot

Burbot catch rates in spring sinking gillnets since 1990 exhibits a significant negative trend in abundance (Figure 30; $r^2 = 0.366$; $p = 0.003$). Burbot catch per net for spring sinking nets has declined an average of 0.016 fish per net since 1990. We did not catch any burbot at the Rexford site in 2010. Burbot catch rates in spring gillnets is however significantly and positively correlated ($r^2 = 0.512$; $p = 0.003$; Figure 31) to daily catch of burbot in baited hoop traps in the stilling basin below Libby Dam (see above), suggesting that burbot abundance in Libby Reservoir may be influencing burbot abundance in the Kootenai River below Libby Dam through entrainment.

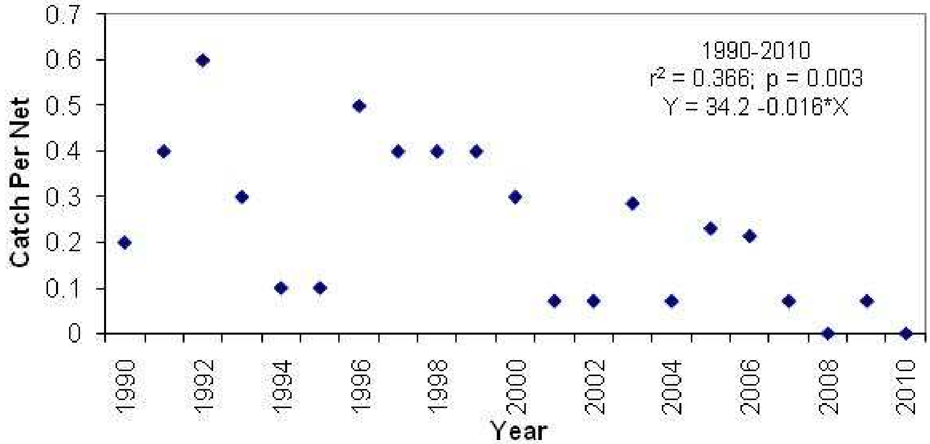


Figure 30. Mean catch per net of burbot in sinking gillnets during spring gillnetting at the Rexford site on Libby Reservoir, 1990-2010.

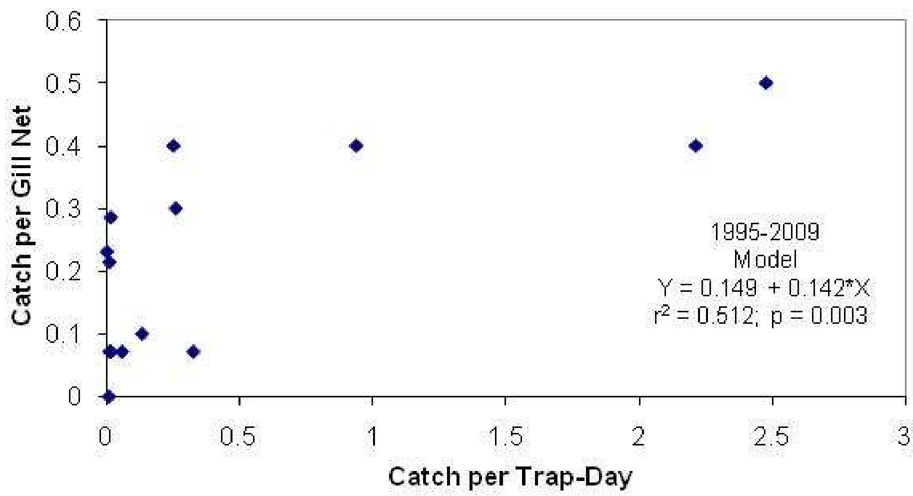


Figure 31. The relationship between mean burbot catch per net for spring sinking gillnets on Libby Reservoir and burbot catch rates (Burbot/trap day) of baited hoop traps in the stilling basin below Libby Dam 1995-2009.

Total Fish Abundance

The long-term trends in total fish abundance in the reservoir reflect the changes that have occurred in the reservoir since impoundment. Total catch (fish per net) for spring gillnets has increased since impoundment, but the trend was not significant (Figure 32; $r^2 = 0.03$; $p = 0.32$; Table 15), and is indicative of an increase in the biomass of species that prefer reservoir habitat including, Columbia River chub, suckers, northern pikeminnow, etc. There is no significant trend in total catch (fish per net) for fall gillnets (Figure 32; $r^2 = 0.0014$; $p = 0.84$; Table 16), averaging 24.9 fish/net. Species composition for the catch of fall and spring gillnets has remained relatively stable since 1993 and 1994, respectively (Table 17).

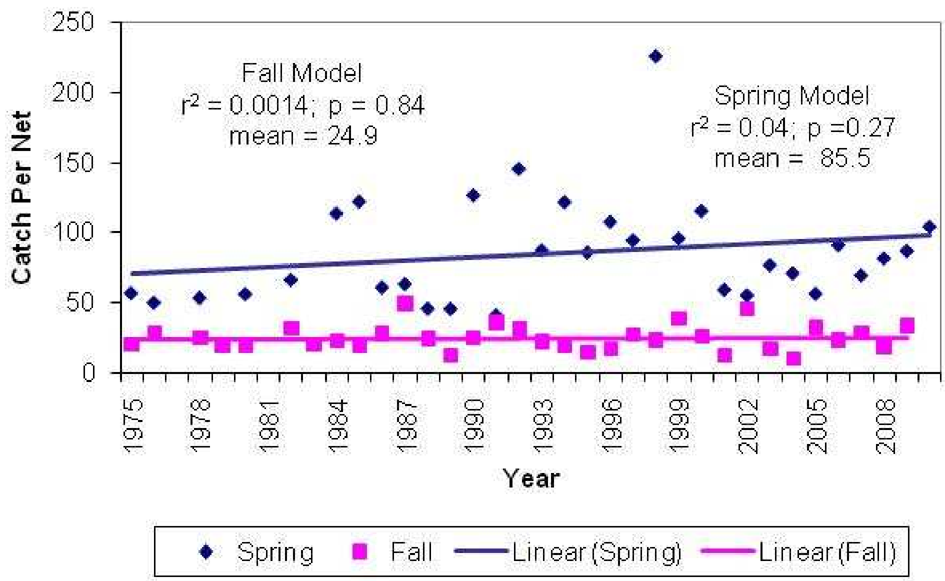


Figure 32. Catch per net (all species combined) in fall floating (1975-2009) and spring sinking gillnets (1975-2010) and associated trend lines in Libby Reservoir.

Table 15. Average catch per net for nine different fish species* captured in floating gillnets set during the fall in the Tenmile and Rexford areas of Libby Reservoir, 1993 through 2009. The Tenmile area was not sampled from 2001-2009.

	YEAR																
	1993	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Date	10/5	9/27	10/10	9/23	9/22	9/21	9/14	9/12	9/20	9/10	9/16	9/14	9/21	9/13	9/11	9/16	9/12
Number Nets	28	28	28	28	28	28	28	28	14	14	14	14	14	14	14	14	14
Res. Elevation	2441	2446	2454	2450	2448	2439	2453	2434	2433	2441	2435	2445	2437	2441	2437	2441	2444
Average number of fish caught per net for individual fish species																	
RBT	0.4	0.2	0.6	0.3	0.3	0.2	0.2	0.6	0.3	0.5	0.5	0.4	0.4	0.6	0.4	0.2	0.4
WCT	0.9	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1
RBT X WCT	0	0	0	0	0	<0.1	0	0	0	0	<0.1	0	0	0	0	0	0
SUB-TOTAL	1.3	0.3	0.7	0.5	0.4	0.3	0.3	0.7	0.4	0.6	0.7	0.4	0.8	0.7	0.5	0.3	0.5
MWF	0.3	0.4	0.3	0.3	0.5	0.4	0.1	0.1	0.2	0.4	0.4	0.6	0.1	0.6	0.9	0	0.4
CRC	17.1	10.4	1.2	11.7	17.8	14.4	24.3	12.9	5.6	21.4	5.0	1.6	11.2	9.9	11.4	9.1	15.7
NPM	2.2	3.4	2.7	1.8	4.0	4.9	6.4	3.9	3.9	8.1	3.36	3.3	7.3	5.6	11.7	4.1	9.9
RSS	0	0.3	0.2	0.1	1.0	0.3	0.3	<0.1	0	0.3	<0.1	0	0.1	0.4	0.6	0	0.5
BT	0.3	0	1.2	<0.1	0	<0.1	<0.1	0.2	0	0.1	0	0.21	0.04	0	0	0.17	0
CSU	0.1	0.1	0	0.4	0.1	0.1	0.1	0.1	0.3	0.1	0.2	0.2	0.2	0.3	2.4	0.1	0.5
KOK	1	4	7.9	2.3	3.1	2.7	7.3	8.0	2.1	14.2	7.4	3.5	11.4	5.4	0.8	4.9	5.0
TOTAL	22.3	18.9	14.2	17.1	26.9	23.1	38.8	25.9	12.5	45.1	17.1	9.8	31.2	23.1	28.5	37.3	33.5

*Species Codes (RBT = rainbow trout, WCT = westslope cutthroat trout, RBXWCT = rainbow and cutthroat trout hybrid, MWF = mountain whitefish, CRC = Columbia River chub, NPM = northern pikeminnow, RSS = redside shiner, BT = bull trout, CSU = coarse scale sucker, and KOK = kokanee.

Table 16. Average catch per net for 12 different fish species* captured in sinking gillnets set during spring in the Rexford area of Libby Reservoir, 1994 through 2010.

	YEAR																
	1994	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Date	5/16	5/8	5/12	5/12	5/11	5/17	5/14	5/15	5/13	5/13	5/11	5/10	5/10	5/21	5/13	5/18	5/17
Number of Nets	28	28	28	28	27	28	14	14	14	14	14	14	14	14	14	14	14
Pool Elevation	2405	2386	2365	2350	2417	2352	2371	2392	2384	2417	2419	2425	2424	2408	2397	2406	2411
Average number of fish caught per net for individual fish species																	
RBT	0.2	0.2	0.7	0.1	<0.1	1.1	0.3	0.2	0.4	0.7	0.6	0.4	0.3	1.5	0.4	0.2	0.2
WCT	<0.1	0.1	0.1	0.2	0.0	0.3	0.1	0	0	0.2	0.2	0.1	0.0	0.1	0.1	0	0
RBT x WCT	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0	0.2	0.0	0	0	0.0	0	0	0	0
SUB-TOTAL	0.2	0.3	0.9	0.3	0.0	1.4	0.4	0.2	0.6	0.9	0.8	0.5	0.3	1.6	0.5	0.2	0.2
MWF	0.3	1.5	1.6	1.3	1.2	0.7	0.8	0.4	1.2	1.2	0.5	0.2	0.8	0.9	0.6	0.4	0.8
CRC	94.2	54.1	60.9	51.1	171.7	54.4	76.4	25	24.1	42.1	44.4	23.1	63.9	26.1	45.2	54.8	67.7
NPM	7.6	8.0	10.0	13.1	15.1	14	12.6	11	9.9	13.0	11.9	9.7	10.9	20.3	17.9	13.5	17.4
RSS	0.0	0.0	0.0	0.1	1.0	0.1	0.4	0	0	0.1	0	0	0.0	0.4	0	0.2	0
BT	3.0	2.3	3.5	3.1	2.5	3.6	6.7	5.4	4.9	5.4	6.4	5.9	4.4	4.5	5.4	3.1	4.4
LING	0.1	0.1	0.5	0.4	0.4	0.4	0.3	0.1	0.1	0.3	0.1	0.2	0.2	0.1	0	0	0
CSU	9.0	12.0	19.9	14.3	21.1	8.3	10.6	14.2	9.9	10.2	5.2	11.8	8.6	9.4	9.6	10.7	11.8
FSU	6.5	3.0	4.8	4.7	9.5	5.9	5.1	1.1	2.9	2.3	0.3	1.1	0.9	2.1	1.0	2.3	1.5
YP	0.7	2.5	3.7	4.75	2.4	1.8	1.3	1.6	0.6	0.1	0.5	0.4	0.4	1.6	0.4	0.2	0.4
KOK	0.3	2.1	2.0	1.4	1.3	5.3	1.0	0.2	1.0	1.2	0.9	3.4	0.6	2.1	0.8	1.4	0.2
TOTAL	121.9	86.3	107.1	93.25	226.2	95.9	115.1	59.2	55.2	76.8	70.9	53.4	0.8	69.4	81.6	87.0	104.3

*Species Codes (RBT = rainbow trout, WCT = westslope cutthroat trout, RBXWCT = rainbow and cutthroat trout hybrid, MWF = mountain whitefish, CRC = Columbia River chub, NPM = northern pikeminnow, RSS = redside shiner, BT = bull trout, LING = burbot, CSU = coarse scale sucker, FSU = fine scale sucker, YP = yellow perch, and KOK = kokanee.

Table 17. Percent composition of major fish species* caught in fall floating and spring sinking gillnets in Libby Reservoir, 1994 through 2010. Blank entries in table indicate either no fish were captured or that they occurred in very small proportions.

	YEAR																	
Species	**1994**		**1995**		**1996**		**1997**		**1998**		**1999**		**2000**		**2001**		**2002**	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Fall	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RB	0.9		4.4		1.1	1.1	1.8		0.9		4.4		1.1	0.2	1.4	0.4	0.4	0.4
WCT	0.7		0.8		0.8	0.8	3.8		0.7		0.8		0.8	0.1	1.7	0	0.1	0
HB	0.0		0.3		0	0	0.2		0.0		0.3		0	0	0	0	0	0
ONC	1.7	0.2	5.5	0.4	1.9	1.9	5.8	0.3	1.7	0.2	5.5	0.4	1.9	0.3	3.1	0.4	0.5	0.4
MWF	2.2	0.3	2.1	1.7	0.5	0.5	1.4	0.2	2.2	0.3	2.1	1.7	0.5	0.7	2.5	0.6	0.3	1.5
CRC	54.3	77.0	8.6	62.9	46.4	46.4	72.8	73.9	54.3	77.0	8.6	62.9	46.4	66.0	49.3	42.2	41.5	62.4
NPM	17.5	6.2	19.6	9.3	18.1	18.1	9.3	5.0	17.5	6.2	19.6	9.3	18.1	10.8	22.5	18.6	14.4	11.8
RSS	1.5	0.0	1.3	0.0	0.1	0.1	0.0	0.0	1.5	0.0	1.3	0.0	0.1	0.4	1.4	0	0.9	0
FSU	0.0	5.3	0.0	3.5	0.1	0.1	0.0	5.2	0.0	5.3	0.0	3.5	0.1	4.0	0	1.9	0	3.4
CSU	0.6	7.3	0.0	13.9	4.0	4.0	0.6	9.7	0.6	7.3	0.0	13.9	4.0	9.1	3.4	24.0	0.6	12.3
KOK	20.6	0.2	57.4	2.4	28.6	28.6	4.4	3.4	20.6	0.2	57.4	2.4	28.6	0.9	17.5	0.4	41.6	1.2
YP		0.9		2.9	0.3	0.3		1.1		0.9		2.9	0.3	1.1	0	2.7	0.1	0.8
BT		2.5		2.8	0	0		1.1		2.5		2.8	0	5.8	0.3	9.2	0	5.9

Table 17. (Continued) Percent composition of major fish species* caught in fall floating and spring sinking gillnets in Libby Reservoir, 1992 through 2010. Blank entries in table indicate either no fish were captured or that they occurred in very small proportions.

	YEAR																	
Species	**2003**		**2004**		**2005**		**2006**		**2007**		**2008**		**2009**		**2010**		**Average**	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall
RB	2.8	0.9	3.7	0.8	1.2	0.8	0.3	2.8	2.2	1.5	0.5	1.1	0.2	1.1	0.3	n/a	0.5	1.7
WCT	0.8	0.3	0.7	0.3	1.1	0.1	0	0.6	0.1	0.3	0.2	0.4	0.0	0.3	0	n/a	0.1	0.7
HB	0.4	0.0	0.0	0.0	0.0	0.0	0	0	0	0	0.0	0	0.0	0	0	n/a	0.0	0.2
ONC	4.0	1.2	4.5	1.1	2.3	0.9	0.3	3.4	2.3	1.8	0.7	1.5	0.4	1.4	0.3	n/a	0.8	2.6
MWF	2.0	1.6	6.0	0.7	0.5	0.4	0.9	2.8	1.3	3.3	0.8	0	63.0	1.1	0.4	n/a	8.0	1.8
CRC	27.7	54.9	16.4	62.6	35.2	41.1	70.1	42.9	37.7	39.9	55.4	48.7	15.5	46.8	63.0	n/a	48.3	42.2
NPM	18.6	16.9	34.3	16.8	22.8	17.2	12.0	24.1	29.2	41.1	21.9	21.8	0.2	29.5	15.5	n/a	14.0	22.3
RSS	0.4	0.1	0.0	0.0	0.5	0.0	0	1.9	0.5	2.0	0.0	0	3.6	1.4	0.3	n/a	0.8	1.1
FSU	0.4	3.0	0.0	0.4	0.0	1.9	1.0	0	3.1	0	1.2	0	0.0	0.3	2.64	n/a	3.8	0.1
CSU	1.2	13.3	2.2	7.4	0.7	20.9	9.5	1.2	13.6	8.5	11.7	0.7	12.3	1.6	12.3	n/a	14.7	2.4
KOK	41.1	1.6	36.6	1.2	36.0	6.1	0.7	23.5	3.1	3.0	1.0	26.4	2.6	15.0	1.6	n/a	2.2	26.2
YP	5.1	0.1	0.0	0.7	1.8	0.6	0.4	0.3	2.3	0	0.4	0	0.2	2.9	0.3	n/a	1.6	0.8
BT	0	7.0	2.2	9.0	0.1	10.5	4.8	0	6.5	0	6.6	0.4	1.6	0	3.6	n/a	5.1	0.3

*Species Codes = RB = Rainbow trout, WCT = westslope cutthroat trout, HB = hybrid rainbow trout X cutthroat trout, ONC= Combined Rainbow, westslope cutthroat and hybrid trout, MWF = mountain whitefish, CRC = Columbia River chub (peamouth), NPM = northern pikeminnow, RSS = red side shiner, FSU = fine scale sucker, CSU = course scale sucker, KOK = kokanee, YP = yellow perch, BT = bull trout.

Libby Reservoir Zooplankton Monitoring

Zooplankton species composition and abundance within Libby Reservoir has remained relatively stable during the past fifteen years (Appendix Tables A6-A9). Similar to tertiary production in the reservoir, we attribute the trends toward secondary equilibrium to the aging process of the reservoir (Kimmel and Groeger 1986) and the operational history of Libby Dam during the past two decades.

During the period 1997 through 2009, *Cyclops* and *Daphnia* have been the first and second most abundant genera of zooplankton present in the reservoir (Figure 33). Other lesser abundant genera in decreasing order of abundance include *Bosmina, Diaptomus, Epischura, Diaphanosoma, and Leptodora* (Figure 33). In 2009 the annual mean densities of *Cyclops*, *Daphnia*, *Bosmina*, and *Diaptomus* were 7.94, 1.44, 1.30, and 0.59 organisms/liter, respectively (Appendix Tables A6-A9). Zooplankton abundance within the reservoir significantly varies by month (Table 18; Figure 34). We found that all seven genera of zooplankton differed significantly by month in 2009 (Table 18). Although we did not perform multiple comparisons required to determine pairwise comparisons, zooplankton abundance varies within a season, with seasonal peaks in abundance over the past ten years (Figure 34) remaining relatively consistent across years. For example, *Daphnia* abundance has peaked during July each year except 2003, 2006, and 2009 (June peak) since 1997, *Diaphanosoma* abundance has peaked in late August or September 10 of the previous 12 years, excluding 2007 since we did not sample zooplankton during the months of September or October in 2007. *Diaptomus* has peaked in either September or October during 10 of the previous 12 years, (including 2009). *Cyclops* has peaked in either May or June during 12 of the last 13 years. In most cases when an individual annual peak differed from the mean peak, the difference was not more than several weeks.

Our sampling design stratified the reservoir into thirds, and although each stratum was long (> 58 km), we believe the stratification was justified and represented an adequate sample design. In 2009, abundance of *Diaphnia, Cyclops,* and *Epischura* all differed significantly between the three sampling areas (Tenmile, Rexford, and Canada; Table 18). Although significant differences existed for these three genera of zooplankton in the reservoir, a longitudinal pattern within the reservoir only existed for *Daphnia* and *Cyclops.* For *Daphnia*, densities were highest in the Canada strata, and decreased progressively downstream to the Rexford and Tenmile strata. However pair wise comparisons indicated that only Daphnia densities in the Canada stratum were significantly higher than both the Tenmile and Rexford strata. We observed an opposite pattern for *Cyclops* in 2009, with densities highest in the lowest stratum (Tenmile), and highest in the Canada stratum, with this comparison being the only one that was significant. However, *Epischura* densities were highest in the Rexford stratum and lowest in the Canada stratum, but none of the multiple comparisons indicating significant differences.

The trends in *Daphnia* abundance (Figure 34) and size (Figures 35 and 36) in Libby Reservoir have remained particularly stable during the past several years. Mean annual

Daphnia densities in Libby Reservoir from 1997 through 2009 have averaged 1.94 *Daphnia* /liter (standard deviation = 0.13/liter). However, the mean abundance of *Daphnia* we observed in 2009 (1.44 *Daphnia*/l) was the second lowest on record since 1997. Mean *Daphnia* length has also varied relatively little since 1991, averaging 0.90 mm (standard deviation = 0.043; Figure 35). Most *Daphnia* since 1993 are between 0.5 – 1.5 mm, with majority of *Daphnia* being represented in the smaller size class 0.5 – 0.99 mm (mean annual proportion = 0.62, standard deviation = 0.051; Figure 36), with the majority of the remainder in the size class 1.0 – 1.499 (mean annual proportion = 0.34, and standard deviation = 0.032). *Daphnia* larger than 1.5 mm have on average comprised less than 4% of the total since 1993 (Figure 36).

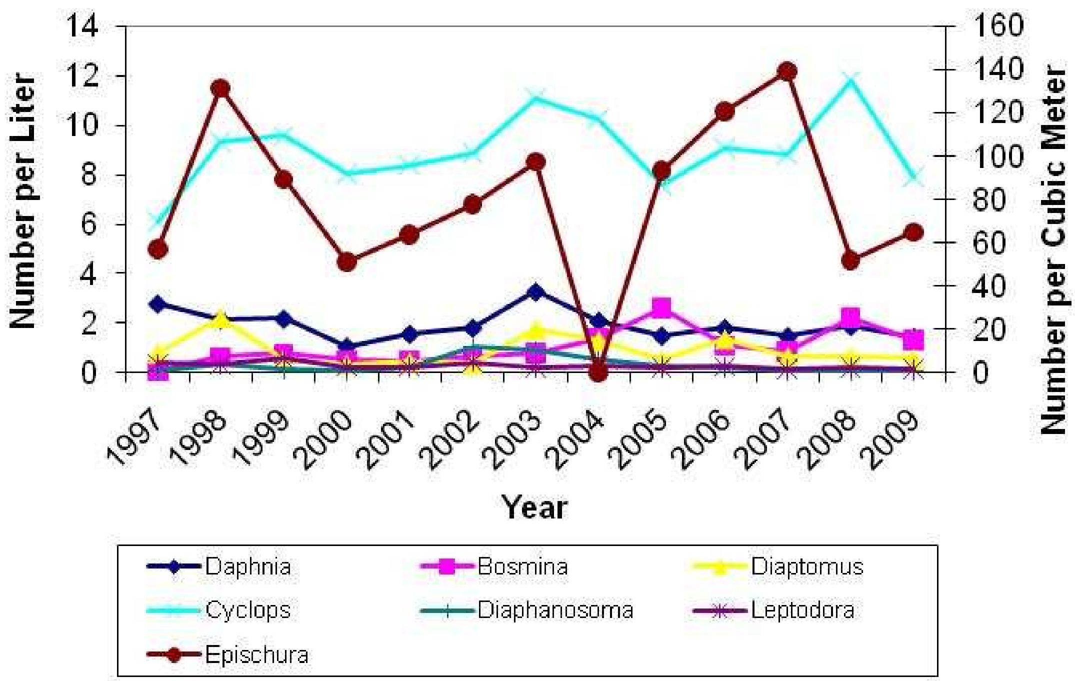


Figure 33. Annual zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2009. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter. The data utilized for this figure are presented in Appendix Table A9.

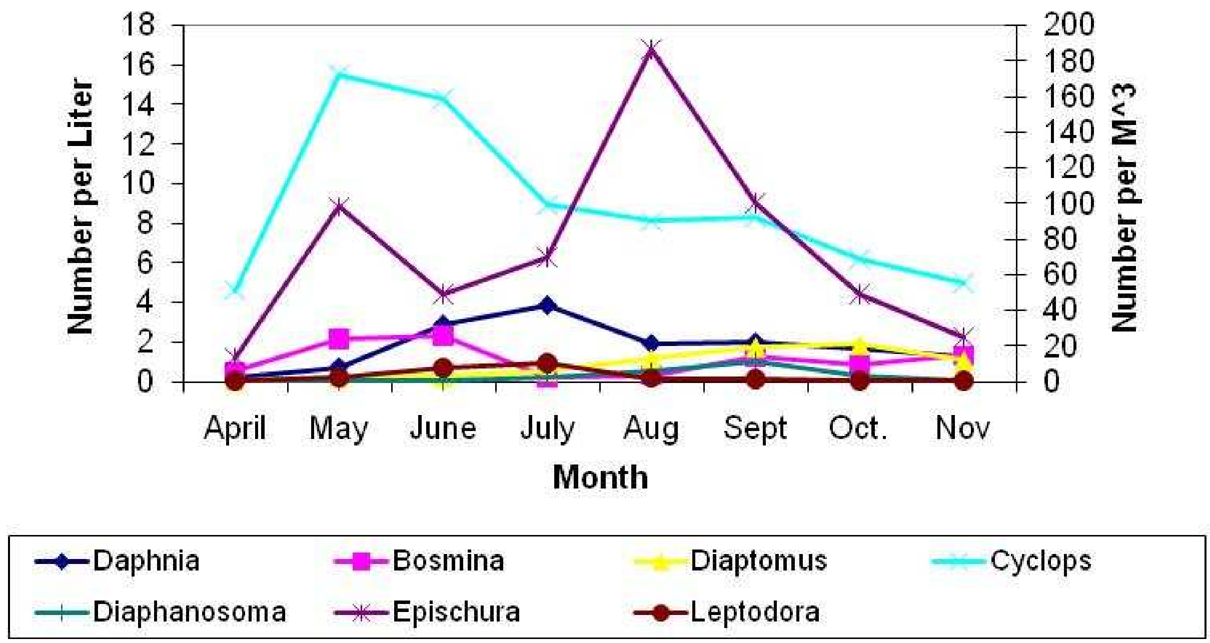


Figure 34. Mean monthly zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2009. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter.

Table 18. Individual probability values (p values) resulting from analysis of variance procedures that tested for differences in zooplankton densities by month (April – November), area (Tenmile, Rexford and Canada) and a month by area interaction in 2009.

Genus	**Month**	**Area**	**Month*Area Interaction**
Daphnia	0.003	0.028	0.025
Bosmina	<0.001	0.201	0.937
Diaptomus	0.012	0.494	0.010
Cyclops	<0.001	0.002	0.005
Leptodora	<0.001	0.095	0.038
Epischura	<0.001	0.042	<0.001
Diaphanosoma	<0.001	0.442	0.451

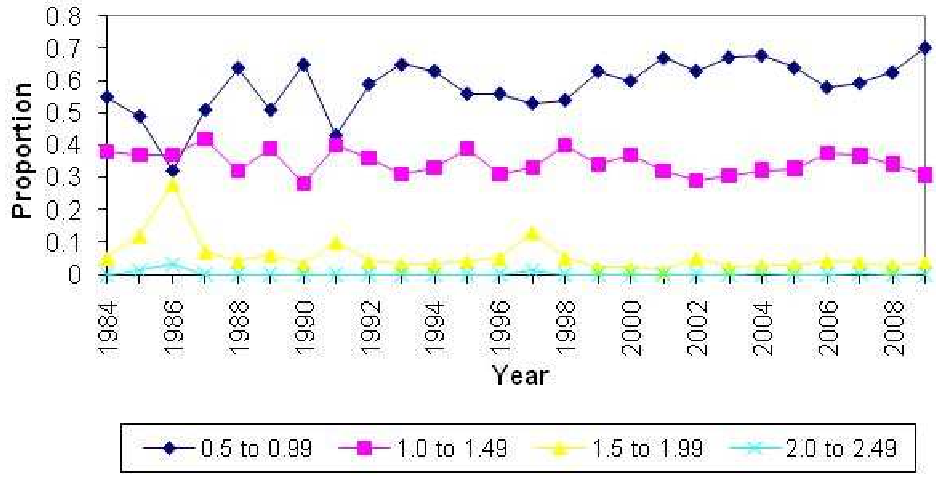


Figure 35. *Daphnia* species size composition in Libby Reservoir, 1984 through 2009.

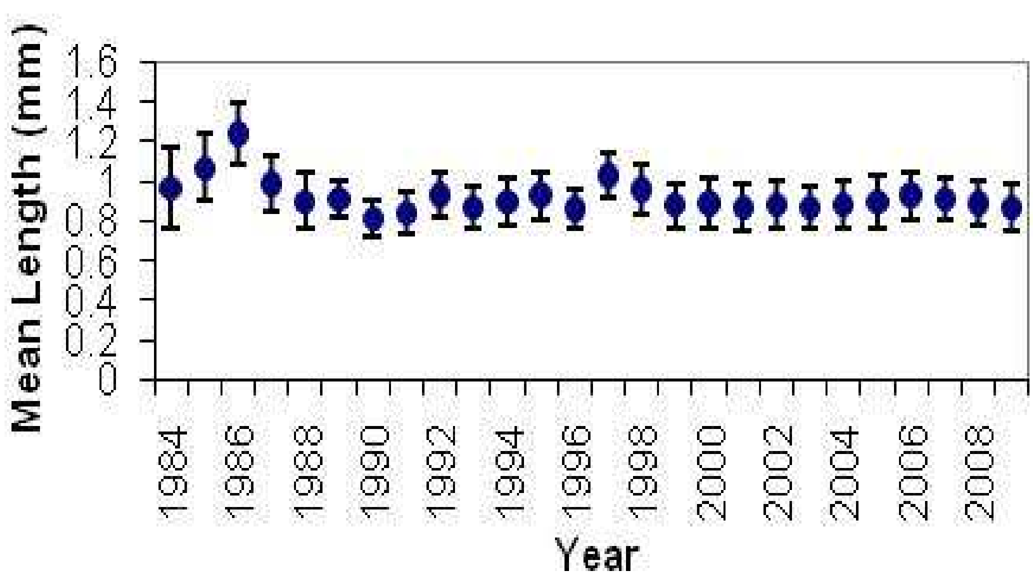


Figure 36. Mean length of *Daphnia* species in Libby Reservoir, 1984 through 2009, with error bars representing plus and minus one standard deviation from the mean.

Bull Trout Redd Counts

Grave Creek

MFWP counted redds in Grave Creek (including Blue Sky, Clarence, Williams and Lewis Creeks) for the first time in 1983, as well as in 1984, 1985, and 1993 through 2009. Grave Creek was surveyed from the confluence of Cat Creek River upstream to near the mouth of Lewis Creek (approximately 4.9 miles), where it becomes intermittent. Most redds in Grave Creek were located upstream from the mouth of Clarence Creek to the confluence with Lewis Creek. MFWP found 10 redds between the confluence with the Tobacco River and one mile below Clarence Creek in 1983. However, we did not find redds in this reach during surveys conducted in 1993 and 2000. The distribution of bull trout redds in Blue Sky, Clarence, Williams and Lewis creeks was similar to observations in previous years (Hoffman et al. 2002).

We observed 131 bull trout redds in Grave Creek in 2009, which was approximately 37% lower than we observed in 2008, and the lowest redd count observed since 2000. The highest redd count was 245 redds and was observed in 2003 (Table 19). Nevertheless, bull trout have exhibited a significant positive trend in spawning abundance in Grave Creek since 1993 (Figure 37; $r^2 = 0.619$; $p = 0.0002$).

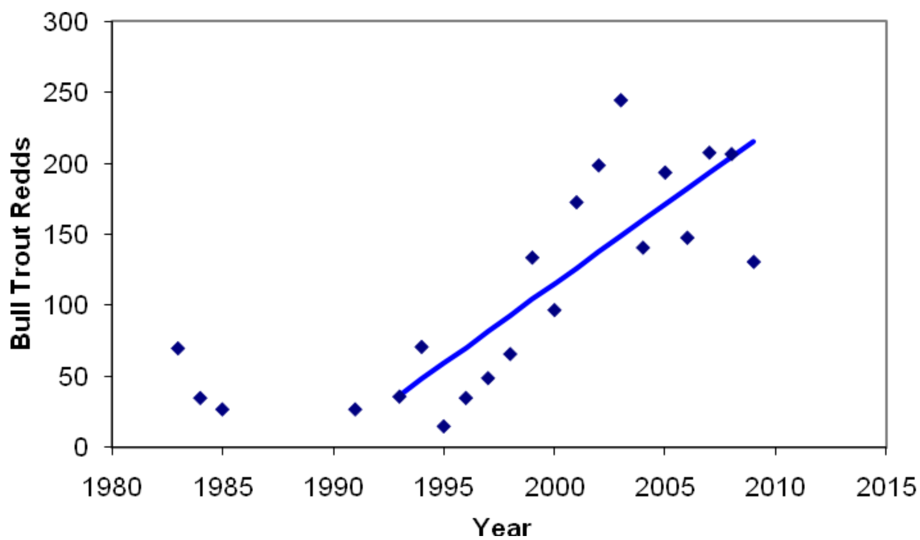


Figure 37. Bull trout redd counts and trend analysis in Grave Creek, 1993 through 2009.

Wigwam Drainage

Bull trout redd counts for the Wigwam River includes the tributary streams of Bighorn, Desolation, and Lodgepole creeks, and the portion of the Wigwam River within Montana. In 2009, a total of 1,575 bull trout redds were observed in the ten index reaches typically surveyed in the Wigwam Drainage (Figure 38). The trend in bull trout redd abundance since 1995 continues to represent a significant positive relationship. The peak count occurring in 2006 at 2298 redds, but has decreased each year since (Table 19). We observed at total of 8 bull trout redds in the Montana portion of the Wigwam River, which represents the upper most reach.

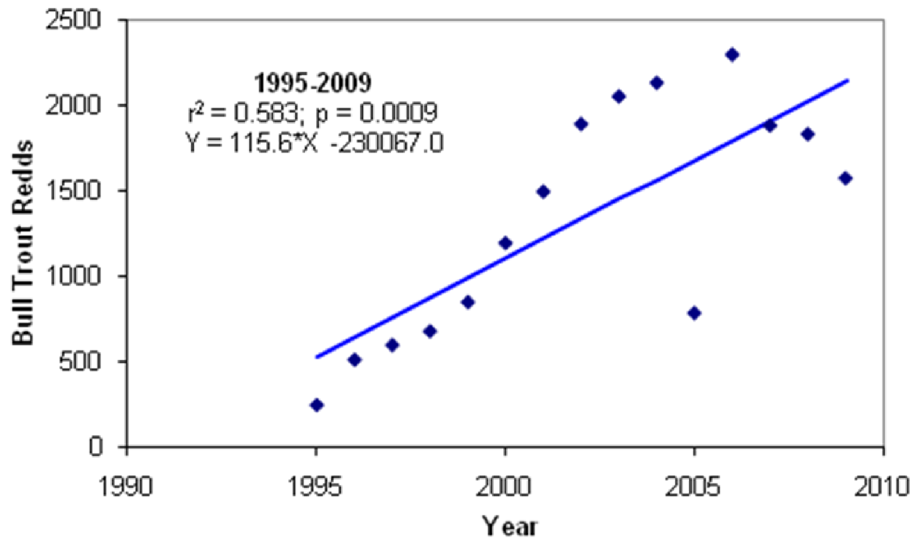


Figure 38. Bull trout redd counts and trend analysis for the Wigwam River (including Bighorn, Desolation, and Lodgepole creeks) 1995-2009.

Table 19. Bull trout redd survey summary for all index tributaries in the Kootenai River Basin.

Stream	Year Surveyed	Number of Redds	Miles Surveyed
Grave Creek	1995	15	9
Includes Clarence and Blue Sky Creeks	1996	35	17
	1997	49	9
	1998	66	9
	1999	134	9
	2000	97	9
	2001	173	9
	2002	199	9
	2003	245	9
	2004	141	9
	2005	194	9
	2006	148	9
	2007	208	9
	2008	207	9
	2009	131	9
Quartz Creek	1995	66	12.5
Includes West Fork and Mainstem	1996	47	12.0
	1997	69	12.0
	1998	105	8.5
	1999	102	8.5
	2000	91	8.5
	2001	154	8.5
	2002	62[e]	8.5
	2003	55	8.5
	2004	49	10.0
	2005	71	8.5
	2006	51	8.5
	2007	35	8.5
	2008	46	8.5
	2009	31	8.5
O'Brien Creek	1995	22	4.5
	1996	12	4.0
	1997	36	4.3
	1998	47	4.3
	1999	37	4.3
	2000	34	4.3
	2001	47	4.3
	2002	45	4.3
	2003	46	4.3
	2004	51	4.3
	2005	81	4.3
	2006	65	4.3
	2007	77	4.3
	2008	79	4.3
	2009	40	4.3
Pipe Creek	1995	5	10
	1996	17	12.0
	1997	26	8.0
	1998	34	8.0
	1999	36	8.0
	2000	30	8.0
	2001	6[a]	8.0

Table 19 (Continued). Bull trout redd survey summary for all index tributaries in the Kootenai River Basin.

Stream	Year Surveyed	Number of Redds	Miles Surveyed
Pipe Creek (continued)	2002	11	8.0
	2003	10	8.0
	2004	8	8.0
	2005	2	8.0
	2006	6	8.0
	2007	0	8.0
	2008	4	8.0
	2009	9	8.0
Bear Creek	1996	10	4.5
	1997	13	4.25
	1998	22	4.25
	1999[b]	36	4.25
	2000	23	4.25
	2001	4[e]	4.25
	2002	17	4.25
	2003	14	4.25
	2004	6	4.25
	2005	3	4.25
	2006	14	4.25
	2007	9	4.25
	2008	14	4.25
	2009	6	4.25
Keeler	1996	74	9.3
Includes South and North Forks	1997	59	8.9
	1998	92	8.9
	1999	99	8.9
	2000	90	8.9
	2001	13[d]	8.9
	2002	102	8.9
	2003	87	8.9
	2004	126	8.9
	2005	186	8.9
	2006	142	8.9
	2007	84	8.9
	2008	62	8.9
	2009	24	8.9
West Fisher Creek	1995	3	10
	1996	4	6
	1997	0	6
	1998	8	6
	1999	18	10
	2000	23	10
	2001	1	10
	2002	1	6
	2003	1	6
	2004	21	10
	2005	27	10
	2006	4	10
	2007	18	10
	2008	6	10
	2009	8	10
Wigwam (B.C and U.S.)	1995	247	22
Bighorn, Desolation, & Lodgepole creeks	1996	512	22

Table 19 (Continued). Bull trout redd survey summary for all index tributaries in the Kootenai River Basin.

Stream	Year Surveyed	Number of Redds	Miles Surveyed
Wigwam River (continued)	1997	598	22
	1998	679	22
	1999	849	22
	2000	1195	22
	2001	1496	22
	2002	1892	22
	2003	2053	22
	2004	2133	22
	2005	642	22
	2006	2298	22
	2007	1883	22
	2008	1833	22
	2009	1575	22
Skookumchuck Creek (B.C.)	1997	66	1.9
	1998	105	1.9
	1999	161	1.9
	2000	189	1.9
	2001	132	1.9
	2002	143	1.9
	2003	134	15
	2004	140	1.9
	2005	111	
	2006	163	
	2007	144	
	2008	137	
	2009	64	
White River (B.C.)	2001	166	7.8
Includes Blackfoot Creek in 2002, 2003, and 2005-2008	2002	261	7.8
	2003	249	
	2004	190	8.1
	2005	243	
	2006	311	
	2007	266	
	2008	210	
	2009	172	

a: Human built dam below traditional spawning area
b: Included resident and migratory redds
c: Libby Creek dewatered at Highway 2 bridge below spawning sites during spawning run
d: Beavers dammed lower portion during low flows, dam was removed but high water made accurate redd counts impossible
e: Log jam may have been a partial barrier

Note that during low water years, beavers in some streams (Keeler, Pipe, Quartz) have an opportunity to build dams across entire stream rather than just in side channels. Some bull trout migrate upstream before dam construction is complete, most either try to build redds below the dams or appear to leave the streams entirely. This happened in Keeler Creek and Pipe Creek in 2001.

Quartz Creek

Bull trout redd counts in Quartz Creek since 1995 have been variable (Figure 39; r^2 = 0.045), and has not differed significantly from a stable (zero slope) population (Figure 39; p = 0.35). We observed a total of 46 redds in Quartz and West Fork Quartz creeks in 2008 (Table 19). The average number of redds of the period of record was 69.8 redds. The 2008 observation of 31 redds was 54.3% lower than the mean over the period of record, and second lowest redd count over the period of record. Despite the relatively low redd count observed in 2009, Quartz Creek still represents the strongest bull trout populations residing in the Kootenai Basin located downstream of Libby Dam. Keeler Creek is also a relatively strong population, but is a disjunct population residing in Lake Creek and Bull Lake.

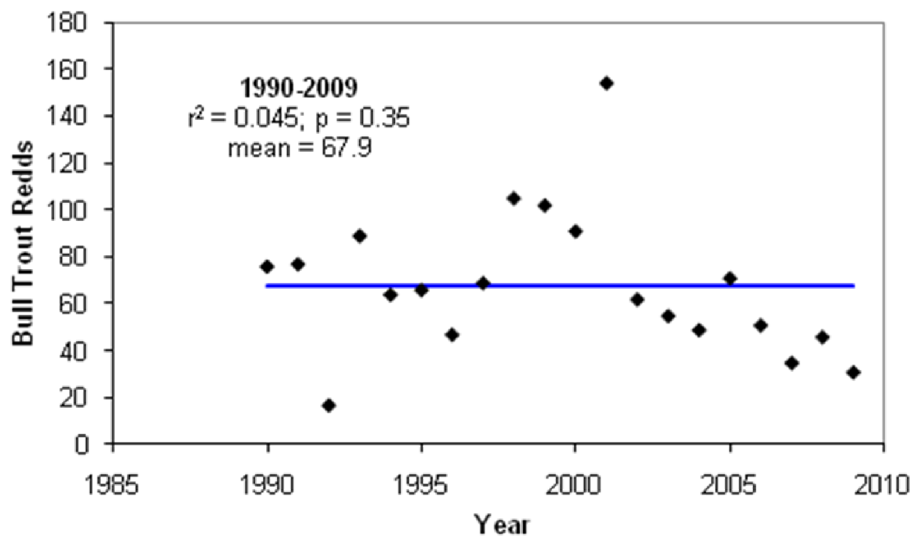


Figure 39. Bull trout redd counts and trend analysis (blue line) for Quartz Creek (including West Fork Quartz) 1990-2009.

Pipe Creek

Bull trout redd counts in Pipe Creek peaked in 1999 at 36 redds. Redd numbers have generally decreased annually since 1996, and dropped to zero in 2007, but rebounded back to 6 redds in 2008, and increased to 9 in 2009, which the highest count since 2003. There is no apparent overall general trend of bull trout redds in Pipe Creek during the period of record (1990-2009; Figure 40). The mean number of bull trout redds since 1990 has been 12.0 redds.

Bear Creek

Bear Creek bull trout redd counts have been variable during the period of record (1995-2009; Figure 41; $r^2 = 0.075$). Although the overall general trend has been a decreasing one since 1995, the relationship is not statistically different than a stable population (Figure 41; $p = 0.322$). We observed 6 redds in Bear Creek in 2009, which was slightly less than half of the average over the period of record (13.1).

O'Brien Creek

The general trend of bull trout redds in O'Brien Creek has significantly increased since 1991 (Figure 42; $r^2 = 0.683$; $p < 0.0001$). However, we only observed 40 redds in O'Brien Creek in 2009, which was the lowest redd count recorded in the past 10 years (Table 19).

West Fisher Creek

The trend in bull trout redd abundance in the West Fisher Creek over the period of record (1993-2009) was not significant different than a stable population (Figure 43; $r^2 = 0.136$; $p = 0.145$). We observed a total of 8 redds in the West Fisher Creek in 2009, which approximately equal to the mean number of the period of record (8.5 redds).

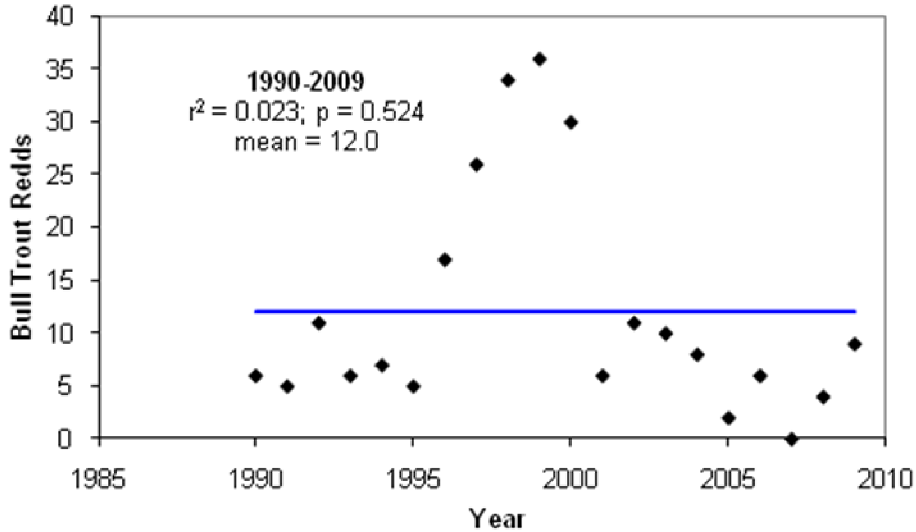


Figure 40. Bull trout redd counts and trend analysis (blue line) for Pipe Creek 1990-2009.

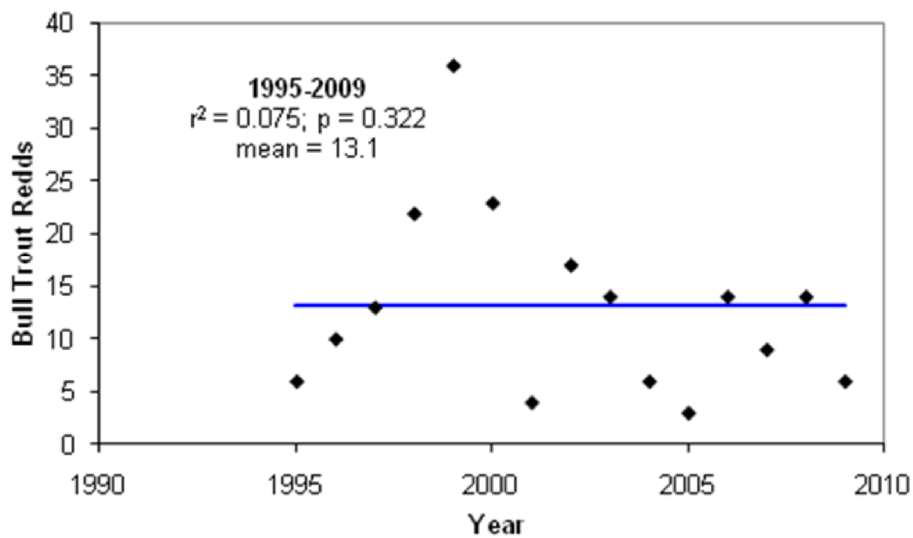


Figure 41. Bull trout redd counts and trend analysis (blue line) in Bear Creek, a tributary to Libby Creek, 1995-2009.

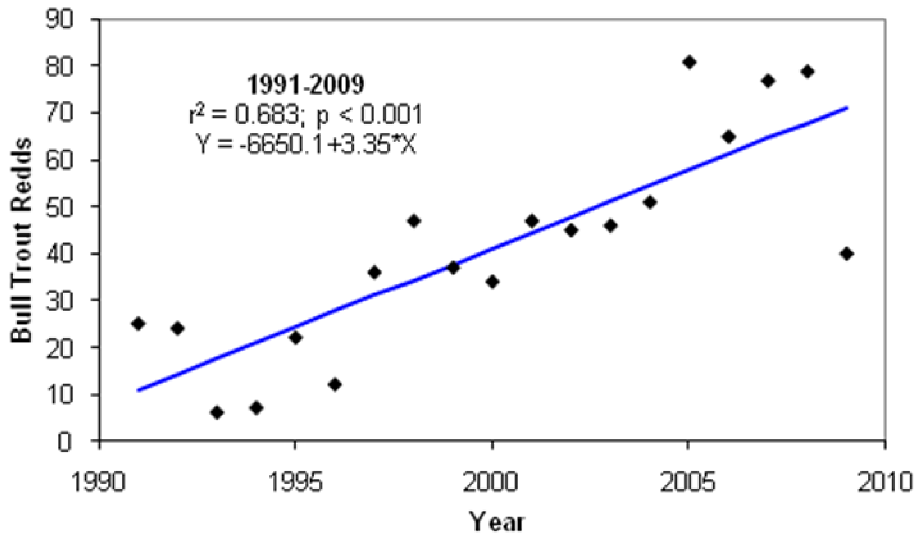


Figure 42. Bull trout redd counts and trend line (blue line) in O'Brien Creek 1991-2009.

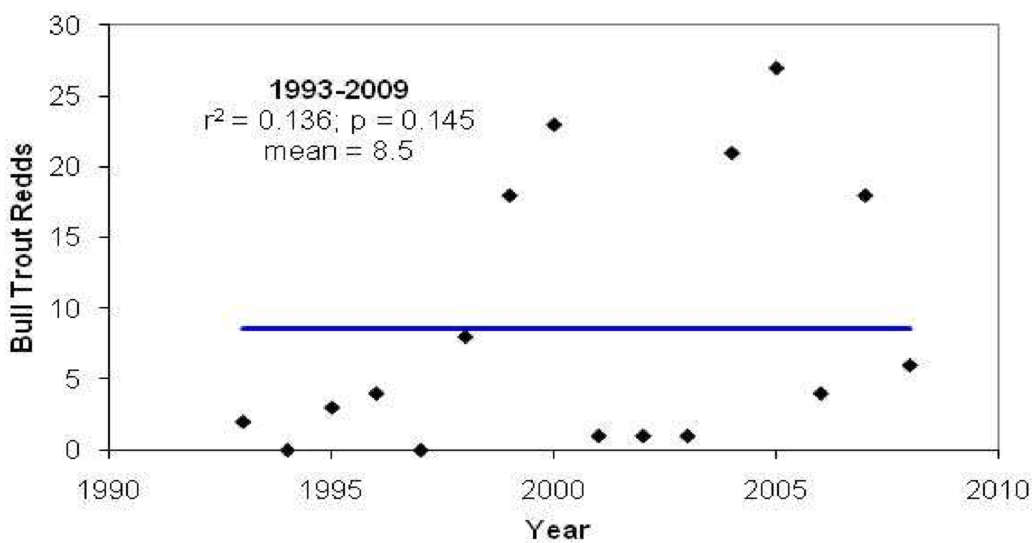


Figure 43. Bull trout redd counts in the West Fisher Creek, a tributary to the Fisher River, 1993-2009.

Keeler Creek

Bull trout that spawn in Keeler Creek (including the North, South and West Forks) are an adfluvial stock that migrates downstream out of Bull Lake into Lake Creek, then up Keeler Creek. This downstream spawning migration is somewhat unique when compared to other bull trout populations (Montana Bull Trout Scientific Group 1996b). Lake Creek, a tributary of the Kootenai River, has an upstream waterfall barrier isolating this population from the mainstem Kootenai River population. A micro-hydropower dam constructed in 1916 covered the upper portion of the waterfall. A series of high gradient waterfalls are still present below the dam, and are barriers to all upstream fish passage. We observed only 24 bull trout redds in Keeler Creek and associated tributaries in 2009, which represented the second lowest count since counts began in 1996 (Table 19), and a 73% reduction from the mean over the period of record (88.6 redds). Redd counts peaked in 2005, but have precipitously decreased annually since. Despite the relatively recent decline in redd counts, we were unable to determine a significant trend in bull trout redds in Keeler Creek since 1995 (Figure 44; $r^2 = 0.041$; $p = 0.489$).

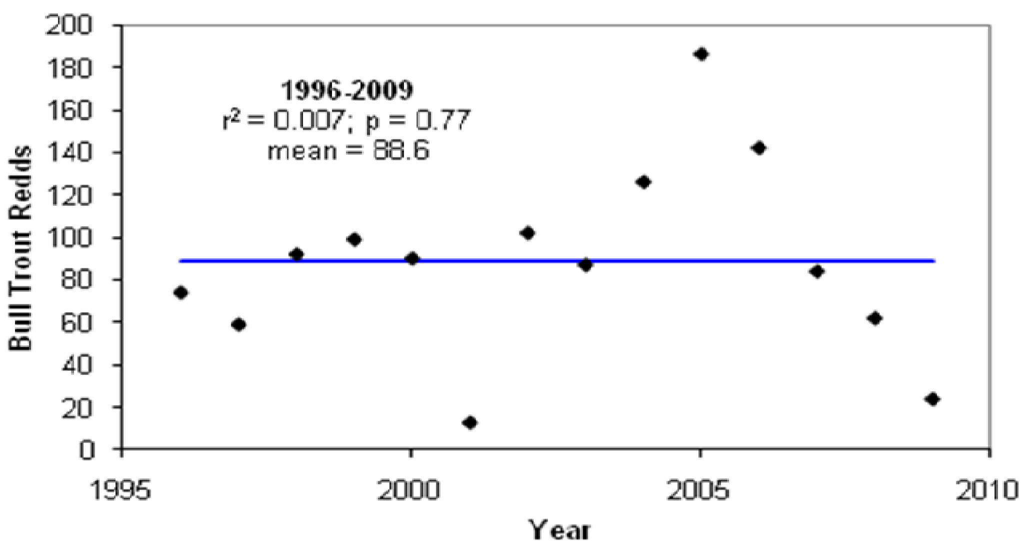


Figure 44. Bull trout redd counts and trend line (blue line) in Keeler Creek, a tributary to Lake Creek, 1996-2009.

Kootenai River Tributaries from Kootenai Falls to Libby Dam

The Montana bull trout spawning tributaries that have direct access to the Kootenai River between Kootenai Falls and Libby Dam include the West Fisher Creek, Bear, Pipe, and Quartz, and O'Brien creeks. These tributaries are somewhat geographically isolated due to complete and partial upstream passage barriers at Libby Dam and Kootenai Falls, respectively. MFWP has documented two bull trout that have ascended Kootenai Falls. One fish was a radio tagged bull trout in 2000 (Dunnigan et al. 2003), and a PIT tagged bull trout in 2008 (Sylvester et al. 2009). Therefore, we documented that Kootenai Falls is not a complete upstream barrier to bull trout migration at some discharges, but it remains likely that the falls represent a substantial barrier at least during certain periods of varying discharge. Therefore, we present two separate analyzes of bull trout redd abundance in the Kootenai River below Libby Dam. One analysis included all tributaries connected to the Kootenai River below Libby Dam including O'Brien Creek (below Kootenai Falls), and the other analysis omits O'Brien Creek. Bull trout redd counts first began in Bear Creek in 1995, and in the West Fisher in 1993, redd counts in the other tributaries began in 1990 (Table 19). Therefore in order to present an accurate assessment, the data presented in both analyzes was limited to the time period 1995-2009.

We observed a total of 54 bull trout redds in the four streams between Kootenai Falls and Libby Dam in 2009. Redd counts during this period peaked in 2001 at 161 redds. The overall mean bull trout redd count for this period equaled 105.2 redds, with no significant trend over this period (Figure 45; $r^2 = 0.231$; $p = 0.070$), and although the trend may not have been significant, it appears that with the exception of the peak in 1999-2001, the populations have been relatively stable. The 54 redds we observed in 2009 represented a 48.7% reduction from the overall average for the period.

The overall trend in total bull trout redds below Libby Dam is very similar when we include counts from O'Brien Creek (Figure 46). We observed a total of 40 bull trout redds in O'Brien Creek in 2009, bringing the total to 94 redds for all five streams in 2009. The overall mean bull trout redd count for this period equaled 153.1 redds, with no apparent trend over this period (Figure 46; $r^2 = 0.08$; $p = 0.61$). Similar to the trend of total redds for all streams located upstream of Kootenai Falls, the total observed in 2009, was lower than the overall average for the period of record by 38.6%.

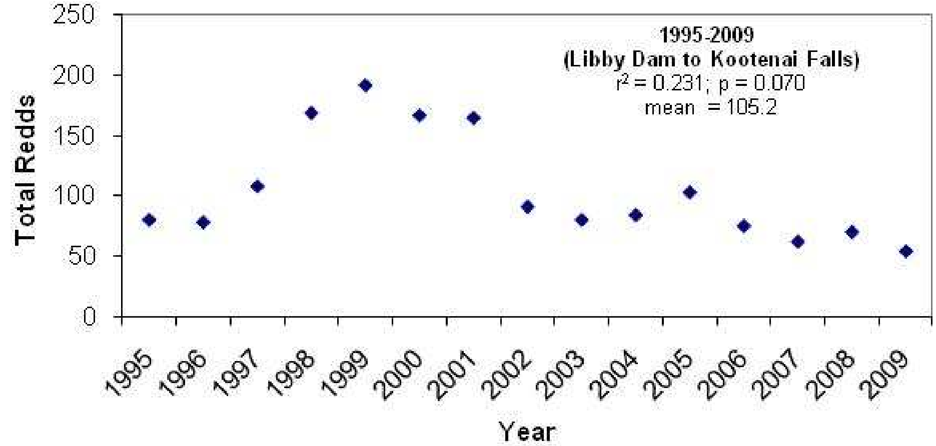


Figure 45. Bull trout redd counts in the tributaries to the Kootenai River between Kootenai Falls and Libby Dam, including West Fisher Creek, Bear, Pipe, and Quartz creeks, 1995-2009.

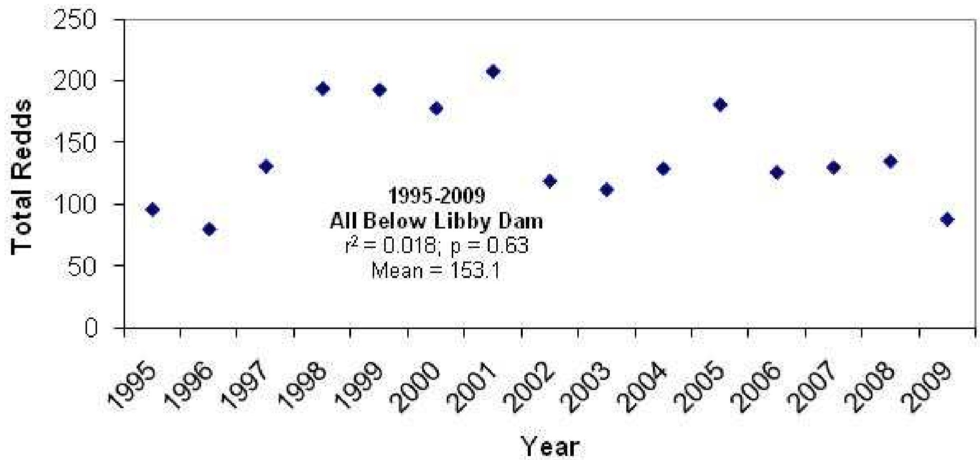


Figure 46. Bull trout redd counts in the tributaries that have direct access to the Kootenai River below Libby Dam, including West Fisher Creek, Bear, Pipe, Quartz, and O'Brien creeks, 1995-2009.

Kootenai River Adult Bull Trout Population Estimate

Montana FWP marked a total of 55 bull trout in the LDT on April 7, 2010. Six days later, we captured 34 bull trout, of which 3 were marked (Table 20). Our efforts yielded an estimate of 489 bull trout within this section prior to spill activities in 2010 (Table 20). However, this estimate failed the validity check (Robson and Regier 1964), and therefore, this estimate to be invalid due to excessive bias. The average bull trout total length for 2010 was 660 mm (range = 402 – 873 mm; Figure 47). The mean length of bull trout in 2004, 2005, 2006, 2007, 2008, and 2009 captured below Libby Dam was 649, 677, 692, 655, 603, and 613 mm, respectively. The mean total length of the bull trout in was similar to most years since we began this work in 2004 (Table 21). Bull trout length in 2010 differed significantly only from fish collected in 2008 (mean = 607.9 mm; Table 21).

We recaptured 27 bull trout during our sampling period April 7 –13, 2010 that were previously marked in 2005, 2006, 2007, 2008 or 2009 below Libby Dam ranging between 79 to 1,819 days prior. The recaptured bull trout grew an average of 142.0 mm (0.22 mm per day), and gained an average of 2293.3g (3.42 g per day; Table 22).

Table 20. The sampling dates for the number of adult bull trout marked, recaptured, and the estimated total population and number of fish per mile in the Kootenai River from Libby Dam downstream to the Fisher River confluence. The 95 percent confidence intervals (CI) are presented in parentheses. However, this estimate is excessively biased, and cannot be considered a valid estimate.

Dates	**Number Marked**	**Number Recaptured**	**Total Population Estimate (95 % CI)**	**Fish per Mile (95 % CI)**
April 7, 2010	55	N/A		
April 13, 2010	34	3	489 (100-879)	140 (28 - 251)

Table 21. Bull trout length summary of fish collected during mark recapture population estimates in the Libby Dam Tailrace area of the Kootenai River 2004-2010. Statistical comparisons between years were made using an analysis of variance and subsequent Tukey's multiple comparisons.

Year	Mean	Range	Standard Deviation	Median	Mode	Significantly Different than (P<0.05)
2004	648.9	343-861	113.3	646.5	647	2008
2006	692.3	425-870	105.2	701	625	2008 & 2009
2007	655.1	308-875	137.0	672.5	658	none
2008	602.9	237-900	158.8	613	795	2004, 2006 & 2010
2009	613.1	319-855	125.1	611	514	2006
2010	659.8	402-873	117.7	680.5	746	2008

Table 22. Recapture summary information for bull trout recaptured below Libby Dam between April 7 and 13, 2010. Information includes the date each fish was originally captured, recaptured, and length and weight for each encounter. Fish were captured via nighttime electrofishing. Mean daily growth rates are presented in parentheses.

Original Tag Date	Recapture Date	PIT tag Number	Length at Capture (mm)	Weight at Capture (g)	Length at Recapture (mm)	Weight at Recapture (g)	Length Increase (mm)	Weight Increase (g)
4/20/2005	4/13/2010	3D9.1BF1C6780E	415	638	803	7185	388 (0.21)	6547 (3.60)
6/19/2006	4/7/2010	3D9.257C5A9765	330	272	806	7581	476 (0.34)	7309 (5.27)
1/22/2010	4/13/2010	3D9.257C5E5840	694	N/A	706	4103	12 0.14)	N/A
4/10/2008	4/7/2010	3D9.257C5E66C4	617	2477	750	5226	133 (0.18)	2749 (3.78)
4/1/2009	4/7/2010	3D9.257C5E66C4	729	4873	750	5226	21 (0.06)	353 (0.95)
8/29/2008	4/7/2010	3D9.257C6BFC78	311	248	562	2062	251 (0.42)	1814 (3.10)
4/9/2008	4/7/2010	3D9.257C6BFF05	566	2015	718	4168	152 (0.21)	2153 (2.96)
9/24/2009	4/7/2010	3D9.257C6C0065	546	1786	569	1990	23 (0.12)	204 (1.05)
4/7/2009	4/7/2010	3D9.257C6C0782	456	886	649	3825	193 (0.53)	2939 (8.05)
5/2/2007	4/13/2010	3D9.257C6C2A58	321	292	751	5419	430 (0.40)	5127 (4.76)
1/8/2008	4/7/2010	3D9.257C6C2AC8	685	N/A	746	3884	61 (0.07)	N/A
2/27/2009	4/13/2010	3D9.257C6C3618	315	N/A	439	798	124 (0.30)	N/A
4/9/2008	4/7/2010	3D9.257C6C3B6F	557	1760	693	3619	136 (0.19)	1859 (2.55)
4/7/2009	4/13/2010	3D9.257C6C3F58	514	1232	644	2685	130 (0.35)	1453 (3.91)
9/5/2008	4/7/2010	3D9.257C6C3FF2	284	164	426	647	142 (0.24)	483 (0.83)
12/30/2009	4/7/2010	3D9.257C6C409B	820	N/A	840	7219	20 (0.20)	N/A
8/29/2008	4/7/2010	3D9.257C6C458A	313	282	521	1788	208 (0.35)	1506 (2.57)
4/7/2009	4/7/2010	3D9.257C6C4712	555	1696	695	4260	140 (0.38)	2564 (7.02)
4/1/2009	4/13/2010	3D9.257C6C4BFF	708	3688	727	4962	19 (0.05)	1274 (3.38)
12/21/2007	4/7/2010	3D9.257C6C4CC5	325	N/A	590	3036	265 (0.32)	N/A

Table 22. (Continued) Recapture summary information for bull trout recaptured below Libby Dam between April 7 and 13, 2010. Information includes the date each fish was originally captured, recaptured, and length and weight for each encounter. Fish were captured via nighttime electrofishing. Mean daily growth rates are presented in parentheses.

Original Tag Date	Recapture Date	PIT tag Number	Length at Capture (mm)	Weight at Capture (g)	Length at Recapture (mm)	Weight at Recapture (g)	Length Increase (mm)	Weight Increase (g)
4/7/2009	4/7/2010	3D9.257C6C4EEE	530	1499	646	2895	116 (0.32)	1396 (3.82)
8/29/2008	4/13/2010	3D9.257C6C57FF	290	188	485	1050	195 (0.33)	862 (1.46)
4/9/2008	4/7/2010	3D9.257C6C5845	537	1681	678	3742	141 (0.19)	2061 (2.83)
4/7/2009	4/13/2010	3D9.257C6C58BF	631	2695	707	4275	76 (0.20)	1580 (4.26)
4/9/2008	4/13/2010	3D9.257C6C5BBA	853	8203	842	9835	-11(-0.01)	1632 (2.22)
12/30/2009	4/13/2010	3D9.257C6C5BBA	845	N/A	842	9835	-3 (-0.03)	N/A
1/24/2010	4/13/2010	3D9.257C6C7DFB	660	N/A	657	3508	-3 (-0.04)	N/A
Mean			**533.6**	**1828.8**	**675.6**	**4252.7**	**142.0 (0.22)**	**2293.3 (3.42)**

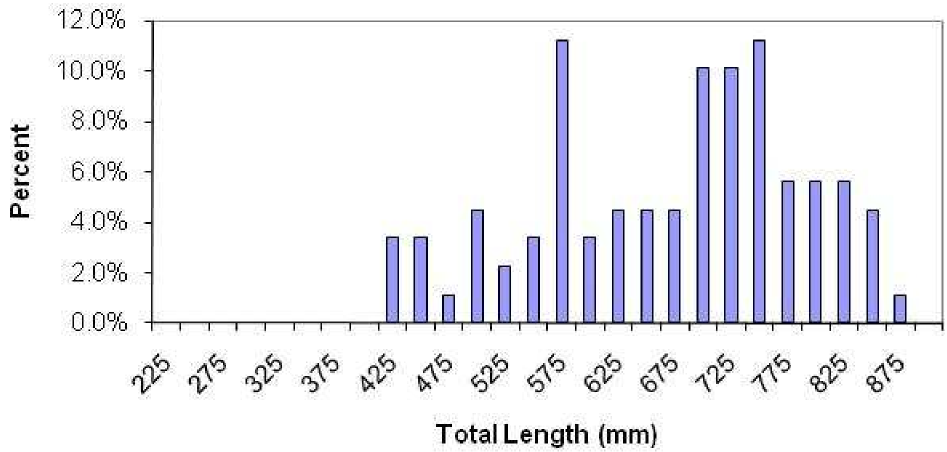


Figure 47. Length frequency distribution of bull trout captured via jet boat electrofishing on April 7 to 13, 2010 in the Kootenai River below Libby Dam. The mean total length for all fish captured was 660 mm.

Bull Spawning Habitat Surveys

The adjunct bull trout population that resides in Bull Lake and spawns in Keeler Creek had the lowest mean annual levels of fine sediment (<6.35 mm) amongst the eight streams we monitored, averaging 22.2% (Figure 48). The percent of fine sediment in the monitoring section of North Fork Keeler Creek averaged 22.2% from 1998-2010 (Figure 48; Appendix Table A6). Fine sediment generally increased from 2000 to 2004 and then gradually decreased to 2010. Levels of fine sediment were significant between years ($p = 0.003$), with fine sediment levels in 2003 and 2004 both being significantly higher than those observed in 2010.

O'Brien Creek had the highest mean levels of fine sediment amongst the eight streams we monitored, averaging 31.8%. Fine sediment levels peaked in 2005 (38.6%) and then generally decreased through 2010 (Figure 49). Mean annual fine sediment was lowest in 2008 (21.6%) and accounted for most of the significant annual comparisons, with 2001-2006 being significantly higher (Figure 49). Fine sediment levels in 2005 were also significantly higher than those we measured in 2010. All other annual comparisons were not significant ($p > 0.05$). A significant inverse relationship exists between the percentage of fine sediment in substrates and survival to emergence of westslope cutthroat trout and bull trout embryos in incubation tests (Weaver and White 1985; Weaver and Fraley 1991, 1993). Mean adjusted emergence success ranged from about 80 percent when no fine material was present, to less than 5 percent when half of the incubation gravel was smaller than 6.35 mm; about 30 percent survival occurs at 35 percent fines. Entombment was the major mortality factor.

Of the four core bull trout spawning tributaries located on the Kootenai River between Libby Dam and Kootenai Falls, West Fisher Creek had the lowest annual mean percent of fine sediment levels (22.9%), ranging from the observed high in 2009 (30.4%) to a low in 2008 (9.7%; Figure 50). Fine sediment levels did differ significantly between years ($p < 0.001$). The relatively low fine sediment values observed in 2008 likely dominated the results of the ANOVA, with fine sediment in 2008 being significantly less than those observed during all other three years. Fine sediment levels on West Fork Quartz Creek have been relatively consistent across years, averaging 26.8% (Figure 51), and not differing significantly ($p = 0.097$) between years of record (1998-2010). The power of this test was moderately high (0.747). Sediment levels near bull trout redds have ranged from a low of 20.7% in 2009 to a high of 30.6% in 2005 (Figure 51). Mean annual fine sediment levels in Bear Creek have been variable, averaging 26.8%, with no apparent trend obvious over the period 2002 to 2010 (Figure 52). Sediment levels on Bear Creek peaked in 2004 (35.0%), with the lowest mean annual value observed in 2008 (15.9%). Significant differences between years existed for seven possible combinations (Figure 52). Mean annual fine sediment levels on Pipe Creek were the second highest value of the eight streams we monitored, ranging from a low of 23.1%in 2008 to a high value of 38.8% in 1998, and averaging 30.4% across years (Figure 53). Mean annual sediment levels in 1998 were significantly higher than 2001 and 2008 (Figure 53).

The two bull trout spawning tributaries located in Montana upstream of Libby Dam (Grave Creek and MT Wigwam) had relatively low fine sediment levels. We monitored fine sediment levels in Grave Creek annually from 1998 to 2010, with the exception of 1999 and 2007. During this time period, fine sediment levels in Grave Creek averaged 26.3%, ranging from 21.4% in 1998 to 30.3% in 2008 (Figure 54; Appendix Table A10). ANOVA suggested that yearly differences in fine sediment levels were nearly significant ($p = 0.066$). The power of this test was 0.816. The trend somewhat suggests an increasing trend in fine sediment between years. However, the trend did not differ significantly from a zero slope ($r^2 = 0.236$; $p = 0.13$). We monitored fine sediment in the Montana portion of the Wigwam River annually from 1998 to 2010, with the exception of 2001, 2002 and 2003 when conditions prevented us from accessing the stream coring sites. Mean annual fine sediment levels in the Montana portion of the Wigwam River averaged 26.3%, and ranged from a low value of 20.5% in 2008 to 38.3% in 2004 (Figure 55; Appendix Table A10). ANOVA results did not declare any annual differences significantly different ($p =0.167$). The power of this test was 0.664. However, The multiple comparison procedures found fine sediment levels in 2008 to be significantly lower than those observed in 2004 ($p=0.026$).

High levels of fine sediment (<6.35 mm) in salmonid redds has been shown to have deleterious effects on incubating embryos. Fine particles within the interstitial spaces have been shown to lower egg to fry survival by impeding movement of water through the gravel, thereby reducing delivery of dissolved oxygen to, and flushing of metabolic wastes away from incubating embryos (Wickett 1958; McNeil and Ahnell 1964; Reiser and Wesche 1979). High levels of fine sediment have also been shown to restrict embryo movement within the redd (Koski 1966; Bjornn 1969; Phillips et al. 1975), alter timing at (Alderdice et al. 1958; Shumway et al. 1964) and and condition of emergence (Silver et al. 1963; Koski 1975). Weaver and Fraley (1991; 1993) demonstrated a significant inverse relationship between the percent of fine sediment and survival to emergence of westslope cutthroat trout and bull trout in laboratory tests. Mean adjusted emergence success ranged from about 80 percent when no fine material was present, to less than 5 percent when 50 percent of the incubation gravel was smaller than 6.35 mm, and about 30 percent survival was observed when 35 percent of the substrate consisted of fines. Entombment was the major mortality factor in this study.

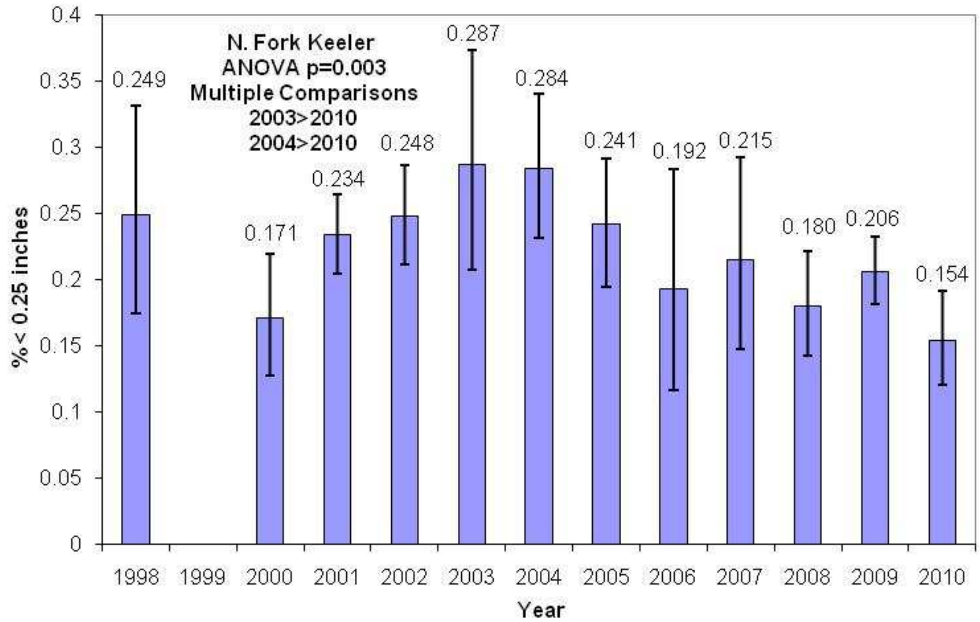


Figure 48. Fine sediment levels (<6.35 mm) in North Fork Keeler Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented. Significant annual differences are listed.

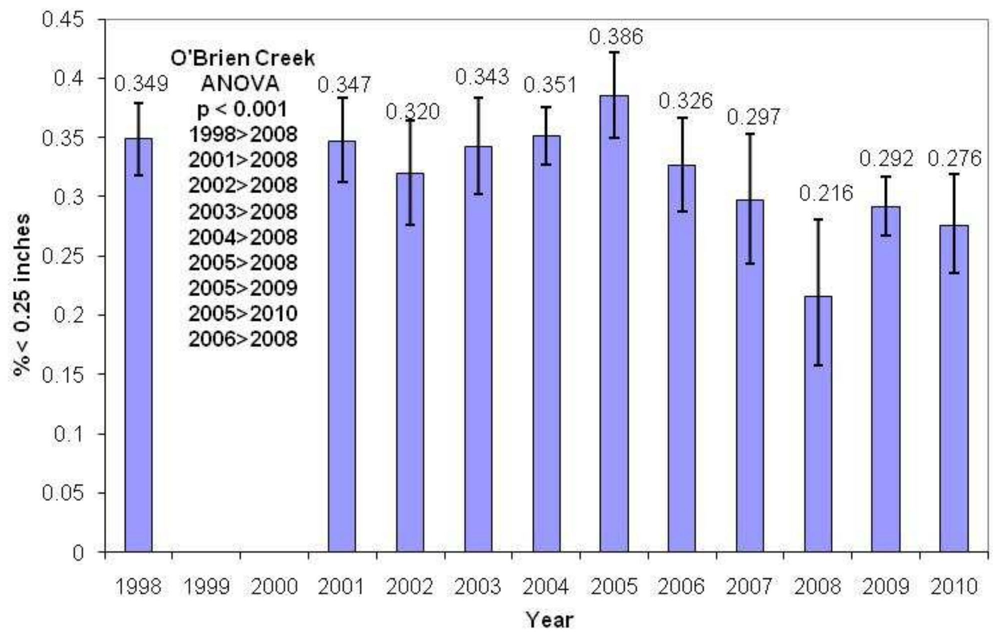


Figure 49. Fine sediment levels (<6.35 mm) in O'Brien Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented. Significant annual differences are listed.

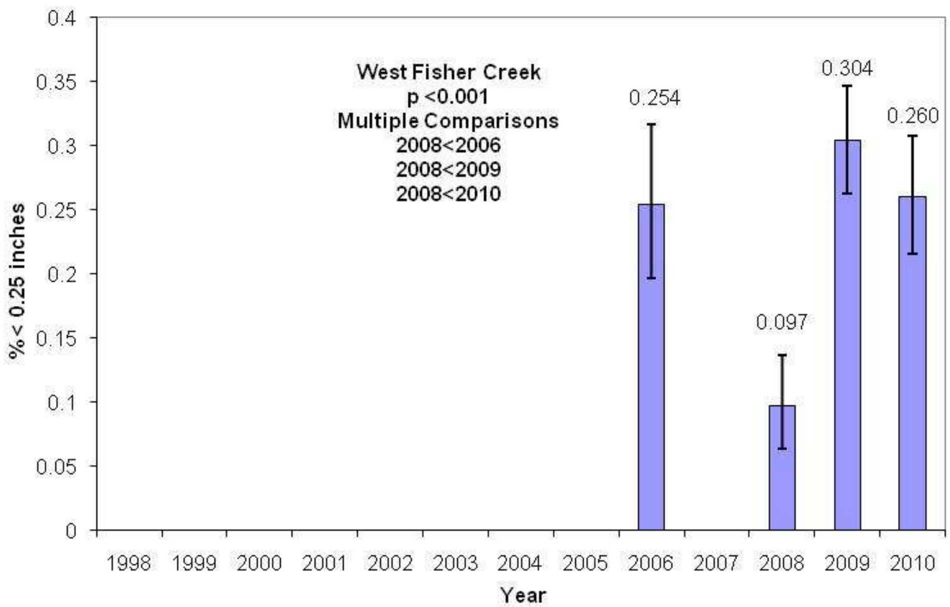


Figure 50. Fine sediment levels (<6.35 mm) in West Fisher Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented. Significant annual differences are listed.

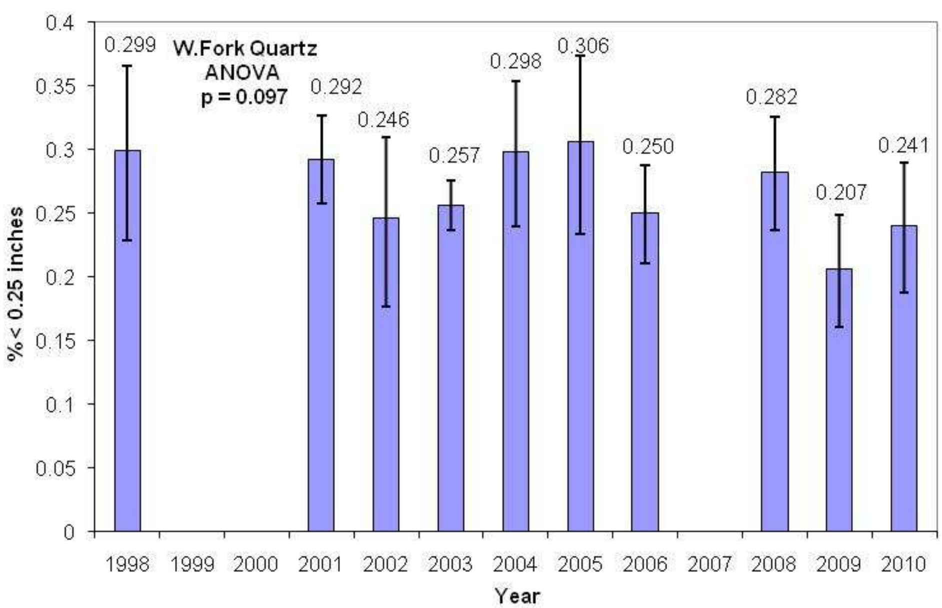


Figure 51. Fine sediment levels (<6.35 mm) in West Fork Quartz Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented.

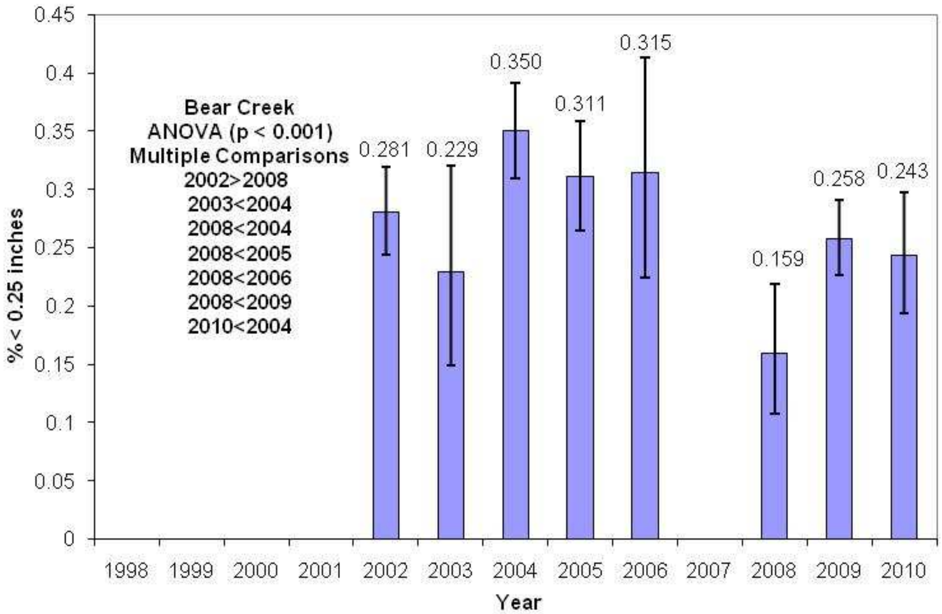


Figure 52. Fine sediment levels (<6.35 mm) in Bear Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented. Significant annual differences are listed.

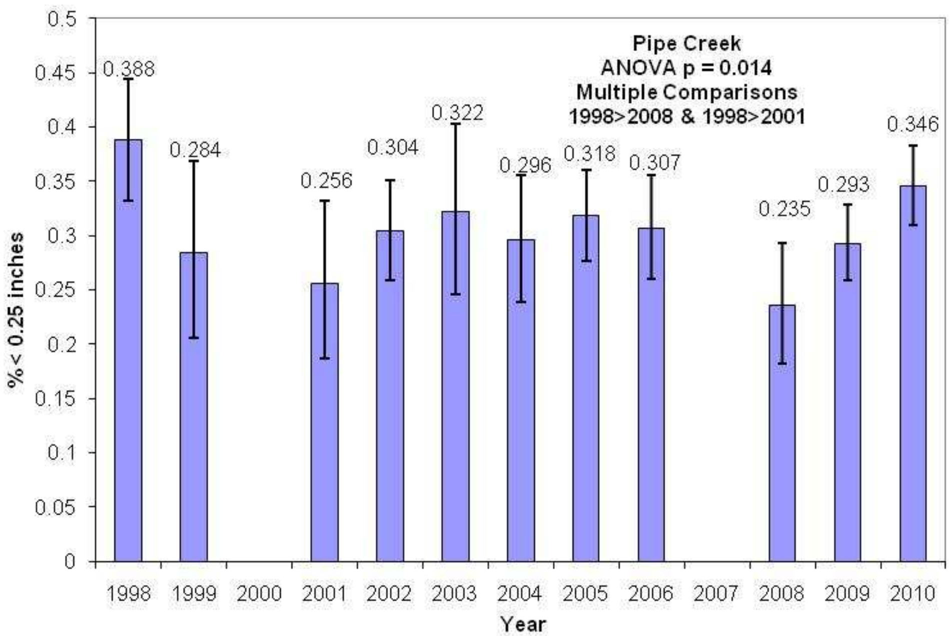


Figure 53. Fine sediment levels (<6.35 mm) in Pipe Creek. The annual mean values appear above each year, and the whisker bars represent the 95% confidence interval. The p-value from an analysis of variance that tested for annual differences is also presented. Significant annual differences are listed.

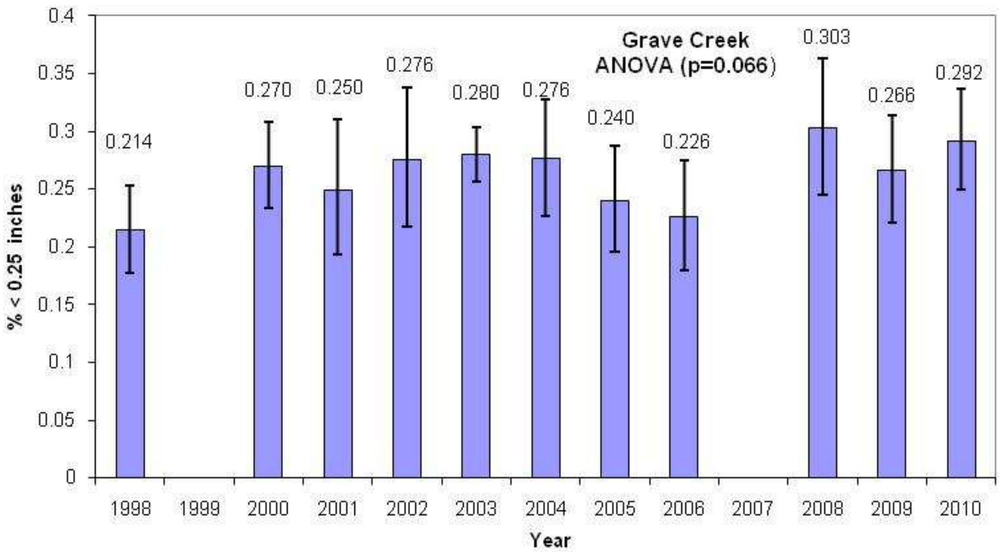


Figure 54. Fine sediment levels (<6.35 mm) in Grave Creek. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented.

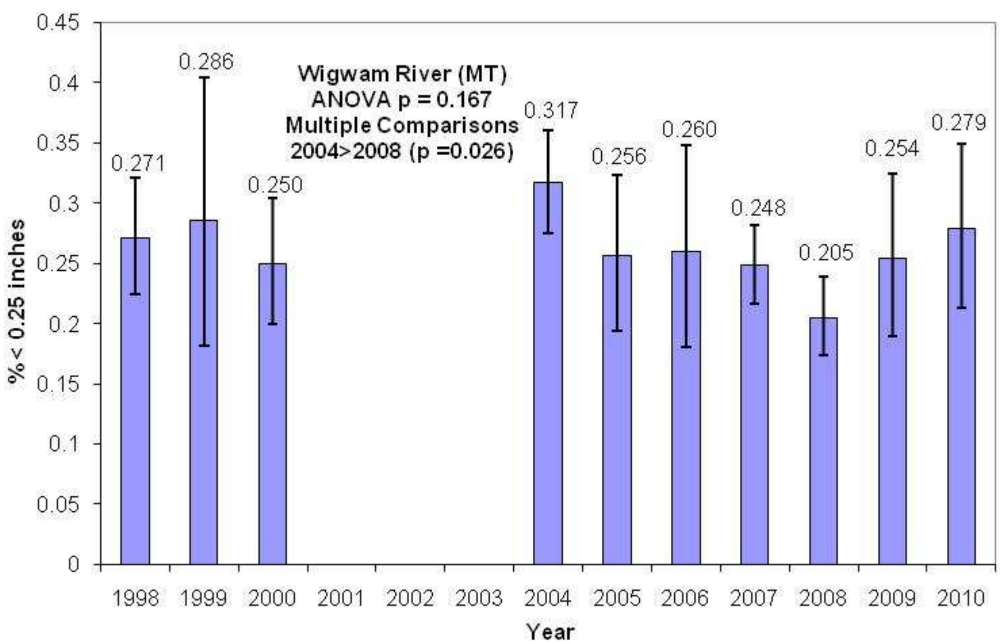


Figure 55. Fine sediment levels (<6.35 mm) in the Montana portion of the Wigwam River. The annual mean values appear above each year, and the whisker bars represent 95% confidence intervals. The p-value from an analysis of variance that tested for annual differences is also presented. The only significant annual difference is listed.

References

Alderdice, D. F. , W. P. Wickett, and J. R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on Pacific salmon eggs. Journal of the Fisheries Research Board of Canada 15: 229-250.

Ardren, W, P. DeHaan, J. Dunnigan. 2007. Genetic analysis of bull trout in the Kootenai River Basin: Final Report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Bernard, D. R., G. A. Pearse and R. H. Conrad. 1991. Hoop traps as a means to capture burbot. North American Journal of Fisheries Management 11:91-104

Bjornn, T. C. 1969. Embryo survival and emergence studies, Job No. 5, Federal Aid in Fish and Wildlife Restoration. Job Completion Report, Project F-49-R-7. Idaho Fish and Game Department, Boise.

Chisholm, I.M., M.E. Hensler, B. Hansen, D. Skaar. 1989. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries. Methods and Data Summary 1983-1987. Prepared for Bonneville Power Administration by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

DeHaan, P., L. Godfrey, and W. Ardren. 2008. Genetic assignments of bull trout collected at Libby Dam 2004 to 2007: Final Report. Montana Fish, Wildlife and Parks, Libby.

Dunnigan, J.L,, J. DeShazer, L. Garrow, B. Marotz, and T. Ostrowski. 2003. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2001-2002 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L,, J. DeShazer, L. Garrow, B. Marotz, T. Ostrowski, and C. Sinclair. 2005. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2004 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L., J. DeShazer, L. Garrow, T. Ostrowski, and M. Benner, R. Leary, J. Tohtz, and D. Neeley. 2009. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2007 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Graham, P.J., P.W. Fredenberg, and J. Huston. 1982. Supplements to recommendations for a fish and wildlife program. Submitted to: Pacific Northwest Power Planning Council by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Hoffman, G. B. Marotz, J. DeShazer, L. Garrow, T. Ostrowski, and J. Dunnigan. 2002. Mitigation for the construction and operation of Libby Dam: Annual report 2000. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Huston, J.E., P.D. Hamlin and B. May. 1984. Lake Koocanusa fisheries investigations final report. Prepared for United States Army Corp of Engineers, Seattle District. Seattle, Washington.

Kimmel, B.L. and A.W. Groeger. 1986. Limnological and ecological changes associated with reservoir aging. Pages 103-109 in G.E. Hall and M.J. Van Den Avyle, editors. Reservoir Fisheries Management: Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society. Bethesda, Maryland.

Kootenai Tribe of Idaho (KTOI) and Montana Fish, Wildlife & Parks (MFWP). 2004. Kootenai Subbasin Plan. Available on CD from the Kootenai Tribe of Idaho, Bonners Ferry, ID and Montana Fish, Wildlife & Parks, Kalispell. Also available at: http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan/

Koski, K. V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. Master’s thesis. Oregon State University, Corvallis, Oregon.

Koski, K. V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled stream environment at Big Beef Creek. Doctoral dissertation. University of Washington. Seattle, Washington.

Lagler, K.F. 1956. Freshwater fishery biology. Wm. C. Brown Company, Dubuque, Iowa.

Leary, R.F., F.W. Allendorf, and S.R. Phelps. 1983. Electrophoretic examination of trout from Lake Koocanusa, Montana: Inability of morphological criteria to identify hybrids. Population Genetics Laboratory Report 83/8, MIMCO. University of Montana, Missoula, Montana.

Leary, R. 2005. Letter to Murray Spring Fish Hatchery from Robb Leary. Eureka, Montana.

Leathe, S.A. and P.J. Graham. 1982. Flathead Lake fish food habits study. Final Report. Prepared for the Environmental Protection Agency by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Marotz, B.L., D. Gustafson, C. Althen and B. Lonnen. 1996. Model development to establish integrated operational rule curves for Hungry Horse and Libby Reservoirs-Montana. Report to Bonneville Power Administration by Montana Department of Fish, Wildlife, and Parks, Kalispell, Montana. 114pp.

Marotz, B.L., D. Gustafson, C.L. Althen, and W. Lonon. 1999. Integrated operational rule curves for Montana reservoirs and application for other Columbia River storage projects. Pages 329-352 In Ecosystem Approaches for Fisheries Management. Alaska Sea Grant College Program. AK-SG-99-01, 1999.

McNeil, W. J. and W. H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U. S. Fish and Wildlife Service, Special Scientific Report 169. Washington, DC

Montana Bull Trout Scientific Group (MBTSG). 1996a. Lower Kootenai River drainage bull trout status report (below Kootenai Falls). Prepared for The Montana Bull Trout Restoration Group. Helena, MT.

Montana Bull Trout Scientific Group (MBTSG). 1996b. Upper Kootenai River drainage Bull Trout status report (including Lake Koocanusa, Upstream of Libby Dam). Prepared for The Montana Bull Trout Restoration Group. Helena, MT.

Montana Fish, Wildlife & Parks (MFWP), Confederated Salish Kootenai Tribes, and the Kootenai Tribe of Idaho. 1998. Fisheries mitigation and implementation plan for losses attributable to the construction and operation of Libby Dam. Montana Fish, Wildlife and Parks, Kalispell, MT., Confederated Salish and Kootenai Tribes, Pablo, Montana, and Kootenai Tribe of Idaho, Bonners Ferry, Idaho.

Phillips, R. W. , R. L. Lantz, E. W. Claire, and J. R. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Transactions of the American Fisheries Society 104:461-466.

Reiser, D. W., and T. A. Wesche. 1979. In situ freezing as a cause of mortality in brown trout eggs. Progressive Fish-Culturist 41: 58-60.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 119.

Robson, D.S., and H.A. Regier. 1964. Sample size in Peterson mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

Shepard, B.B., and P.J. Graham. 1983. Fish resource monitoring program for the upper Flathead Basin. Environmental Protection Agency, Water Division, Denver, Colorado.

Shumway, D. L. , C. E. Warren, and P. Doudoroff. 1964. Influence of oxygen concentration and water movement on the growth of steelhead trout and coho salmon embryos. Transactions of the American Fisheries Society 93:342-356.

Silver, S. J. , C. E. Warren, and P. Doudoroff. 1963. Dissolved oxygen requirements of developing steelhead trout and chinook salmon embryos at different water velocities. Transactions of the American Fisheries Society 92:327-343.

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski and B. and Thornberg. 1996. Quantification of Libby Reservoir levels needed to enhance reservoir fisheries. Investigations of fish entrainment through Libby dam, 1990-1994. Final Report. Montana Department of Fish, Wildlife and Parks - Region 1. Prepared for Bonneville Power Administration. Project Number 83-467.

Sylvester, Ryan, Joel Tohtz, and Brian Marotz. 2009. Evaluation of the Biological Effects of the Northwest Power Conservation Council's Mainstem Amendment on the Fisheries Upstream and Downstream of Libby Dam, Montana. 2007-2008 Annual Report, Project No. 200600800, Contract Number 36186.

Van Deventer, J.S., and W.S. Platts. 1983. Sampling and estimating fish populations from streams. Transactions North American Wildlife and Natural Resources Conference 48:349-354.

Weaver, T. M. , and J. J. Fraley. 1991. Fisheries habitat and fish populations. Flathead basin forest practices, water quality and fisheries cooperative program. Flathead Basin Commission, Kalispell, Montana.

Weaver, T. M. and J. J. Fraley. 1993. A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel. North American Journal Fisheries Management 13:817-822.

Weaver, T. M. , and R. G. White. 1985. Coal Creek fisheries monitoring study No. III. Quarterly progress report. U. S. Forest Service, Montana State Cooperative Fisheries Research Unit, Bozeman, Montana.

Wickett, W. P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. Journal of the Fisheries Research Board of Canada. 15:1103-1126.

U.S. Fish and Wildlife Service. 1999. Endangered and threatened wildlife and plants; determination of threatened status for bull trout in the coterminous United States. Federal Register. 64**:**(1 November 1999), 58910-58933.

U.S. Fish and Wildlife Service. 2002. Chapter 4, Kootenai River Recovery Unit, Oregon. 89 pages. *In*: U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

Chapter 2

Stream Restoration and Mitigation Projects in the Montana Portion of the Kootenai River Basin

Abstract

MFWP cooperated with the landowner, Plum Creek Timber Company, to complete the Libby Creek Demonstration Project in the fall of 2001 which is located at approximately RM 12.3. The restoration project constructed one meander length the Libby Creek stream channel (approximately 1,700 feet). The restoration work significantly changed the stream channel dimensions, which ultimately resulted in a deeper and narrower channel, which translated into a significantly lower width/depth ratio after project implementation, and increased the quantity and quality of rearing habitat for native salmonids within the project reach. Stream channel dimensions within the project area are similar to the as-built conditions. The project continues to meet the original objectives including limiting instream sediment from two large sources within the project area. Stream channel instability immediately outside the project area has increased, while bank erosion within the project area has remained low.

The Libby Creek Upper Cleveland Restoration Project was completed in the fall of 2002, and restored 3,200 feet of stream channel. The Libby Creek Lower Cleveland Phase Restoration Project Area is located approximately one mile downstream of the Upper Cleveland Project. The Lower Project was conceived as a three-phase effort, with Phases I and II completed in the fall of 2005 and 2006, respectively. Despite a large rain on snow weather event in fall 2006 created substantial changes in the plan form on these three projects, stream channel dimensions within riffle and pool habitats within these three projects continue to recover from the changes that resulted from this relatively large flood event. The habitat conditions in these three projects are better than existed prior to restoration, and even exceed conditions represented during the as-built surveys in some instances.

MFWP completed the Young Creek State Lands Restoration Project in the fall of 2003, which changed the stream channel dimensions within this area. The monitoring results presented in this document evaluated whether these physical changes were maintained since construction. The steam channel dimensions within the riffles of this section of Young Creek changed only slightly between years. Pool dimensions and numbers changed little since construction (generally < 10%) within the project area. This project continues to meet the original objectives set forth for this project.

MFWP partnered with The Kootenai River Network (KRN), the USFWS Partners for Wildlife and the local landowner in 2004 and 2005 to complete the Therriault Creek Restoration Project, which reconstructed a total of 9,100 feet of entirely new stream channel, which represented a two-fold increase in stream length. This project also created approximately 55 acres of prior converted wetland. The largest fundamental change that

resulted from this project was that of stream channel type and planform. The existing stream channel was an entrenched G4 and F4 Rosgen stream type, and restoration work converted it to an E4 channel type, with low entrenchment and width to depth ratios. The planform remains nearly identical that as-built conditions. Stream channel dimensions have also changed little since 2004. The riffle/run habitats within this section of Therriault Creek remain narrower and deeper than existed prior to the work. MFWP implemented maintenance and supplemental vegetation treatments in the fall of 2009 including maintenance watering, expansion of many of the existing browse protectors, and installation of additional browse protectors on residual shrubs that had never been previously protected. Solarization fabric was an effective method to remove undesirable pasture grasses, and areas were reseeded with a native seed mix consisting of shrubs, grasses, and forbs. Fabric removed from the plot was placed along the edges of the plot to create a buffer around the newly exposed bare soil. Effectiveness monitoring of previous revegetation techniques was also completed. Protection of residual shrubs using browse protectors is a relatively simple and cost-effective treatment for reducing browse and allowing shrubs to grow. However, browse is occurring on portions of protected shrubs growing outside of browse protectors. Containerized shrubs and trees had continued high survival rates. Pasture grasses continue to dominate the understory in the planting units. However, brush blankets are effectively controlling grass cover immediately adjacent to installed plants. Planted solarization plots in 2008 and 2009 showed comparable survival with other planting units. Plant growth was also monitored in solarization plots and some species showed a high level of growth between 2008 and 2009. Vegetated soil lifts have provided stable areas within the high stress land-water interface, allowing the dormant willows used in this treatment to take root and sprout, and willow cutting survival is good. The vegetated soil lifts are creating stable areas for woody vegetation to establish and therefore achieving the desired function. The willow fascine treatment has been variable in terms of achieving the intended function of increasing root mass and providing long term bank stability. The five woody debris structures installed in 2007 may be improving floodplain hydrology at this site including trapping sediments and prolonging floodplain inundation. However, non-native pasture grasses remain the dominant species along each transect. Coir logs appear to be creating a suitable environment on outer meander bends for the establishment of willow cuttings and natural recruitment of wetland shrubs and forbs. Herbicide is effectively reducing the infestations and densities of target species.

MFWP worked with the landowner of the largest single irrigation diversion on Deep Creek, a tributary to the Tobacco River to develop a cost share project to upgrade the existing system in order to improve ease of operation, eliminate fish entrainment and decrease maintenance at the point of diversion. The system was designed by the Montana FWP Libby staff and was installed in the spring of 2010. We installed a new trash rack in front of the existing headgate, removed 26 feet of the existing water pipe, and installed the prefabricated fish screen and 16 feet of new water pipe. The fish screen structure was a 4-foot diameter turbulent fountain fish screen design. The screen was also fitted with a hinged cover for safety purposes. The new screen and associated system prevents fish entrainment and requires less maintenance.

MFWP treated lower Boulder Lake and Boulder Creek, a tributary to Koocanusa Reservoir, with various commercial formulations of rotenone in September 2009 to remove a hybridized population of cutthroat trout. Monitoring conducted in early 2010 indicated that a single piscicide achieved a complete removal of these fish. MFWP restocked the lake and creek with westslope cutthroat trout fry in the summer of 2010. This project expanded the current distribution of westslope cutthroat trout within the Montana portion of the Kootenai River Subbasin upstream of Libby Dam by about 20%. However, it will probably be several years until the stocked hatchery cutthroat trout fry become large enough to support a viable recreational fishery in both the lake and the creek.

Introduction

Libby Dam, on the Kootenai River, near Libby, Montana, was completed in 1972, and filled for the first time in 1974. The dam was built for hydroelectric power production, flood control, and recreation. However, the socio-economic benefits of the construction and operation of Libby Dam have come at the cost to the productivity and carrying capacity of many of the native fish species of the Kootenai River Sub-basin. Libby Reservoir inundated 109 stream miles of the mainstem Kootenai River in the United States and Canada, and 40 miles of tributary streams in the U.S. that provided some of the most productive habitat for spawning, juvenile rearing, and migratory passage. Impoundment of the Kootenai River blocked the migrations of fish populations that once migrated freely between Kootenai Falls (29 miles downstream of Libby Dam) and the headwaters in Canada.

Operations of Libby Dam cause large fluctuations in reservoir levels and rapid daily fluctuations in the volume of water discharged to the Kootenai River. Seasonal flow patterns in the Kootenai River have changed dramatically, with higher flows during fall and winter, and lower flows during spring and early summer. Reservoir operations that cause excessive drawdowns and refill failure are harmful to aquatic life in the reservoir. Jenkins (1967) found a negative correlation between standing crop of fish and yearly vertical water fluctuations in 70 reservoirs.

Problems occur for resident fish when Libby Reservoir is drawn down during late summer and fall, the most productive time of year. The reduced volume and surface area reduces the potential for providing thermally optimal water volume during the high growth period, limits production of fall-hatching aquatic insects, and also reduces the deposition of terrestrial insects from the surrounding landscape. Surface elevations continue to decline during winter, arriving at the lowest point in the annual cycle during April. Deep drafts reduce food production and concentrate young trout with predators. Of greatest concern is the dewatering and desiccation of aquatic dipteran larvae in the bottom sediments. These insects are the primary spring food supply for westslope cutthroat, a species of special concern in Montana, and other important game and forage species. Deep drawdowns also increase the probability that the reservoirs will fail to refill. Refill failure negatively effects recreation and reduces biological production, which decreases fish survival and growth in the reservoir (Marotz et al. 1996, Chisholm et al. 1989). Investigations by Daley et al. (1981), Snyder and Minshall (1996), and Woods and Falter (1982) have documented the declining productivity of the Kootenai System and, specifically, reduced downstream transport of phosphorous and nitrogen by 63 percent and 25 percent, respectively.

Large daily fluctuations in river discharge and stage (4-6 feet per day) strand large numbers of sessile aquatic insects in the varial zone (Hauer and Stanford 1997). The reduction in magnitude of spring flows has caused increased embeddedness of substrates, resulting in loss of interstitial spaces in cobble and gravel substrates, and in turn, loss of habitat for algal colonization and an overall reduction in macroinvertebrate species diversity and standing crop (Hauer and Stanford 1997). Aquatic insects are affected by the reduction of microhabitat and food sources, as evidenced by the loss of species and total numbers since impoundment (Voelz and Ward 1991). Hauer and Stanford (1997) found a significant reduction in insect production for nearly every species of insect during a 13-14 year interval in the Kootenai River. These losses can be directly attributed to hydropower operations. Benthic macroinvertebrate densities are one of the most important factors influencing growth and density of trout in the Kootenai River (May and Huston 1983).

The mitigation and implementation plan developed by MFWP, the Kootenai Tribe of Idaho and the Confederated Salish and Kootenai Tribes documents the hydropower related losses and mitigation actions as called for by the Northwest Power Planning Council's Fish and Wildlife Program (MFWP et al. 1998). This plan identifies several mitigation actions capable of partially mitigating impacts to Montana's aquatic resources associated with the construction and operation of Libby Dam. These include aquatic habitat improvement, fish passage improvements, off-site mitigation, fisheries easements, and conservation aquaculture and hatchery products.

Grave Creek is a fourth order tributary to the Tobacco River, with a watershed area of approximately 55 square miles. Grave Creek is one of the most important bull trout spawning streams in the Montana portion of the Kootenai River (see Chapter 1), and has been designated as critical habitat within the U.S. Fish and Wildlife Service's Bull Trout Recovery Plan (USFWS 2002). Grave Creek is also currently on the Montana Water Quality Limited Segment List as an impaired stream. The State of Montana has proposed that Grave Creek be a high priority for Total Mean Daily Load allocation (TMDL). Grave Creek also provides water for westslope cutthroat trout habitat, agriculture and other riparian dependent resources. Timber harvest and road construction in the headwaters and agriculture, grazing, riparian vegetation losses, channel manipulation, and residential and industrial encroachment in lower reaches have impacted the lower three miles of Grave Creek by reducing stream stability, the quality and quantity of available fish habitat, and the composition of the riparian community. Therefore, lower Grave Creek is much less stable than it was historically, which has likely resulted in a reduction of salmonid productivity and carrying capacity. Restoration activities on Grave and Libby creeks are consistent with those strategies identified in the Fisheries Mitigation and Implementation Plan for the Losses attributable to the Construction and Operation of Libby Dam (MFWP et al. 1998) and the Kootenai Subbasin Plan (KTOI and MFWP 2004).

The Libby Creek watershed is the second largest tributary between Kootenai Falls and Libby Dam, and has an area of 234 square miles. Libby Creek provides critical spawning and rearing habitat and a migratory corridor for the threatened bull trout, and resident redband trout. The U.S. Fish and Wildlife Service's Bull Trout Recovery Plan designates Libby Creek as part of the Kootenai River and Bull Lake Critical Habitat Sub-Unit (USFWS 2002). Libby Creek has been degraded by past management practices, including road building, hydraulic and dredge mining, and riparian logging. These past activities disrupted the natural equilibrium within Libby Creek resulting in accelerated bank erosion along a number of meander bends, causing channel degradation. This resulted in impaired fish habitat that likely reduced the productivity and carrying capacity for resident salmonids within Libby Creek. Prior to restoration the stream channel is over-widened and shallow with limited pool habitat (Sato 2000). Many of the problems related to unstable conditions within the Libby Creek watershed are a result of land management activities that occurred in the upper watershed, and therefore restoration activities should first focus on the upper watershed (Sato 2000).

Young Creek is one of the most important westslope cutthroat trout spawning tributaries to Libby Reservoir, containing one of the last known genetically pure populations of westslope cutthroat trout in the region. We identified and prioritized a restoration project on Young Creek because it is one of the most potentially productive tributaries to Libby Reservoir, and the degraded habitat on the state owned section of the creek. During the 1950's, approximately 1,200 feet of the channel located on the state owned section (DNRC School Trust Land) was straightened, diked, and moved near the toe of the hill slope. This channelization compromised the stream's ability to effectively transport sediment through the channelized area, causing the channel to aggrade (deposit bedload materials) and exacerbating flood conditions. Sediment aggradation caused numerous problems with the stream, including poor aquatic habitat, increased flood potential, lateral bank scour and increased sediment supply. Additionally, livestock grazing and timber management in the upper reaches of Young Creek likely contributed to channel instability.

Therriault Creek is a tributary to the Tobacco River and is located approximately 6 miles southeast of the town of Eureka in Lincoln County, Montana. MFWP identified a 4,500 foot long section of Therriault Creek as a priority restoration project because it contained a native fish assemblage, was substantially degraded, but has a high potential for restoration, and the lower section was owned by a single landowner that was willing to partner to improve conditions on Therriault Creek.

Stream restoration efforts when applied appropriately can be successful at restoring streams to a state of equilibrium. However, there are several critical fundamental issues that must be resolved prior to the design and implementation of any restoration project (Rosgen 1996). These include a clear definition and causes of the problems, an understanding of the future potential of the stream type as related to the watershed and valley features, and an understanding of the probable stable form of the stream under the current hydrology and sediment regime (Rosgen 1996). The restoration projects described below were designed and implemented after considering these issues and other recommendations found in Rosgen (1996). The following sections describe the restoration projects completed and discuss monitoring results to date.

Deep Creek, a third order 17.7 km long tributary that runs south out of the Whitefish Mountains, before entering the Tobacco River provides habitat for westslope cutthroat trout resident bull trout and non-native brook and rainbow trout. The largest irrigation diversion on Deep Creek is located approximately 1.7 miles upstream from the confluence. This system prior to replacement did not have a functional fish screen and represented the largest single loss of fish due to entrainment within the drainage.

The Boulder Lake/Creek watershed is located approximately 15 miles southwest of Eureka, Montana. Boulder Creek begins at the outlet of Lower Boulder Lake and flows approximately 8 miles before flowing into Lake Koocanusa. The Boulder Creek watershed was likely historically fishless prior to Montana FWP stocking the lake and creek in the 1940s and 50s, which resulted in a hybridized population of non-native trout. Westslope cutthroat trout occupy only a fraction of their historical habitat within the Kootenai Subbasin. Specifically within the Montana portion of the Kootenai Subbasin upstream of Libby Dam, genetically pure populations only exist in the headwater regions of Dodge, Young and Grave creeks.

Methods and Results

Grave Creek Phase I Restoration Project

MFWP partnered with the Kootenai River Network to restore approximately 4,300 feet of channel within the lower three miles of Grave Creek, named the Grave Creek Phase I Restoration Project, which begins at the downstream end of the Grave Creek Demonstration Project (see Dunnigan et al. 2005). Project construction was completed during fall 2002. The objectives of the project were to: 1) Reduce the sediment sources and bank erosion throughout the project area by incorporating stabilization techniques that function naturally with the stream and which decrease the amount of stress on the stream banks, 2) Convert the channelized portions of stream into a channel type that is self maintaining and will accommodate floods without major changes in channel pattern or profile, 3) Use natural stream stabilization techniques that will allow the stream to adjust slowly over time and be representative of a dynamic natural stream system, 4) Improve fish habitat, particularly for bull trout, and improve the function and aesthetics of the river and adjacent riparian ecosystem, and 5) Reduce the effects of flooding on adjacent landowners.

The Grave Creek Phase I Restoration Project changed the dimension, pattern and longitudinal profile within the project area. These changes were designed to achieve the long-term project objectives and are described in detail in Dunnigan et al. (2005). The 41 stream restoration structures that the restoration project constructed increased channel diversity within the project area along the length of the project area and are described in Dunnigan et al. (2005). The existing stream channel prior to implementing this project contained long riffle sections and relatively low diversity and complexity (Figure 1). This project constructed a stream pattern that decreased the overall stream gradient by increasing stream length (increased sinuosity). As a result of the restoration work conducted in 2002, bankfull width and width to depth ratio significantly decreased and maximum and mean bankfull depth increased throughout the project area in 2002 and 2003 compared to pre-existing conditions (Dunnigan et al. 2005). However, the changes made to the physical habitat are intended to provide stream channel stability over a relatively short term (approximately 10- 20 years). The long-term stream channel stability will occur as a result of restoration of the riparian vegetation. Project cooperators dedicated substantial effort in 2008 to riparian vegetation restoration. The Kootenai River Network has continued working to restore a functioning riparian community at this site including active revegetation techniques and effectiveness monitoring to guide efforts through an adaptive management process. Although the Libby Mitigation Project did not contributed to these efforts during this fiscal year, this information is presented for informational purposes, and the reader is directed to several other reference sources for additional detailed information including Geum Environmental Consulting (2008a; 2008c and 2009).

Montana FWP continued to monitor the physical stream dimensions, pattern and profile of Grave Creek Phase I Project area annually to determine if the reconstructed stream channel changes through time. We re-photographed the 25 photo points that were originally established shortly after project construction, documenting as built conditions. We currently have photo documentation for the post construction from 2002 through 2005. However, photo points were not replicated in 2006-2009. Initially, we established six permanent cross-sections that were annually surveyed in 1999 (pre project) through 2002-2005 (post-project). These cross sections were originally located in riffle habitats in 1999, but after project construction, they were located in various habitat classifications. We were unable to relocate the locations for these permanent cross sections in 2006, so these points have not been surveyed since. We surveyed the longitudinal profile of this section of Grave Creek in 2008 (Dunnigan et al. 2010), but did not in 2009.

The Grave Creek Phase I Restoration Project increased the quality and quantity of rearing habitat for native salmonids by increasing the total number and depth of pools compared to conditions that existed prior to restoration (Dunnigan et al. 2004 and 2005). Due to the importance of pool habitat to rearing native salmonids within lower Grave Creek, we continued to monitor pool habitat after project construction to evaluate whether the pools maintained depth, width and length through time. We measured the mean width, length and maximum bankfull depth, total length and total surface area of all pools within the project area annually since 2002 (Table 1). There were a total of 26 pools in 2002, 27 pools in 2003 and 2004, but the total number of pools decreased to 23 in 2005, 21 in 2006, and then increased to 22 in 2007 and 2008 and decreased to 26 in 2009. We did not perform a statistical comparison for these data because the pool measurements represented all pools within the project area (i.e. complete census), making statistical comparisons unnecessary. Of the six pool related parameters we measured, all remained remarkably stable since 2006 (Table 1). The total number of pools has shown the highest relative change since 2006, changing as much as 23.8% (2006 to 2009), but remaining very similar to the original number of pools originally constructed in 2002 (Table 1). However, other pool parameters have changed relatively little since 2006, with annual changes generally less than 15% from 2006 to 2009, and remaining very similar to those conditions that represented during the as-built survey in 2002. The overall total number of pools within this section of Grave Creek remains higher than the three that were present prior to the restoration work (Dunnigan et al. 2004), and given the disparity between the total number of pools prior to the restoration work and after (Figure 1), and although we did not measure total pool area or volume in 1999, it also likely remains higher as a result of this project. These data suggest that pool quantity and quality (depth) continued to be sustained within this section of Grave Creek as a result of the restoration work implemented six years earlier.

In addition to a complete census of all pools within the project area, we also assessed riffle dimensions within the project area in order to evaluate changes through time. We used the six permanent cross-sections we established 1999 to characterize riffle dimensions that existed prior to the project, and even though we did resurvey these cross sections in 2002-2005, we did not compare these data to that collected in 1999 because after project construction, the cross sections were located in various habitat classifications. In 2003 we began measuring the dimensions of all riffles within the project area. Since 2003, cross sectional surveys were performed at the longitudinal mid-point of each riffle, where we measured the bankfull width, maximum and mean depths, cross sectional area, and slope. Surveys were conducted in each respective year after the conclusion of the spring freshet. Since the data collected in 1999 was not a complete census of all riffle habitats within the project area we performed an analysis of variance to test for significant differences between mean width, depth, cross sectional area, width to depth ratio, and maximum depth in 1999 and 2009. In 2009, the riffles within this section of Grave Creek remained significantly narrower, deeper (mean depth) and had a lower width to depth ratio than existed prior to the restoration work in 1999 (Table 2). Cross sectional area in 2009 was 21.9% lower than in 1999, but this difference was not significant. Maximum depth remained similar between 1999 and 2009 (Table 2). Riffle dimensions have remained similar since 2006, generally changing less than 15% (Table 2). Riffle slope exhibited the highest relative annual change during this period (2006/2008) decreasing by approximately 18% (Table 2). We did not measure riffle slope in 1999. Similar to stream channel dimensions in pool type habitats, dimensions in riffle-type habitats have generally been sustained in this section of Grave Creek since the restoration work was implemented, and remain substantially and functionally different than conditions that existed prior to the work.

Table 1. Mean bankfull width, maximum bankfull depth, and mean length, total length and surface area measured from all pool-type habitats in 2002-2009 located in the Grave Creek Phase I Project. Variance estimates for annual mean values are presented in parentheses. A statistical comparison of annual mean values was not performed because all pools within the project area were surveyed, and therefore represents a complete census. The percent change for each parameter year to year is also presented.

Year	Number of Pools	Mean Bankfull Width (ft)	Maximum Bankfull Depth (ft)	Mean Length (ft.)	Total Length (ft.)	Total Area (ft^2)
2002	27	49.5 (18.3)	6.5 (1.1)	64.7 (359.0)	1748	86,526
2003	27	54.0 (46.4)	5.6 (1.9)	74.8 (842.3)	1,944	109,058
2004	27	49.5 (63.6)	4.9 (1.0)	66.9 (341.6)	1,739	89,412
2005	23	51.1 (56.1)	5.1 (0.7)	61.2 (278.8)	1,407	71,892
2006	21	53.6 (58.2)	5.1 (0.9)	74.7 (814.1)	1,569	84,054
2007	22	55.9 (107.8)	5.2 (1.0)	77.5 (1,529.8)	1,705	94,668
2008	22	56.9 (94.8)	5.0 (0.8)	75.7 (606.6)	1,666	94,711
2009	26	55.5 (46.4)	5.2 (0.6)	65.5 (418.0)	1,703	94,534
Percent Change						
2002/2003	0.0%	9.1%	-13.8%	15.6%	11.2%	26.0%
2002/2009	-3.7%	12.1%	-20.5%	1.2%	-2.6%	9.3%
2003/2009	-3.7%	2.8%	-7.7%	-12.4%	-12.4%	-13.3%
2004/2009	-3.7%	12.1%	5.5%	-2.1%	-2.1%	5.7%
2005/2009	13.0%	8.6%	1.3%	7.0%	21.0%	31.5%
2006/2007	4.8%	4.4%	2.0%	3.7%	8.7%	12.6%
2006/2008	4.8%	6.1%	-1.5%	1.4%	6.2%	12.7%
2006/2009	23.8%	3.6%	1.3%	-12.3%	8.5%	12.5%
2007/2008	0.0%	1.6%	-3.4%	-2.3%	-2.3%	0.0%
2007/2009	18.2%	-0.8%	-0.6%	-15.5%	-0.1%	-0.1%
2008/2009	18.2%	-2.4%	2.9%	-13.5%	2.2%	-0.2%

Table 2. Mean bankfull width, depth, maximum bankfull depth, cross sectional area, width to depth ratio, and slope of riffles located in the Grave Creek Phase I Restoration Project in 1999 - 2009. Variance estimates for annual mean values are presented in parentheses. The percent change for each parameter year to year is also presented.

Year	Number of Riffles	Mean Bankfull Width (ft)	Maximum Bankfull Depth (ft)	Mean Bankfull Depth (ft.)	Cross Sectional Area (sq. ft.)	Width to Depth Ratio	Riffle Slope (%)
1999 (Existing)	6	110.7 (1135.1)	2.85 (0.8)	1.26 (0.1)	136.0 (1322)	96.1 (2461)	n/a
2002 (as-built)	6	53.7 (51.5)	4.67 (2.5)	2.06 (0.2)	114.7 (885.5)	27.0 (39.8)	n/a
2003	7	49.4 (31.0)	3.3 (0.12)	2.16 (0.03)	106.0 (61.3)	23.2 (18.3)	1.06 ($2.65*10^{-5}$)
2004	7	51.7 (36.0)	3.5 (0.05)	2.22 (0.01)	114.7 (132.2)	23.3 (11.1)	0.86 ($9.87*10^{-6}$)
2005	10	52.3 (64.2)	3.5 (0.31)	2.18 (0.16)	111.5 (274.3)	25.2 (76.1)	0.88 ($1.42*10^{-5}$)
2006	11	54.2 (44.6)	3.1 (0.29)	1.90 (0.15)	102.3 (428.8)	29.9 (69.9)	1.26 ($3.45*10^{-5}$)
2007	9	55.7 (79.4)	3.0 (0.06)	1.94 (0.08)	107.8 (555.6)	29.5 (57.8)	1.24 ($2.80*10^{-5}$)
2008	8	58.1 (54.9)	3.2 (0.19)	2.09 (0.09)	119.4 (222.7)	28.7 (56.0)	1.03 ($1.45*10^{-5}$)
2009	8	57.1 (46.6)	2.8 (0.21)	1.88 (0.11)	106.2 (233.7)	31.7 (85.1)	1.06 ($1.42*10^{-5}$)
Percent Change							
1999/2002	n/a	-51.5%	63.9%	63.5%	-15.7%	-71.9%	n/a
1999/2009	n/a	-55.45%	15.8%	71.4%	-22.1%	-75.9%	n/a
2002/2009	n/a	-48.4%	-1.3%	49.3%	-21.9%	-67.0%	n/a
2003/2009	14.3%	15.6%	-14.8%	-12.9%	0.2%	36.6%	-0.1%
2004/2009	14.3%	10.4%	-19.6%	-15.3%	-7.4%	36.0%	23.1%
2005/2009	-20.0%	9.2%	-19.6%	-13.7%	-4.8%	25.8%	20.4%
2006/2007	-18.2%	2.8%	-3.9%	1.9%	5.3%	1.3%	-1.2%
2006/2008	-27.3%	7.2%	1.6%	9.9%	16.7%	-3.9%	-17.9%
2006/2009	-27.3%	5.4%	-9.3%	-1.0%	3.8%	6.0%	-15.9%
2007/2008	-11.1%	4.2%	5.8%	7.9%	10.8%	-2.6%	-16.9%
2007/2009	-11.1%	2.5%	-5.6%	-2.8%	-1.5%	7.4%	-14.9%
2008/2009	0%	-1.7%	-10.7%	-9.9%	-11.1%	10.3%	2.5%

Grave Creek Phase II Restoration Project

MFWP partnered with the U.S Fish and Wildlife Service Private Stewardship Grant Program, the U.S. Forest Service Resource Advisory Committee, the U.S. Environmental Protection Agency/MT Department of Environmental Quality (319 Program), the U.S. Fish and Wildlife Service Partners for Wildlife Program, the Lincoln County Conservation District and the Flanagan Family (landowners) to restore approximately 3,050 feet of channel within the lower three miles of Grave Creek, named the Grave Creek Phase II Restoration Project. This project was administered by the Kootenai River Network, and begins at the downstream end of the Grave Creek Phase I Restoration Project (see above). The project was originally proposed to encompass 4,875 feet of lower Grave Creek. However, the lower most landowner on this section of the creek declined to participate in the project. Therefore, the project was shortened to the upper 3,050 feet beginning at the lower end of the Phase I Project. Project construction was completed during fall 2004. The objectives of the project were to: 1) Reduce both instream and floodplain derived sediment sources by incorporating stabilization techniques that function naturally with the stream and decrease the amount of stress on streambanks and the channel perimeter; 2) demonstrate the use of natural stream stabilization techniques that will allow the stream to adjust slowly over time and be representative of a naturally dynamic stream system; 3) improve native fish habitat, particularly overwintering and migratory habitat for threatened bull trout, by improving the form and function of the river and adjacent riparian habitats and; 4) apply knowledge learned from monitoring of the Grave Creek Demonstration and Phase I Restoration projects to further advance and encourage techniques that function naturally with the stream system and minimize the introduction of large rock and foreign material (RDG 2003).

The initial phase of stream restoration work constructed 3,050 feet of new channel including an average design bankfull width and depth of 50-76 and 2-2.8 feet, respectively. The resulting stream pattern design increased sinuosity (stream length divided by valley length) from 1.06 to 1.35, and subsequently increased total stream length from approximately 2,790 to 3,050 feet. During construction phase of this project, numerous structures were installed including 5 engineered log jams, 3 straight log vanes, 5 log J-hook vanes, 2 rootwad composites, 3 cobble grade control structures, and 8 deflector log composites to provide bank stabilization, gradient control and pool habitat. However, severe icing conditions in lower Grave Creek in the winter of 2005/2006 and high spring flows in 2006 damaged some of the previously completed work, and as a result, substantial maintenance and revegetation work to this section of Grave Creek was completed in the fall of 2006. This work, like the original project, was a cooperative effort, with this project funding a portion of the work described in detail in Dunnigan et al. (2008).

Montana FWP and the cooperating partners of this project continued our efforts to restore the riparian community in the fall of 2008. The Kootenai River Network developed an extensive riparian vegetation restoration plan (Geum Environmental Consulting 2008a) that identified the need and prioritized the scope of work for these efforts. Table 3 briefly summarizes the work implemented in October 2008. Geum Environmental Consulting

(2009) presents a detailed description of the riparian vegetation treatments and associated monitoring completed in 2009.

Table 3. Structures types, meander and station of the maintenance work performed on the Grave Creek Phase 2 Project in October 2008.

Structure Type	**Metric**	**Metric**
Riparian Planting Area Maintenance	2 Sites	
Point Bar Revegetation (6 Sites)	28 pounds seed	58 2-5 gallon containerized plants
Vegetated Soil Lifts (1 Site)	30 feet	
Coir Log (1 Site)	50 feet	
Willow Facine (2 Sites)	200 feet	
Weed Control (2 Sites)	4 acres	
Install Engineered Log Jam (1 Site)	2 structures	

Geum Environmental Consulting Inc. was contracted to conduct effectiveness monitoring for six treatments. Monitoring was completed in July 2009. A detailed discussion of the monitoring results is presented in Geum Environmental Consulting (2009). However, important findings are summarized below. The browse protectors of riparian containerized plants at two sites were removed because they had been damaged by ice flows, and are re-sprouting at their bases. Plants with expanded browse protectors have increased in width and some have grown to the top of the protectors despite continued browse pressure. There is no evidence of recent lateral erosion of the bank along the planting areas. Solarization fabric installed in 2005 and removed in 2008 was very effective at killing undesirable grasses, and seeded grasses in these areas (2008) appear to be germinating. Cottonwood seedlings are also colonizing these areas, but weed species like houndstongue, knapweed, toadflax and oxeye daisy are also colonizing. Monitoring data show steadily decreasing survival rates for each of the planting units from 2005, and that this treatment along the outer meander reaches is only a marginally effective as a revegetation treatment. However, installing containerized plants within natural or created microsites and other protected locations within the floodplain appears to be more effective at this site.

Point bar revegetation treatments installed in 2008 were also monitored to estimate plant survival, percent cover of herbaceous species, and evidence of browse. Survival of containerized plants within these treatments was 100%, and browse within the electric fence exclosure was not evidence, but slight to moderate browse outside the fence was evident. On average, plants within the fence were one to two feet higher than those outside. Woody debris placed around planted shrubs in combination with the steep sides of the constructed swales is relatively effective at preventing extensive browse. Grasses and forbs, as well as naturally recruited and seeded shrubs are also colonizing the bottom and sides of the swales, and some swales have very high cottonwood seedling densities. Weed species are present in some of the swales, but not dominant. Monitoring continues to indicate this is an effective treatment.

Monitoring of the vegetated soil lifts and coir log fascines installed in 2005, 2006, and 2008 yielded the following observations. Average shoot height (new growth) recorded for willows in 2005 and 2006 structures ranged from 12 to 72 inches. Maximum height recorded during the 2008 monitoring was 36 inches. Average shoot height for willows in the 2008 structures ranged from two to 18 inches on coir log fascines and six to 18 inches on the vegetated soil lifts. No new rips or tears or toe scour were observed. Total percent willow cover on the 2005 and 2006 structures ranged from 23 to 93%, and on the 2008 foil lifts it averaged 53%, and on the 2008 coir logs fascines it averaged 37%. There was no evidence of browse on any of the structures located within the electric fence, but browse was evident on structures outside the fence. However, in general, browse was more extensive in 2008 than in 2009. Weed cover on soil lifts remained similar to 2008 and was generally low. Soil lifts installed in 2008 had almost no weed cover. Desirable species such as sedges, rushes and native forbs are becoming more abundant on some of the 2006 soil lifts, especially those with more shade.

Monitoring of the buried coir/willow fascines resulted in the following observations and conclusions. In general, willow survival and growth is good, but browse may affect growth over the long term. Overall, minimal amounts of organic matter and woody debris have accumulated around the fascines. This may be an effective treatment to establish islands of willow on constructed point bars, but continued monitoring will be required to determine if these treatments can provide long term stability and promote successional processes.

Constructed point bars were also monitored in 2009, and resulted in several observations. Treatments including swales, woody debris, seeding, and containerized plantings on point bars appear to provide the structure that supports ecological processes necessary for desired pioneer plant species to colonize and plant community succession to occur. The survival of containerized plants is high, native shrubs, trees and forbs are colonizing the swales and other microsites, and flood deposited sediment and debris is accumulating around woody debris.

The only vegetated set back bank treatment within the project area was also monitored in 2009. Willow survival along the edges of the trench was estimated to be 80 to 90%. There are a few sparse patches that may fill in over time. Containerized plant survival was also high (>80%). The majority of the cottonwood pole cuttings are re-sprouting from the base while other have new growth along the entire pole. Weed cover within the trench is low, but the surrounding area has high densities of knapweed and oxeye daisy. Seeded grass cover is low, but grasses were beginning to germinate in the bottom of the trench. Pasture grasses were also present.

MFWP has annually monitored this section of Grave Creek since 2004 with the intent of quantifying the physical changes to the stream channel as a result of original restoration work, maintenance activities and the overall sustainability of those changes through time. The monitoring results from 2006 were completed after the maintenance activities were completed, but prior to the spring freshet. A longitudinal profile was surveyed for this section of Grave Creek annually since 2004 with the exception of 2006 and 2009 (Dunnigan et al. 2010).

Due to the importance of pool habitat to salmonids inhabiting Grave Creek, we devoted a substantial effort to monitor pool habitat before and after project construction to evaluate whether the restoration and maintenance efforts increased the quantity and quality of pool habitat within the project area. Prior to the initiation of this project in the summer of 2004, we measured bankfull depth, width, length, maximum bankfull depth, total area and total volume of the 3 pools within the project area. We repeated these measurements on all existing pools each year thereafter following the spring freshets. We did not perform a statistical comparison for these data because the pool measurements represented all pools within the project area (i.e. complete census), making statistical comparisons unnecessary. The initial restoration effort overwhelmingly increased the total number of pools present in this section of Grave Creek (Table 4), and even though we observed a slight decrease the following two years after the project was initially constructed, the number of pools was remained stable through 2009. This included a total count of pools after the winter of 2005/2006 that damaged some of the structures within the project area. However, after the spring freshet of 2007, we observed an increase in the total number of pools from 10 in 2005 and 2006 to 16 (60%; Table 4). This increase is partially attributed to the installation of seven engineered debris jams that were installed during the maintenance activities in the fall of 2006, which scoured 2 new pools during the 2007 spring freshet. However, the increase in the number of pools as a result of the maintenance activities has been sustained through 2009.

We observed changes in channel dimensions within pool habitats through time. Pools that resulted from this construction project through 2009 were slightly shorter than existing prior to the project. However in 2007, mean pool length increased to 79.2 feet, which was slightly longer than existed prior any restoration activity, but decreased to 63.6 feet in 2008, and then increased again in 2009, to exactly the average of pre-restoration (Table 4). Mean width decreased slightly in 2009 from the previous year (2.7%; Table 4). Despite the slight decrease in mean width in 2009, the increase in the mean pool length and depth resulted in an overwhelming increase in total pool area and volume in 2009, which greatly exceeded existing conditions in 2004 by approximately 242% and 329%, respectively (Table 4). Our monitoring efforts associated with this restoration project demonstrate that the quantity of salmonid rearing habitat was increased over existing conditions, and that the these changes were self-sustaining even up until the time that maintenance activities were performed in the fall of 2006 and 2008. The maintenance activities installed several features that further enhanced the quantity of pool habitat within this section of Grave Creek. Furthermore, although we did not attempt to quantify pool cover complexity for salmonids, our field observations strongly suggested that this project also increased the quality of rearing habitat for salmonids within this section of Grave Creek.

We also monitored the stream channel dimensions within riffle habitats before and after restoration efforts. During the summer of 2004, we measured stream channel morphology at 3 cross-sectional survey locations in riffle habitat within the project area in order to characterize the stream channel dimensions in the riffle type habitat prior to project construction (existing). After project construction during the fall of 2004 we began measuring every riffle within the newly completed project area (as built). At each transect we measured mean bankfull width, depth, width to depth ratio, and cross sectional area. We used analysis of variance (ANOVA) and a subsequent multiple comparison test (Tukey Test; Zar 1996) to test for significant differences between existing and all subsequent years after construction (alpha = 0.05; Table 5). Statistical comparisons between 2004 (as built) and all subsequent years riffle dimensions were unnecessary since these measurements were performed on all riffle habitats within the project area (i.e. complete census). Mean bankfull width and width to depth ratio were significantly reduced from existing conditions when compared to 2004-2009 conditions, with decreases ranging from 39.7 to 43% for width and 52.5% to 61.8% for width to depth ratio (Table 5). Mean bankfull width increased slightly in 2005, from as built conditions, but has remained very similar since (Table 5). Maximum and mean bankfull depth increased as a result of the restoration activities, but has remained relatively stable during the past five years. Mean and maximum depth in riffle habitats in 2009 decreased slightly (<5%) from 2008 to 2009 (Table 5). We were unable to declare any of the post restoration annual differences in mean or maximum depth significantly different from mean depths prior to restoration even though increases in mean depth increased by over 27% (Table 5). Our lack of power in this test was most likely due to the small number of riffles sampled (3) to characterize the existing conditions prior to restoration activities. We observed a similar trend for cross sectional area after project completion, with mean cross sectional area, which has consistently remained lower each year since the project was completed than existed prior to the work (Table 5). The Grave Creek Phase II Restoration Project created a significantly deeper and narrower stream channel within the riffle habitats, with these changes being self-sustaining after project completion. The maintenance activities conducted in the fall of 2006 and 2008 had little effect on stream channel dimensions within the riffle habitats.

Table 4. Mean bankfull width, maximum bankfull depth, and mean length, total length and surface area measured from pools located in the Grave Creek Phase II Project. The project area was surveyed in the summer of 2004, prior to project implementation (existing), the fall of 2004 after the project was completed (as built), and in 2005 -2009 after the spring freshets. Variance estimates for annual mean values are presented in parentheses. A statistical comparison of annual mean values was not performed because all pools within the project area were surveyed, and therefore represents a complete census. The percent change for each parameter between some years is also presented.

	Number of Pools	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Mean Length (ft.)	Total Area (ft^2)	Total Volume (ft^3)
2004 (Existing)	3	77.0 (48.0)	2.0 (0.1)	4.4 (1.7)	78.7 (646.3)	18,236	37,570
2004 (As Built)	14	59.0 (344.0)	2.9 (0.7)	5.6 (1.5)	57.1 (421.9)	46,252	141,092
2005	10	62.3 (72.6)	2.5 (0.1)	5.2 (1.1)	70.9 (452.3)	43,629	108,993
2006	10	57.8 (238.3)	2.6 (0.4)	5.4 (1.5)	59.1 (74.1)	33,884	87,768
2007	16	50.1 (46.9)	2.5 (0.5)	4.9 (1.3)	79.2 (1,036.8)	63,050	166,316
2008	15	54.0 (38.8)	2.5 (0.2)	4.9(0.7)	63.6 (419.8)	52,131	127,067
2009	15	52.6 (45.3)	2.6 (0.2)	4.7 (0.7)	78.7 (716.9)	62,270	161,325
Percent Change							
Exist/2004	-366.7%	23.4%	-45.0%	-27.3%	27.4%	-153.6%	-275.5%
Exist/2009	400.0%	-31.7%	29.9%	7.9%	0.0%	241.5%	329.4%
2004/2009	7.1%	-10.9%	-10.4%	-15.2%	37.9%	34.6%	14.3%
2005/2009	50.0%	-15.6%	3.9%	-8.7%	11.0%	42.7%	48.0%
2006/2007	60.0%	-13.3%	-3.4%	-8.9%	34.0%	86.1%	89.5%
2006/2008	50.0%	-6.6%	-4.3%	-9.0%	7.6%	53.9%	44.8%
2006/2009	50.0%	-9.0%	-0.1%	-12.1%	33.2%	83.8%	83.8%
2007/2008	-6.3%	7.8%	-1.0%	-0.1%	-19.7%	-17.3%	-23.6%
2007/2009	-6.3%	4.9%	3.4%	-3.5%	-0.6%	-1.2%	-3.0%
2008/2009	0.0%	-2.7%	4.4%	-3.4%	23.8%	19.4%	27.0%

Table 5. Mean bankfull width, depth, maximum bankfull depth, cross sectional area, width to depth ratio, and slope of riffles located in the Grave Creek Phase II Restoration Project. All riffles were surveyed in 2004-2009, but only sub-sampled in 2004 (existing). Variance estimates for annual mean values are presented in parentheses. An analysis of variance was preformed for each parameter, subsequent multiple comparisons were performed using the Tukey Test. Significant comparisons are indicated via * (alpha < 0.05).

	Sample Size	**Mean Bankfull Width (ft)**	**Maximum Bankfull Depth (ft)**	**Mean Bankfull Depth (ft.)**	**Cross Sectional Area (ft^2)**	**Width to Depth Ratio**	**Riffle Slope**
2004 (Existing)	3	100 (1657)	2.83 (0.04)	1.44 (0.11)	135.3 (382.3)	77.1 (2726.0)	Not collected
2004 (As Built)	7	58.2 (36.7)	3.17 (0.29)	2.03 (0.12)	118.3 (495.9)	29.4 (42.2)	0.0108 ($6.3*10^{-6}$)
2005	8	60.3 (52.6)	3.01 (0.30)	1.91 (0.16)	113.0 (182.6)	33.8 (168.1)	0.009 ($2.08*10^{-5}$)
2006	9	60.1 (152.7)	2.95 (0.21)	1.84 (0.16)	106.9 (182.7)	35.9 (327.0)	0.012 ($7.9*10^{-6}$)
2007	9	56.8 (48.6)	2.81 (0.30)	1.61 (0.11)	91.5 (505.9)	36.6 (76.4)	0.011 ($1.1*10^{-5}$)
2008	10	60.3 (60.2)	2.90 (0.22)	1.92 (0.10)	111.2 (229.5)	32.9 (126.8)	0.013 ($6.0*10^{-6}$)
2009	10	59.0 (20.4)	2.79 (0.41)	1.79 (0.07)	105.3 (233.0)	33.8 (49.4)	0.012 ($2.3*10^{-5}$)
P-value		0.009	0.815	0.107	0.009	0.003	
Percent Change							
Exist/2004	-133.3%	41.8%*	-12.1%	-41.3%	12.6%	61.8%*	n/a
Exist/2009	233.3%	-41.0%*	-1.4%	24.4%	-22.2%	-56.1%*	n/a
2004/2009	42.9%	1.4%	-12.0%	-11.9%	-11.0%	14.9%	13.6%
2005/2009	25.0%	-0.8%	-7.4%	-6.3%	-6.8%	1.0%	36.9%
2006/2007	0.0%	-5.6%	-4.7%	-12.6%	-14.5%	2.1%	-7.7%
2006/2008	11.1%	0.3%	-1.4%	4.4%	4.0%	-8.1%	5.9%
2006/2009	11.1%	-1.9%	-5.4%	-2.7%	-1.6%	-5.7%	1.6%
2007/2008	11.1%	6.2%	3.5%	19.5%	21.6%	-10.0%	14.7%
2007/2009	11.1%	3.9%	-0.8%	11.4%	15.1%	-7.7%	10.1%
2008/2009	0.0%	-2.2%	-4.1%	-6.8%	-5.4%	2.7%	-4.0%

Libby Creek Demonstration Project

MFWP cooperated with the landowner, Plum Creek Timber Company, to complete the Libby Creek Demonstration Project within this area in the fall of 2001 located at approximately RM 12.3. The restoration project constructed one meander length the Libby Creek stream channel (approximately 1,700 feet), and all channel and structure construction was completed in the dry. The work was accomplished by installing 7 rock J-hook vanes, 7 rootwad and log complexes, and numerous channel plugs to fill the old stream channel (Dunnigan et al. 2003). Two of the largest point sediment sources within the Libby Creek Watershed existed above the confluence of Elliot Creek (RM 12.0), and were contributing substantial amounts of course and fine sediment to Libby Creek each year. The largest eroding bank within the project site was over 700 feet long, averaged 80 feet high and was contributing an estimated average of 5,900 cubic yards of sediment annually to Libby Creek. The second large unstable bank was located in the lower section of the project area and was also contributing substantial amounts of sediment to Libby Creek. These sediment sources were increasing sediment deposition; accelerated bank erosion; increased width/depth ratio and decreased meander width ratio in Libby Creek both within and downstream of the Demonstration Project area. The main objectives of this project were to: 1) Decrease coarse and fine sediment sources, 2) Decrease the stream's width depth ratio, and 3) Return the stream channel to a properly functioning configuration able to efficiently transport bed load sediment during high discharge events; and 4) Increase the quality and quantity of fisheries habitat within this reach of Libby Creek.

Dunnigan et al. (2003) reported that the restoration work significantly changed the stream channel dimensions, which ultimately resulted in a deeper and narrower channel, which translated into a significantly lower width/depth ratio after project implementation. The stream restoration work on lower Libby Creek also increased the quantity and quality of rearing habitat for native salmonids within the project reach. The total number of pools within the project reach increased by 25%, and maximum pool depth measured during summer base flow increased by over 45% (Dunnigan et al. 2003). This project also reduced bank erosion within the project reach by limiting creek access to the two large eroding banks located within the project reach. Therefore, monitoring work completed at this site in 2009 was intended to determine if these trends continued.

We established five permanent cross sections within the project area to monitor stream channel dimensions within this section of Libby Creek (Figures 1 and 2). We surveyed these cross sections before (1998) and after (2002-2004 and 2009) project implementation, measuring bankfull width, mean and maximum depth, cross sectional area, and width to depth ratio at each cross section. We compared each of these stream channel dimensions using a repeated measures analysis of variance and subsequent Tukey multiple comparisons. We also established two cross sections upstream of the project area in 2002 and two downstream of the project area in 2005. These four cross sections were intended to serve as controls. However, all but one of the cross sections located upstream of the project area has since eroded, and was surveyed in 2009.

The mean bankfull width measured at the five permanent cross sections within the project area was significantly wider prior to project implementation (Table 6). Mean bankfull width was slightly wider in 2009 compared to years 2002-2004, but not significantly so. Both mean and maximum bankfull depth were significantly deeper at the permanent cross sections after the restoration work, but mean depth did not differ between 2002, 2003, 2004, or 2009. Maximum bankfull depth in 2009 at these cross sections remains significantly higher than existed prior to the restoration work. However, maximum depth in 2003 did not differ from 1998 (Table 6). These changes ultimately translated into a significantly lower width/depth ratio after project implementation (Table 6). The narrower and deeper stream channel effectively increased shear stress at high flows, which resulted in the stream channel's ability to mobilize larger substrate particle size.

Our intent of the cross sections located outside of the project area was to have them serve as relative control sites to evaluate stream bank stability and erosion rates on lower Libby Creek in the near vicinity of the Libby Creek Demonstration Project and compare those results to our monitoring within the project area. Dunnigan et al. (2005) demonstrated that the dimensions of the stream channel outside the Libby Creek Demonstration Project area were significantly wider, shallower and had a higher width to depth ratio than within the project area. Unfortunately three of the four replicates located outside of the project area were lost due to excessive bank erosion even though our cross section bank pins were located 25-30 feet away from the streambank at the time these were installed. Despite the loss of many of our replicates that preclude statistical analyses, the one remaining cross section in 2009 was wider and shallower than those cross sections within the project area (Table 7). The mere fact that three of the permanent pins for the control cross sections outside the project eroded illustrates the unstable nature of the stream channel outside the project area.

Finally, one of the primary objectives of this project was to reduce the amount of course and fine sediment introduced into Libby Creek from several large eroding banks. The largest bank was located on the upper portion of the project area, and was approximately 700 feet long and 80 feet tall. Prior to the project, the Libby Creek thalweg was adjacent to this high bank and actively eroding it. Permanent cross sections 1-3 were located along this bank (Figure 1). Libby Creek has not accessed this sediment supply since the project was completed (Figure 3).

Table 6. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for 5 permanent cross sections within the Libby Creek Demonstration Project area surveyed in 1998, 2002-2004 and 2009. Results from a repeated measures analysis of variance Tukey multiple comparison is presented in parentheses with groups with the different letters are significantly different (alpha = 0.05).					
Year	Bankfull Width(ft)	Bankfull Area (ft^2)	Mean Bankfull Depth (ft)	Max. Bankfull Depth (ft)	W/D Ratio
1998 (pre-project)	110.8 (A)	223.0 (A)	2.05 (A)	4.13 (A)	56.8 (A)
2002	68.4 (B)	224.2 (A)	3.30 (B)	5.70 (B)	21.2 (B)
2003	67.6 (B)	214.8 (A)	3.10 (B)	5.28 (A)	22.0 (B)
2004	68.4 (B)	224.8 (A)	3.20 (B)	5.62 (B)	21.5 (B)
2009	75.3 (B)	251.2 (A)	3.29 (B)	6.09 (B)	23.1 (B)

Table 7. The difference (outside – within project) of cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for permanent cross sections within and upstream of the Libby Creek Demonstration Project area surveyed in 2002-2004 and 2009.					
Year	Bankfull Width(ft)	Bankfull Area (ft^2)	Mean Bankfull Depth (ft)	Max. Bankfull Depth (ft)	W/D Ratio
2002	19.8	59.8	-0.08	0.5	5.8
2003	3.9	-47.4	-0.75	-0.68	8
2004	11	-63.8	-1.16	-1.22	17.5
2009	10.3	19.4	-0.13	-2.09	3.9

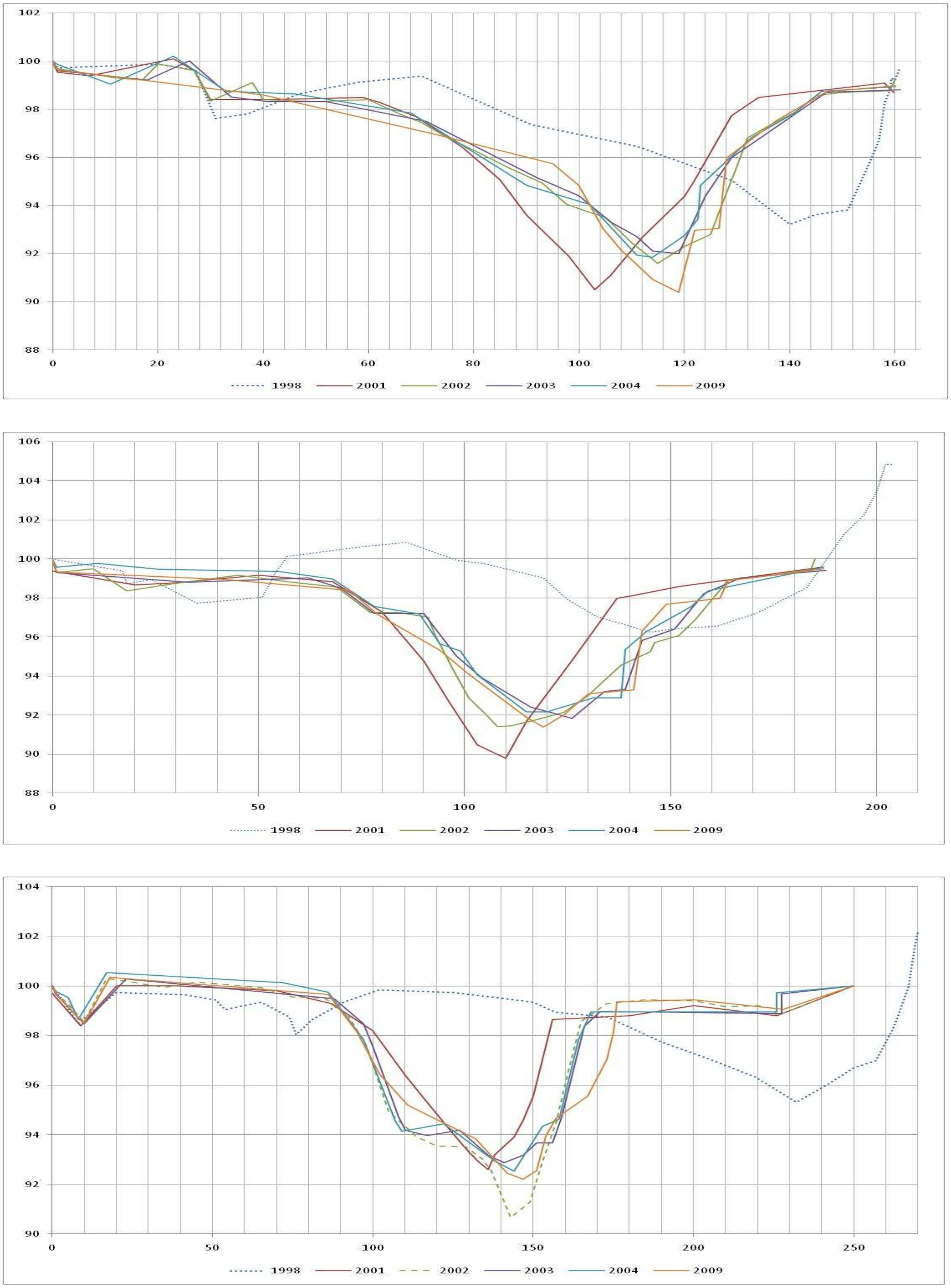
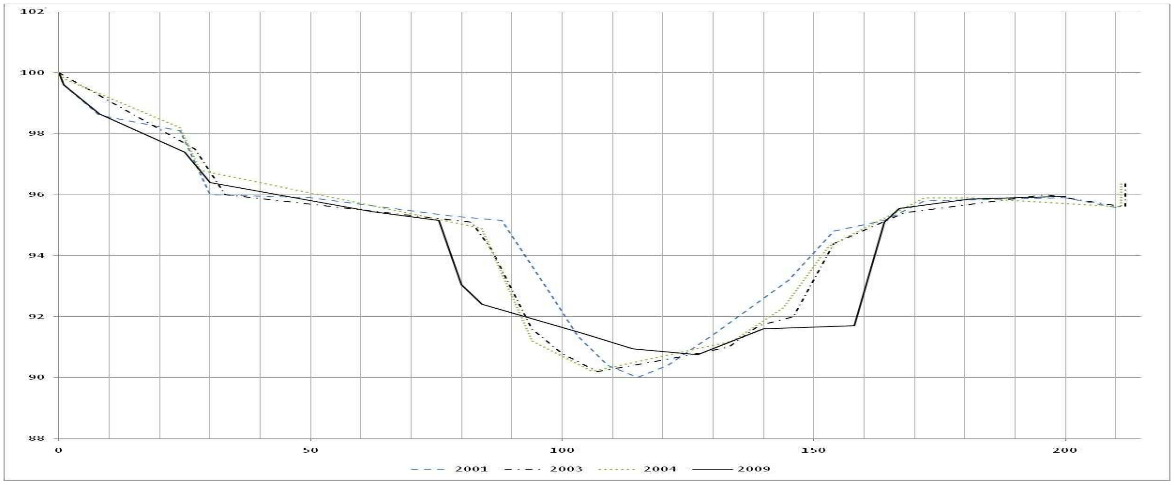


Figure 1. Cross sections 1-3 (top to bottom, respectively) on the Libby Creek Demonstration Project.



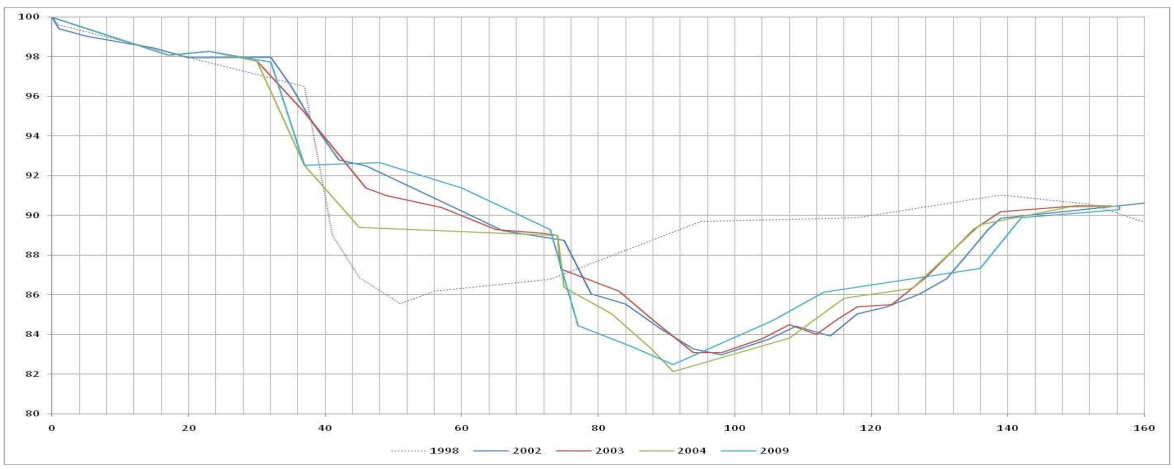


Figure 2. Cross sections 4 and 5 (top to bottom, respectively) on the Libby Creek Demonstration Project. Cross section 4 was not surveyed prior to the project completion (1998).

Figure 3. Top photograph shows the largest of the two eroding banks within the Libby Demonstration Project prior to project implementation. The lower photograph was taken after project construction. Note the position of the stream in the upper photograph against the eroding hillside that was over 700 feet long and averaged 80 feet high.

Libby Creek Upper Cleveland Project

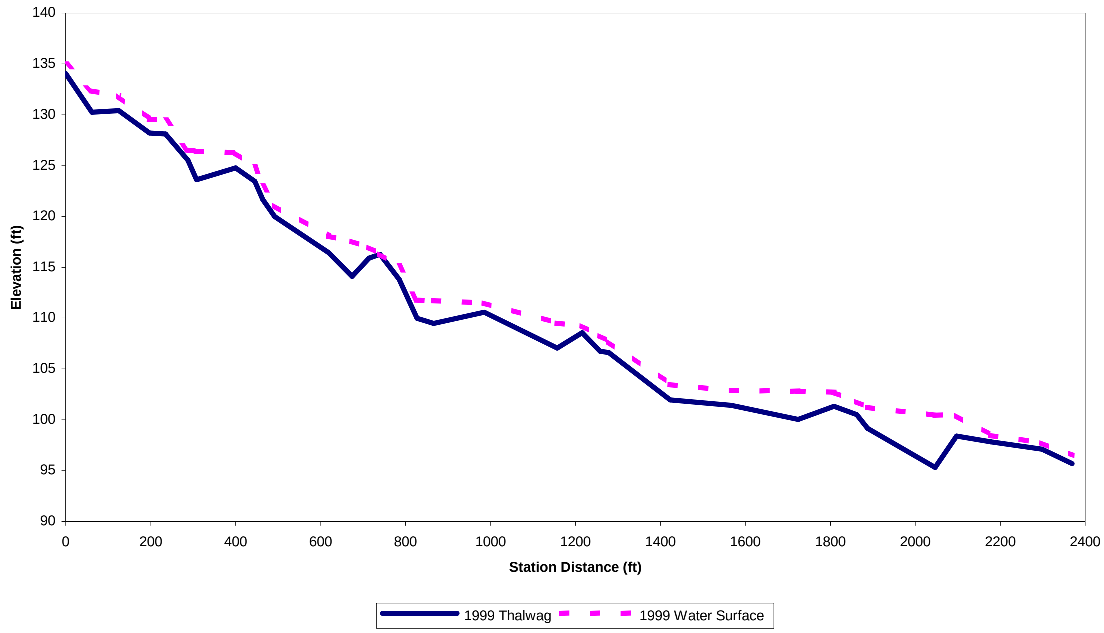
MFWP completed the Libby Creek Upper Cleveland Stream Restoration Project in the fall of 2002 (approximate river mile 22), which restored approximately 3,200 feet of stream channel to the proper dimension, pattern and profile (Dunnigan et al. 2005). Past land management activities including logging, mining, riparian road construction, and stream channel manipulation have resulted in accelerated bank erosion along a number of meander bends, resulting in an over widened, unstable, and shallow channel (Sato 2000), which has resulted in low quality habitat for native salmonids including bull trout and redband trout. The existing channel prior to this restoration project was over-widened with frequent lateral migration of the active stream channel. These conditions resulted in frequent multiple channels within the project reach (Dunnigan et al. 2004). Width depth ratios were high and bankfull channel depths were shallow.

Dunnigan et al. (2004; 2005; 2007; 2008; 2009) demonstrated that this restoration project decreased the bankfull width and bank erosion and increased stream depth, overall length, substrate mean particle size, and the quality and quantity of salmonid rearing habitat through 2006. However, during the first week of November 2006, the Libby Creek watershed experienced a rain on snow weather event that created higher than average runoff conditions throughout the entire watershed including the headwater regions. The US Forest Service gauged the peak flows at Hammer Cutoff (river mile 8.5) during this event at 3,093 cubic feet per second, which translated to a 19-year return interval using the Log-Pearson type III Flood Frequency Analysis (J. Boyd, US Forest Service, personal communication). Therefore, this report evaluates changes in the physical habitat within this section of Libby Creek after this event by comparing current conditions to those that existed before restoration (1999) and after the November 2006 flow event, in order to evaluate if changes made during the restoration are sustained after the flow event.

We surveyed the stream restoration project area before (1999) and after (2002-2009) using a Nikon Model DTM-420 Total Station Survey Instrument, which records the geo-referenced location of stream channel features. The most conspicuous changes within this section of Libby Creek as a result of the November 2006 flow event were changes in the stream plan form. The restoration work increased the stream length within the project area by approximately 900 feet by increasing sinuosity. The rain on snow event of November 2006 created two chute cut offs within the project area (see Dunnigan et al. 2009 for detailed locations). These chute cut offs reduced total stream length within the project area in 2007 to 3,181 feet, and in 2008 stream length was further reduced to by 41 feet to 3,140 feet. However, in 2009, the stream length increased by 8 feet from the previous year. Two years after the November 2006 flow event; this section Libby Creek remained 778 feet longer (32.8%) than existed prior to the restoration work in 2002. The stream channel plan from in 2009 remained very similar to 2008 conditions.

We surveyed riffles within the project area to evaluate changes in stream channel dimensions from 1999-2009 (excluding 2004). Cross sectional surveys were performed at the longitudinal mid-point of each riffle, were we measured mean bankfull width, depth, width to depth ratio, and cross sectional area. We also measured riffle slope of all riffles present within the project area in 2002-2009. We used analysis of variance (ANOVA; alpha = 0.05; Table 8) and a subsequent multiple comparison test (Tukey Test; Zar 1996) to test for significant differences between 1999 (pre-project) and all other years, since all riffles were surveyed (complete census) from 2002-2009, but not 1999. The restoration work performed in 2002 made a narrower and deeper stream channel, but after the 2006 rain on snow event in Libby Creek riffles widened to dimensions that were nearly equal to pre-restoration values, and although depth also decreased after the flood event, the riffle habitats remained deeper than before restoration. However, in 2009, the riffle habitats within this section of Libby Creek regained depth and narrowed compared to the two years after the flood event and prior to restoration (Table 8). These changes in turn also influenced width to depth ratio and cross sectional area, which changed by 10.3% and -11.1%, respectively (Table 8). The riffle habitats in 2009 were significantly deeper, had a lower cross sectional area and width to depth ratio than conditions prior to restoration, and although not significant, the riffles also remain narrower in 2009 by 6%.

Due to the importance of pool habitat to rearing redband and bull trout within the project area, we also devoted substantial effort to monitor pool habitat within the project area in order to evaluate changes in pool spacing, numbers, depth (mean and maximum), width and length after project construction. The only pool dimension we measured in 1999 was pool spacing. However, from 2002-2009, we established cross sectional surveys at the point within each pool where we measured maximum depth, mean bankfull width, depth, and cross sectional area. We calculated total pool surface area by multiplying mean length by mean bankfull width by the total number of pools present. We calculated total pool volume by multiplying total pool surface area by mean bankfull depth. The complete census of pools during these years made statistical comparison unnecessary. The restoration work completed in 2002 installed numerous structures that increased the quantity of pool habitat within the project area (Dunnigan et al. 2004), which is evident on the longitudinal profiles (Figure 4). The November 2006 flow event changed pool attributes. The largest relative changes in pool dimensions were a decrease in the number of pools, and an increase in pool spacing, mean depth, length total area and volume (Dunnigan 2009; Table 9). However, in 2008 and 2009, the total number of pools reversed this trend which resulted in an increase of increased by 5 pools within the project area (33.3%; Table 9) after the flow event. The increase in the number of pools also reduced pool spacing to 149.5, which is the second lowest observed since the restoration work. Mean bankfull width in 2009 was slightly lower than existed in 2008, and nearly identical to the as-built conditions in 2002. However, mean and maximum bankfull depth within pool habitats in 2009 decreased by 19 and 13.9%, respectively from 2008 (Table 9). Mean pool length decreased slightly (10.9%%) from 2008 to 2009 (Table 9). However, the overall slight decreases in pool width, mean depth and length resulted in a decrease in the total pool area and volume from 2008 to 2009. However, total pool area in 2009 was slightly higher (6.2%) than existed in 2002 (as-built), but total pool volume was 21.7% lower in 2009 (Table 9). Although we did not measure stream channel dimensions in pool habitats in 1999, we are confident that both total pool area and volume within the project area in 2009 are higher than existed prior to restoration due to the increased number of pools that have been sustained annual since the restoration work was completed, despite having undergone an approximate 20 year flood event.



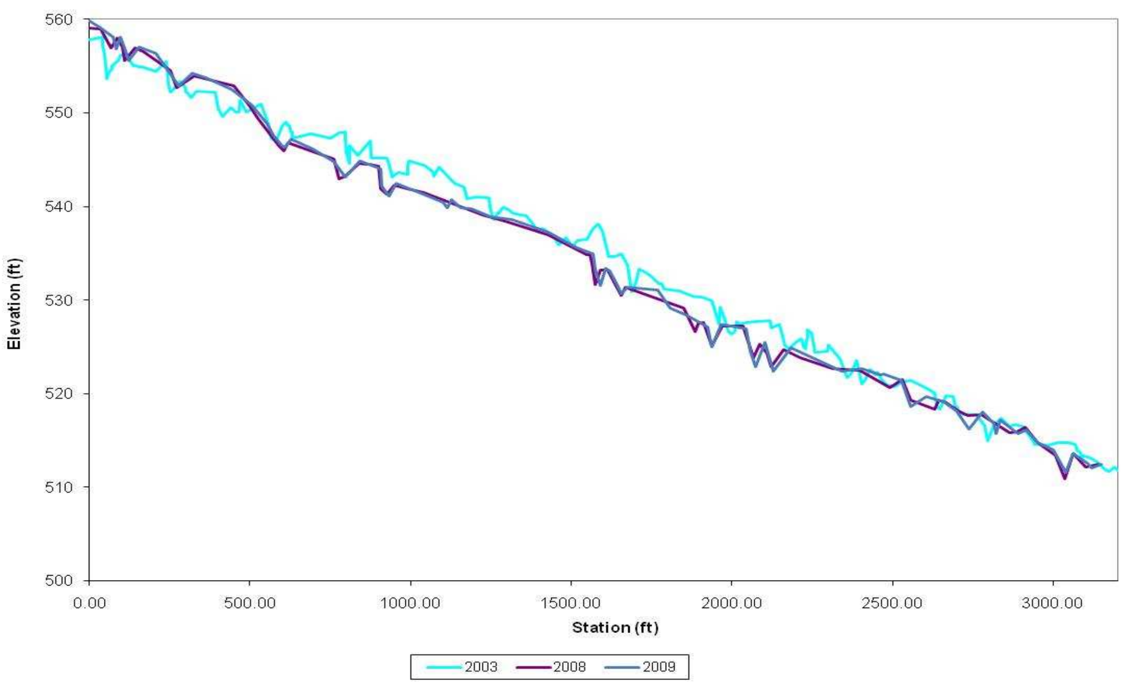


Figure 4. The longitudinal profiles of the Libby Creek Upper Cleveland Restoration Project area for the pre-construction (upper; 1999) and after (lower) construction (2003, 2008, and 2009). The survey begins at the upper project boundary (station 0) and proceeds downstream to the lower project boundary. Due to differences in stream length and pattern, the before and after figures could not be displayed on the same graphic.

Table 8. Mean bankfull width, depth, cross sectional area, width to depth ratio, and slope of riffles located in the Libby Creek Upper Cleveland Restoration Project. Variance estimates for annual mean values are presented in parentheses. An analysis of variance was preformed for each parameter, and multiple comparisons were performed using the Tukey Test with significant comparisons are indicated via * (alpha < 0.05). The riffle slope was measured for every riffle in the project area in 2002-2009.

	Sample Size	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Width to Depth Ratio	Cross Sectional Area (Square ft.)	Slope (%)
1999 (Pre)	5	41.5 (35.2)	0.94 (0.07)	47.6 (359.8)	39.6 (211.3)	Not Measured
2002 (As Built)	9	34.3 (30.5)	1.33 (0.09)	26.7 (59.0)	46.0 (114.3)	1.91 ($7.50*10^{-5}$)
2003	9	31.5 (18.5)	1.48 (0.04)	21.8 (25.4)	47.9 (62.5)	1.28 ($1.94*10^{-5}$)
2005	15	31.9 (32.8)	1.36 (0.05)	24.3 (65.0)	43.0 (26.7)	1.46 ($2.55*10^{-5}$)
2006	15	28.3 (11.8)	1.31 (0.02)	22.1 (18.6)	36.7 (30.0)	1.96 ($2.57*10^{-5}$)
2007	10	40.9 (37.8)	1.34 (0.11)	33.0 (96.0)	54.4 (188.9)	1.64 ($2.67*10^{-5}$)
2008	13	46.6 (140.3)	1.45 (0.23)	37.0 (376.9)	64.3 (258.4)	1.94 ($3.41*10^{-5}$)
2009	11	39.0 (45.8)	1.53 (0.17)	26.2 (71.6)	58.7 (222.5)	2.24 ($1.10*10^{-4}$)
Percent Change						
1999/2002	80.0%	-17.6%	44.4%	-43.9%*	16.2%	n/a
1999/2009	120.0%	-6.0%	66.7%*	-45.0%*	48.2%*	n/a
2002/2003	0.0%	-7.9%	15.4%	-18.4%	4.1%	-33.0%
2002/2009	22.2%	14.0%	15.4%	-1.9%	27.6%	17.3%
2003/2009	22.2%	23.8%	0.0%	20.2%	22.5%	74.9%
2005/2009	-26.7%	22.4%	10.5%	7.7%	36.5%	52.7%
2006/2009	-26.7%	37.8%	14.5%	18.6%	59.9%	11.4%
2007/2008	30.0%	13.9%	11.9%	12.1%	18.2%	13.2%
2007/2009	10.0%	-4.6%	11.9%	-20.6%	7.9%	27.8%
2008/2009	-15.4%	-16.3%	0.0%	-29.2%	-8.7%	12.8%

Table 9. Pool dimensions within the Libby Creek Upper Cleveland Restoration Project including mean bankfull width, depth, maximum bankfull depth, length and total volume from 1999-2009. Variance estimates for annual mean values are presented in parentheses. A statistical comparison of annual mean values was not performed because all pools within the project area were measured, and therefore represents a complete census. The percent change for each parameter from year to year is also presented. Mean bankfull depth was used to calculate total volume.

	# Pools	Pool Spacing (ft)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Length (ft.)	Total Area (ft^2)	Total Volume (ft^3)
1999 (Existing)	5	325	N/A	N/A	N/A	N/A	N/A	N/A
2002 (As Built)	20	N/A	38.0 (23.8)	2.6 (0.8)	4.3 (1.1)	36.7 (205.2)	27,892	72,519
2003	20	173	34.5 (16.1)	2.2 (0.3)	3.8 (0.7)	30.2 (130.8)	20,838	45,843
2005	18	191	28.8 (31.7)	1.8 (0.2)	3.9 (0.9)	36.9 (75.69)	19,129	34,432
2006	17	152	28.1 (40.1)	1.9 (0.2)	3.8 (0.8)	46.6 (109.5)	22,261	42,296
2007	12	223	36 (144.5)	2.1 (0.3)	4.0 (0.4)	55.4 (361.2)	24,531	50,534
2008	16	196	39 (44.0)	2.4 (0.4)	4.7 (1.0)	52.8 (340.9)	33,032	79,276
2009	17	149.5	37.5 (34.5)	1.9 (0.2)	4.0 (0.6)	47.1 (402.1)	29,614	57,548
Percent Change								
1999/2002	300.0%	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1999/2009	240.0%	-53.9%	N/A	N/A	N/A	N/A	N/A	N/A
2002/2003	0.0%	N/A	-9.2%	-18.0%	-11.6%	-17.7%	-25.2%	-38.7%
2002/2009	-15.0%	N/A	-1.3%	-26.3%	-5.9%	28.1%	6.2%	-21.7%
2003/2009	-15.0%	-13.4%	8.7%	-10.1%	6.5%	55.6%	42.0%	27.6%
2005/2009	-5.6%	-21.5%	30.1%	2.3%	3.8%	27.5%	54.8%	58.3%
2006/2009	0.0%	-1.4%	33.3%	2.3%	6.5%	1.0%	33.0%	36.1%
2007/2008	33.3%	-12.0%	6.0%	16.5%	18.4%	-4.7%	34.7%	56.9%
2007/2009	41.7%	-32.8%	1.5%	-5.7%	1.9%	-15.1%	20.7%	13.9%
2008/2009	6.3%	-23.6%	-4.2%	-19.0%	-13.9%	-10.9%	-10.3%	-27.4%

Libby Creek Lower Cleveland Phase I Project

The lower Cleveland property on Libby Creek is located approximately 1 mile downstream of the upper Cleveland Property, near the original Libby town site, and was previously identified by MFWP as a high priority site for stream restoration. Past land management activities including logging, mining, riparian road construction, and stream channel manipulation have resulted in accelerated bank erosion along a number of meander bends, resulting in an over widened, unstable, and shallow channel, which has resulted in low quality habitat for native salmonids including bull trout and redband trout. The length of Libby Creek through the entire lower Cleveland property prior to restoration efforts was approximately 9,100 feet. MFWP developed a restoration strategy to implement the restoration of this large site in 3 phases. The first phase was implemented in October 2005, and is referred to as the Libby Creek Lower Cleveland Phase I Project (approximate river mile 20-21). The restoration work excavated approximately 2,950 feet of new channel according to the design criteria including an average design bankfull width and depth of 32 feet and 3 to 7 feet, respectively. Dunnigan et al. (2007) presents a complete description of the materials and structures installed in this section of Libby Creek.

During the first week of November 2006, the Libby Creek watershed experienced a rain on snow weather event that created higher than average runoff conditions throughout the entire watershed including the headwater regions. US Forest Service gauged the peak flows during this event at a minimum flow of 3,093 cubic feet per second, which translated to a 19-year return interval using the Log-Pearson type III Flood Frequency Analysis (J. Boyd, US Forest Service, personal communication). This storm event changed the stream plan form, and channel dimensions (Dunnigan et al. 2009). Therefore, this report compares current habitat conditions to those prior to restoration and after the 2006 flow event.

We surveyed the stream restoration project area before (2004), October 2005 (as built), and 2006-2009 using a Nikon Model DTM-420 Total Station Survey Instrument, which records the geo-referenced location of stream channel features including channel dimensions, profile and plan form. The most conspicuous changes within this section of Libby Creek as a result of the November 2006 flow event were changes in the stream plan form. Dunnigan et al. (2009) documented changes in stream plan form and estimated that net erosion exceeded net deposition in this section of Libby Creek before and after the November 2006 flow event. Monitoring in 2008 and 2009 indicated that the plan form and lateral stream migration within this section of Libby Creek were relatively stable since the substantial channel adjustments that occurred as a result of that large rain on snow event.

We measured total stream length during all years along the channel thalweg. The stream channel length in 2004 was 2,695 feet (Figure 5), and the restoration work increased stream length to 2,793 feet, representing a 3.6% increase due to increased sinuosity (1.24 and 1.30, respectively) due to increased meander frequency. However, as a result of several chute cutoffs that occurred throughout the project area during the November 2006 flood event, the stream channel lost 260 feet (2,533 feet total length), representing a loss of 9.3% relative to as-built conditions. Stream length after the flood event (2007) was 162 feet shorter (6.0%) than existed prior to the project. Sinuosity decreased to 1.16 in 2007 and has remained at 1.16 in 2008 and 2009. Stream channel length in 2008 and 2009 was 2,555 feet, which was slightly longer (138 feet) than 2007, but 24 feet shorter (1%) than existed prior to the restoration work.

We completed physical monitoring of pool habitats within the project area before and after restoration in order to evaluate changes in the quantity and quality through time. We established cross sectional surveys at the point within each pool where we measured maximum depth, mean bankfull width, depth, and cross sectional area. We calculated total pool surface area by multiplying mean length by mean bankfull width by the total number of pools present. We calculated total pool volume by multiplying total pool surface area by mean bankfull depth. The complete census of pools during these years made statistical comparison unnecessary. We also measured the distance between pools within the project area in order to estimate mean pool spacing. Mean pool spacing within this section of Libby Creek in 2004 was 811 feet. The design criteria (as built; 2005) reduced mean pool-to-pool spacing to 152 feet, representing an 81.3% reduction from 2004 conditions. After the November 2006 flow event, mean pool spacing increased to 259 feet, representing an increase of 70.4% compared to as built (2005) conditions, but remained 68.1% lower than conditions existing prior to restoration work in 2004. Mean pool spacing in 2008 increased 26 feet to an average of 285 feet, which represented a decrease of 133 feet (87.5%) from as built conditions (2005), but remained 526 feet shorter (64.8%) than existed prior to restoration. Mean pool spacing in 2009 increased again to 346 feet, which represented a 67% increase from as-built conditions, but 57% lower than existed prior to the restoration work. The increase in pool spacing from 2008 to 2009 was due to the loss of 2 pools, but despite this decrease, the total number of pools within the project area in 2009, remained 50% higher than existed in 2004, but was only about a third of the as-built in 2005 (Table 10). Mean pool bankfull width has remained similar between all years, including pre-restoration, as-built and all subsequent years, with annual changes generally less than 10%. However, mean pool width in 2009 (44.1 feet) was the highest of any year measured (Table 10). Mean pool bankfull depth and maximum bankfull depth both increased from 2008 to 2009, which was substantially deeper than existed in 2004, and approximately equal to as-built conditions (Table 10). Mean pool length also increased from 2008 to 2009 (Table 10), remaining almost 50% higher than existed prior to restoration and 75% higher than as-built conditions (Table 10). Total pool area remained similar between 2008 and 2009, but remained almost 150% higher than existed prior to the restoration work, but about 40% lower than as-built and pre-flood event conditions (Table 10). Total pool volume followed a similar trend (Table 10).

In addition to a complete census of all pools within the project area, we also surveyed riffles habitats within the project area to evaluate changes in riffle dimensions as a result of the restoration effort and the stream response after the November 2006 flow event. We measured mean bankfull width, depth, and width to depth ratio, of all riffles throughout the project area in 2004-2009 (Table 11), and since all riffles were measured, statistical comparisons were unnecessary. The restoration work we performed created a narrower stream channel within the riffle habitats in 2005. Mean bankfull width within the riffles decreased from 69.8 feet to 34.1 feet (51.1%) from 2004 to 2005 (Table 11). However, as a result of the 2006 flood event, riffle widths in 2007 increased to an average of 45.2 feet, and mean bankfull depth decreased by 8.8%, but remained substantially lower than existed prior to the restoration work (Table 11). Riffle dimensions remained relatively stable from 2007 to 2008 within the project area, and increased slightly in 2009 to 47.5 feet (Table 11). However, both mean and maximum depth in the riffle habitats decreased in 2009, to the lowest values observed. Mean depth decreased by 0.5 feet from 2008 to 2009, and maximum depth decreased by almost as much (0.4 feet). The observed decrease in depth may have been caused by a short and protracted spring freshet in 2009 due to limited snow pack the previous winter. The decrease in depth and the slight increase in width also translated into an increase in width to depth ratio from 2008 to 2009 (34.8%), but remained almost 30% lower in 2009 than prior to the restoration work (Table 11). We did not survey riffle slopes in 2004. However, mean riffle slope changed only slightly between 2005 and 2009, ranging from 2.4% in 2005 to a low of 2.0% in 2009 (Table 11).

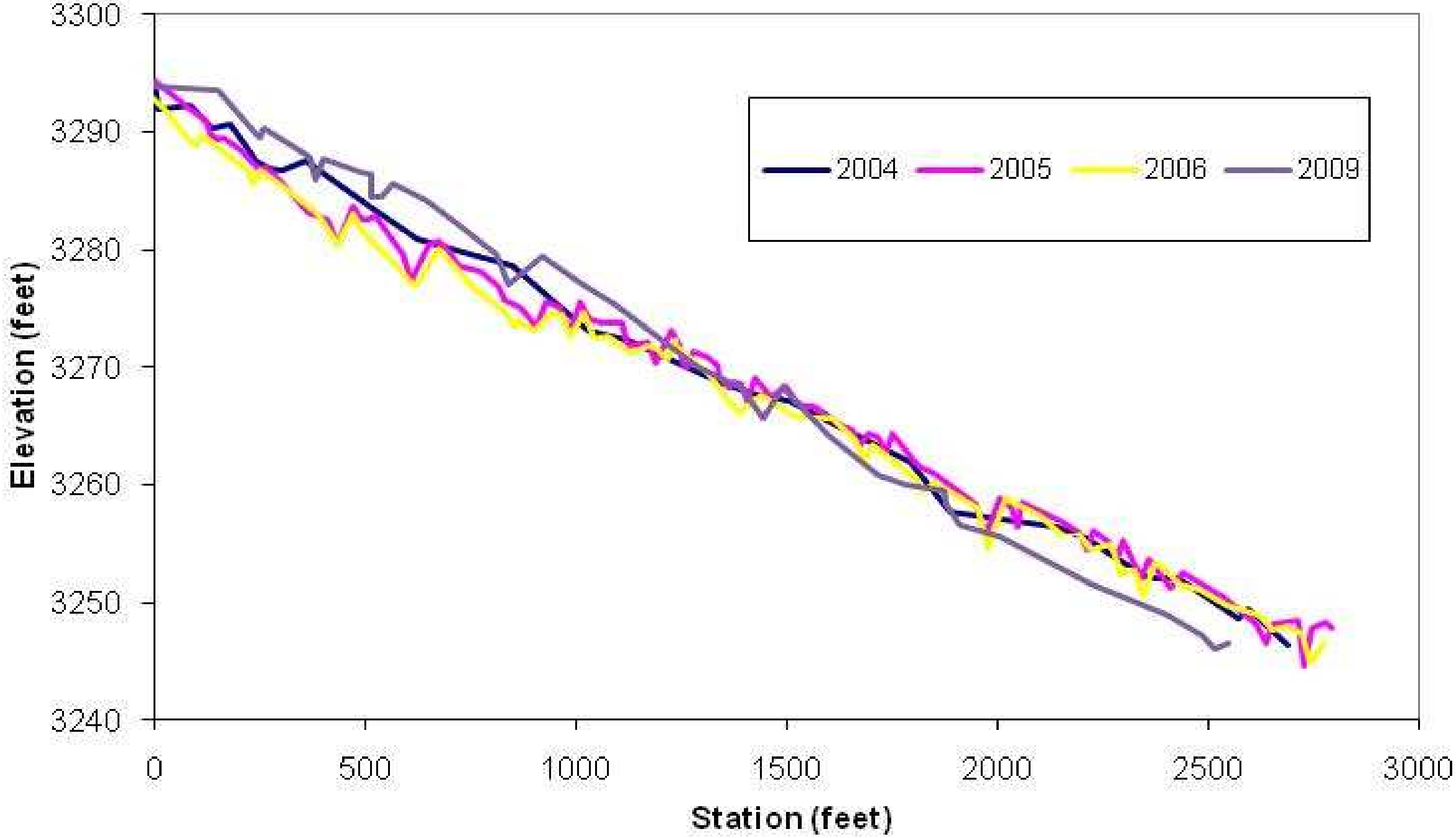


Figure 5. The longitudinal profile of the Libby Creek thalweg within the Lower Cleveland Phase I Restoration Project surveyed in 2004 (existing), 2005 (as built), 2006, and 2009. The survey was conducted beginning at station 0 (upper project boundary) to the downstream project boundary. Stream channel length varied between years due to differences in channel sinuosity.

Table 10. Pool dimensions including mean bankfull width, depth, maximum bankfull depth, length and total volume in 2004 (existing), 2005 (as built), and 2006-2009 for the Libby Creek Lower Cleveland Phase I Restoration Project. Variance estimates for annual mean values are presented in parentheses. A statistical comparison of annual mean values was not performed because all pools within the project area were measured, and therefore represents a complete census. The percent annual change is also presented.

	Number	**Pool Spacing (ft)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Length (ft.)**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2004 (existing)	4	811	42.2 (44.2)	2.33 (0.34)	4.2 (1.05)	42.8 (131.6)	7,260	16,186
2005 (As Built)	18	152	39.6 (63.9)	2.84 (0.34)	5.32 (0.85)	38.8 (95.1)	28,249	84,023
2006	13	183	39.9 (721.6)	2.64 (0.13)	4.98 (0.79)	57.7 (591.2)	30,534	80,477
2007	6	259	38.4 (35.5)	2.83 (0.59)	5.20 (1.70)	76.1 (769.4)	17,733	48,344
2008	8	285	39.9 (21.9)	2.56 (0.23)	4.73 (0.76)	54.5 (647.8)	17,397	44,472
2009	6	346	44.1 (68.5)	2.83 (0.15)	4.80 (0.42)	68.1 (779.1)	17,997	50,961
Percent Change								
2004/2005	350.0%	-81.3%	-6.2%	22.3%	26.7%	-9.3%	289.1%	419.1%
2004/2006	225.0%	-77.4%	-5.4%	13.4%	18.5%	35.0%	320.6%	409.6%
2004/2007	50.0%	-68.1%	-9.0%	21.6%	23.8%	78.0%	144.2%	198.7%
2004/2008	100.0%	-64.9%	-5.5%	9.9%	12.5%	27.6%	139.6%	174.8%
2004/2009	50.0%	-57.4%	4.5%	21.8%	14.3%	59.2%	147.9%	214.9%
2005/2006	-27.8%	20.4%	0.8%	-7.3%	-6.5%	48.8%	8.1%	-1.8%
2005/2007	-66.7%	70.4%	-3.0%	-0.6%	-2.3%	96.2%	-37.2%	-42.5%
2005/2008	-55.6%	87.2%	0.8%	-10.1%	-11.2%	40.6%	-38.4%	-47.1%
2005/2009	-66.7%	127.4%	11.4%	-0.4%	-9.8%	75.5%	-36.3%	-39.3%
2006/2007	-53.8%	41.5%	-3.8%	7.2%	4.5%	31.9%	-41.9%	-41.4%
2006/2008	-38.5%	55.5%	-0.1%	-3.1%	-5.1%	-5.5%	-43.0%	-46.1%
2006/2009	-53.8%	88.9%	10.4%	7.4%	-3.6%	18.0%	-41.1%	-38.2%
2007/2008	33.3%	9.9%	3.9%	-9.6%	-9.1%	-28.3%	-1.9%	-8.0%
2007/2009	0.0%	33.4%	14.8%	0.2%	-7.7%	-10.5%	1.5%	5.4%
2008/2009	-25.0%	21.4%	10.5%	10.8%	1.6%	24.8%	3.4%	14.6%

Table 11. Riffle dimensions including mean bankfull width, depth, maximum bankfull depth and width to depth ratio in 2004 (existing), 2005 (as built) and 2006-2009 for the Libby Creek Lower Cleveland Phase I Restoration Project. Variance estimates for annual mean values are presented in parentheses. The riffle slope was not measured in 2004.

	Sample Size	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Width to Depth Ratio	Slope
2004 (existing)	7	69.8 (695.9)	1.94 (0.20)	3.16 (0.07)	41.2 (305.3)	N/A
2005 (As Built)	9	34.1 (13.9)	2.21 (1.7)	3.39 (0.39)	15.9 (12.4)	0.024 ($1.9*10^{-5}$)
2006	9	34.5 (22.1)	2.14 (0.06)	3.08 (0.11)	16.4 (15.0)	0.023 ($5.85*10^{-5}$)
2007	7	45.2 (106.9)	1.95 (0.13)	2.97 (0.30)	24.6 (68.3)	0.021 ($4.72*10^{-5}$)
2008	6	44.6 (62.9)	2.08 (0.08)	3.05 (0.24)	22.0 (34.0)	0.022 ($2.52*10^{-5}$)
2009	5	47.5 (139.6)	1.58 (0.17)	2.65 (0.32)	29.6 (150.3)	0.020 ($1.05*10^{-5}$)
Percent Change						
2004/2005	28.6%	-51.2%	14.1%	7.3%	-62.2%	
2004/2006	28.6%	-50.6%	10.2%	-2.5%	-60.3%	
2004/2007	0.0%	-35.2%	0.4%	-6.1%	-40.7%	
2004/2008	-14.3%	-36.2%	6.9%	-3.4%	-46.9%	
2004/2009	-28.6%	-32.0%	-18.5%	-16.1%	-28.5%	
2005/2006	0.0%	1.1%	-3.4%	-9.2%	5.0%	17.2%
2005/2007	-22.2%	32.6%	-11.9%	-12.5%	56.8%	3.6%
2005/2008	-33.3%	30.7%	-6.3%	-10.0%	40.3%	10.0%
2005/2009	-44.4%	39.2%	-28.6%	-21.8%	89.2%	0.0%
2006/2007	-22.2%	31.2%	-8.8%	-3.6%	49.4%	-11.6%
2006/2008	-33.3%	29.3%	-3.0%	-0.9%	33.7%	-6.2%
2006/2009	-44.4%	37.7%	-26.0%	-13.9%	80.2%	-14.7%
2007/2008	-14.3%	-1.5%	6.4%	2.8%	-10.5%	6.2%
2007/2009	-28.6%	4.9%	-18.9%	-10.6%	20.6%	-3.4%
2008/2009	-16.7%	6.5%	-23.8%	-13.1%	34.8%	-9.1%

Libby Creek Lower Cleveland Phase II Project

The lower Cleveland property on Libby Creek is located approximately 1 mile downstream of the upper Cleveland Property, and has been identified by MFWP as a high priority site for stream restoration, and consists of approximately 9,100 feet of stream channel. MFWP planned to implement the restoration of this large site in 3 phases. Phase I of this project was completed in the fall of 2005 (see above), and Phase II was completed in October 2006. Past land management activities including logging, mining, riparian road construction, and stream channel manipulation have resulted in accelerated bank erosion along a number of meander bends, resulting in an over widened, unstable, and shallow channel, which has resulted in low quality habitat for native salmonids including bull trout and redband trout. The Libby Creek Lower Cleveland Phase II Project started at the downstream boundary of the Phase I project area and continued 3,273 feet downstream (see above). This project constructed a variety of structures intended to improve fish habitat and increase bank stability (Dunnigan et al. 2007).

During the first week of November 2006, the Libby Creek watershed experienced a rain on snow weather event that created higher than average runoff conditions throughout the entire watershed including the headwater regions. US Forest Service gauged the peak flows during this event at a minimum flow of 3,093 cubic feet per second, which translated to a 19-year return interval using the Log-Pearson type III Flood Frequency Analysis (J. Boyd, US Forest Service, personal communication). This storm event changed the stream planform, and channel dimensions (Dunnigan et al. 2009). Therefore, this document evaluates changes in the physical habitat within this section of Libby Creek after this event by comparing current conditions to those existing before restoration (1999) and after the November 2006 flow event.

We surveyed the stream restoration project area before (2004), October 2006 (as built), and 2007-2009 using a Nikon Model DTM-420 Total Station Survey Instrument, which records the geo-referenced location of stream channel features including channel dimensions, profile and plan form. The most conspicuous changes within this section of Libby Creek as a result of the November 2006 flow event were changes in the stream plan form. Changes in Phase II as a result of the 2006 flow event were more severe than either the Lower Cleveland Phase I or the Upper Cleveland Restoration Project areas. Dunnigan et al. (2009) documented changes in stream plan form at seven major locations within the Phase II project area and estimated net erosion exceeded net deposition in this section of Libby Creek as a result of the November 2006 flow event. The plan form of this section of Libby Creek in 2007-2009 was relatively similar.

The stream channel profile prior to project construction consisted of a total of 2,632 feet of stream channel, and the restoration work increased stream length to 3,175 feet, representing a 20.6% increase due to increased sinuosity due to increased meander frequency (Figure 6). However, as a result of several chute cutoffs that occurred throughout the project area, the stream channel lost 486 feet (2,689 feet total length) after the flood event, representing a loss of 15.3% relative to as-built conditions. However, after the flood event, stream length remained 57 feet longer (2.2%) than existed prior to the project. The stream channel adjusted slightly during the 2008 spring freshet, resulting in a slight shortening of total length to 2,558 feet, representing a loss of 131 feet from 2007 (4.9%). The stream channel in 2009 was 90 feet longer existed in 2008 (3.5%) and 36 feet longer than existed prior to restoration (Figure 6).

Prior to project construction, the mean pool-to-pool distance was 690 feet. The newly constructed channel mean pool-to-pool spacing was 123 feet, representing an 82.2% reduction from existing conditions. We found that mean pool-to-pool spacing increased in 2007 to 257 feet, representing an approximate doubling compared to as built (2006) conditions, but remained 62.7% lower than conditions existing prior to restoration work in 2004. Pool spacing decreased from 2007 to 2008 to 201 feet (21.6% reduction). However, in 2009, pool spacing again increased to an average of 262 feet. Despite this slight increase, pool spacing in 2009 remains 62% lower than prior to the restoration work. The overall number of pools ultimately determines pool spacing and has an overwhelming effect on the total number of pools and the total surface area and volume of pool habitat (Table 12). Overall, the number of pools was dramatically reduced as a result of the 2006 flow event, and has remained low since. In 2009 there were only four pools remaining in this section of Libby Creek, which was the same number that existed prior to the restoration work, but mean depth, width and length in 2009 all remained higher than existed in 2004, which resulted in an increase in total pool area and volume (Table 12). However, total pool area and volume have also increased since 2007, the first year after the flow event, remaining about 70 and 67%, respectively higher in 2009 than in 2007. Therefore, despite the substantial loss of pool habitat as a result of the November 2006 flow event, pool habitat within this section of Libby Creek has rebounded substantially and the quantity of pool habitat remains higher than existed prior to our restoration work or immediately after the 2006 flow event.

In addition to a complete census of all pools within the project area, we also surveyed all riffles habitats within the project area to evaluate changes in riffle dimensions as a result of the restoration efforts and the November 2006 flood. In 2004 (existing), 2006 (as built), and 2007-2009, we measured mean bankfull width, depth, width to depth ratio, and cross sectional area of riffles throughout the project area. Since we surveyed all riffle habitats within the project area, statistical comparisons were unnecessary. The restoration work we performed created a significantly narrower and deeper stream channel within the riffle habitats in 2006. Mean bankfull width within the riffles decreased from 70.4 feet to 36.9 feet (47.6%), and mean bankfull depth decreased from 1.4 feet to just over 2 feet (45%) from 2004 to 2006 (Table 13). However, mean bankfull width, cross sectional area and width to depth ratio increased after the 2006 flow event (Table 13). In 2008, we observed a slight increase in mean riffle width (15.1%), and a slight decrease in mean riffle depth (15.9%) compared to 2007 (Table 13), but in 2009, the trend reversed itself, with the riffle habitats becoming slightly deeper and narrower (Table 13). As a result, the width to depth ratio we observed in 2009 was the lowest (mean = 23.1) in the previous three years (Table 13). Mean riffle slope in 2009 (2.6%) was similar to 2006 (as-built) and 2008, and remained higher than existed prior to the restoration work (Table 13). The riffle habitats within this section of Libby Creek remain substantially narrower and deeper than existed prior to restoration work we completed in 2006, and the stream channel dimensions are remaining relatively stable or trending toward recovery after the flow event in 2006.

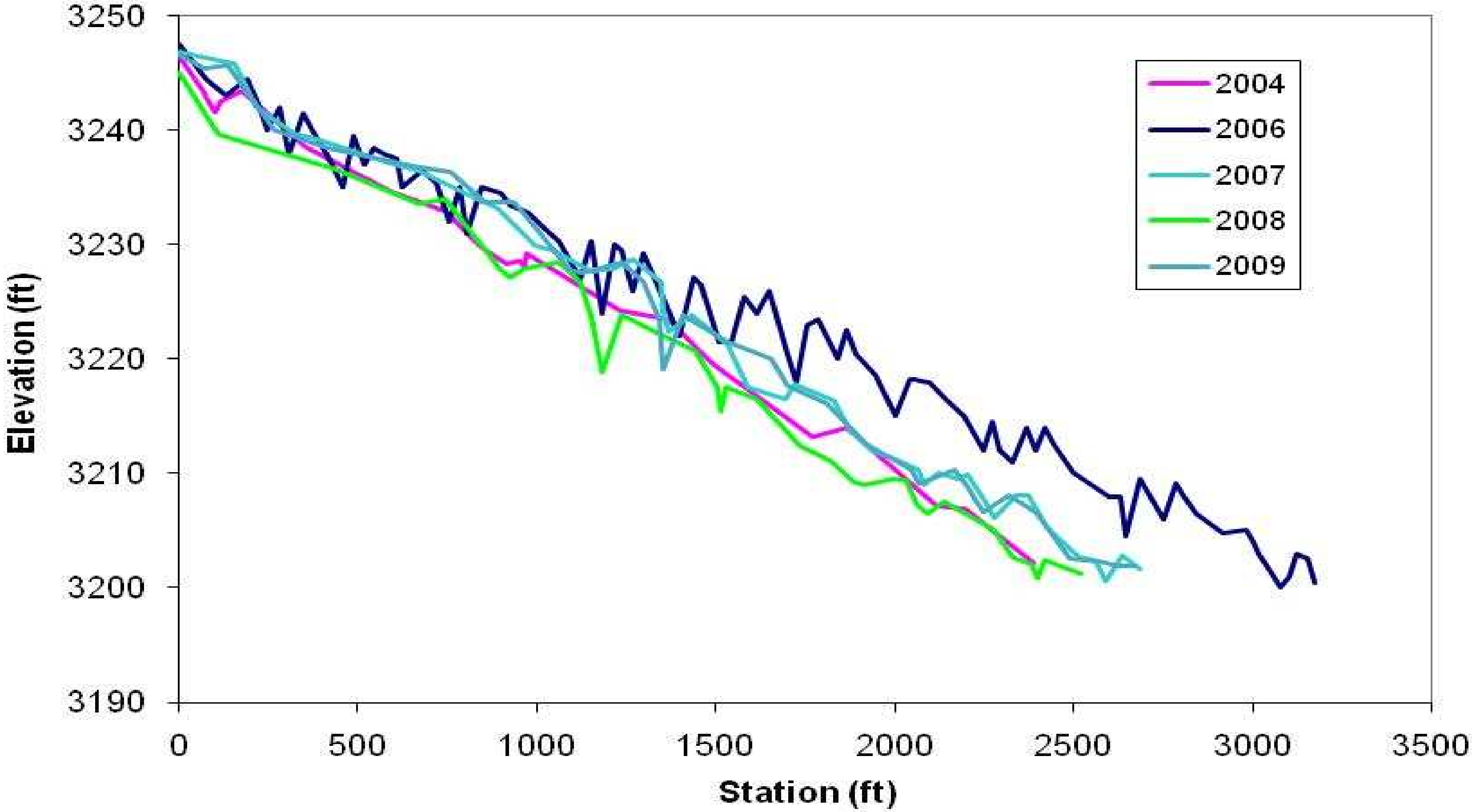


Figure 6. The longitudinal profile of the Libby Creek thalweg within the Lower Cleveland Phase II Restoration Project surveyed in 2004 (existing), 2006 (as built), and 2007-2009. The survey was conducted beginning at station 0 (upper project boundary) to the downstream project boundary. Stream channel length varied between years due to differences in channel sinuosity.

Table 12. Pool dimensions including mean bankfull width, depth, maximum bankfull depth, length and total volume in 2004 (pre-existing), 2006 (as built), and 2007-2009 for the Libby Creek Lower Cleveland Phase II Restoration Project. Variance estimates for annual mean values are presented in parentheses. The percent annual change is also presented.

	Number	**Pool Spacing (ft)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Length (ft.)**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2004 (existing)	4	690	42.9 (75.1)	2.24 (0.21)	4.18 (0.70)	87.3 (1546.9)	15,600	35,035
2006 (as-built)	27	123	41.6 (26.3)	3.24 (0.38)	5.50 (1.11)	43.3 (77.3)	48,635	157,576
2007	5	257	37.0 (417.8)	2.61 (0.53)	4.92 (0.28)	61.8 (474.2)	10,595	27,496
2008	6	201	47.9 (88.8)	2.82 (1.61)	5.68 (6.57)	81.5 (2605.3)	23,404	66,037
2009	4	262	43.0 (27.5)	2,55 (1.74)	5.00 (3.57)	104.5 (1368.5)	17,974	45,833
Percent Change								
2004/2006	575.0%	-82.2%	-2.9%	44.7%	31.7%	-50.4%	211.5%	352.8%
2004/2007	25.0%	-62.8%	-13.8%	16.2%	17.8%	-29.2%	-32.1%	-21.5%
2004/2008	50.0%	-70.8%	11.7%	25.8%	35.9%	-6.6%	50.0%	88.5%
2004/2009	0.0%	-62.0%	0.3%	13.7%	19.8%	19.7%	15.2%	30.8%
2006/2007	-81.5%	108.9%	-11.2%	-19.7%	-10.5%	42.7%	-78.2%	-82.7%
2006/2008	-77.8%	63.7%	15.0%	-13.0%	3.2%	88.2%	-51.8%	-58.4%
2006/2009	-85.2%	113.3%	3.4%	-21.4%	-9.0%	141.2%	-63.0%	-71.1%
2007/2008	20.0%	-21.6%	29.5%	8.3%	15.3%	31.9%	120.9%	140.2%
2007/2009	-20.0%	2.1%	16.4%	-2.1%	1.6%	69.0%	69.6%	66.7%
2008/2009	-33.3%	30.3%	-10.1%	-9.6%	-11.9%	28.2%	-23.2%	-30.6%

Table 13. Riffle dimensions including mean bankfull width, depth, maximum bankfull depth and width to depth ratio in 2004 (pre-existing), 2006 (as built), and 2007-2009 for the Libby Creek Lower Cleveland Phase II Restoration Project. Variance estimates for annual mean values are presented in parentheses.

	Sample Size	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Cross Sectional Area (ft^2)	Width to Depth Ratio	Slope
2004 (existing)	4	70.4 (417.0)	1.4 (0.14)	95.3 (458.1)	54.3 (622.3)	1.5% ($6.67*10^{-6}$)
2006 (As Built)	12	36.9 (26.8)	2.03 (0.05)	75.3 (217.5)	18.4 (6.6)	2.8% (0.007)
2007	6	47.6 (62.1)	2.1 (0.23)	98.9 (64.9)	23.5 (67.9)	1.9% ($1.76*10^{-5}$)
2008	9	54.9 (145.8)	1.8 (0.18)	82.8 (1076.8)	35.0 (298.8)	2.6% ($1.45*10^{-4}$)
2009	5	46.1 (48.6)	2.09 (0.16)	94.5 (56.7)	23.1 (45.2)	2.6% ($8.83*10^{-5}$)
Percent Change						
2004/2006	200.0%	-47.55%	44.40%	-20.97%	-66.05%	83.89%
2004/2007	50.0%	-32.33%	51.92%	3.77%	-56.68%	26.67%
2004/2008	125.00%	-22.11%	27.81%	-13.09%	-34.87%	71.85%
2004/2009	25.00%	-34.44%	48.63%	-0.79%	-57.46%	76.00%
2006/2007	-50.0%	29.03%	5.21%	31.30%	27.60%	-31.12%
2006/2008	-25.00%	48.52%	-11.49%	9.97%	91.86%	-6.55%
2006/2009	-58.33%	25.01%	2.93%	25.53%	25.32%	-4.29%
2007/2008	50.00%	15.10%	-15.87%	-16.25%	50.35%	35.67%
2007/2009	-16.7%	-3.1%	-2.2%	-4.4%	-1.8%	38.9%
2008/2009	-44.4%	-15.8%	16.3%	14.2%	-34.7%	2.4%

Young Creek State Lands Restoration Project

MFWP reconstructed 1,200 feet of the Young Creek stream channel in the fall of 2003 (Dunnigan et al. 2005). The Young Creek State Lands Restoration Project significantly changed the dimension, pattern and longitudinal profile of this section of Young Creek (see Dunnigan et al. 2005). The stream restoration project significantly ($p < 0.05$) reduced the mean width and width to depth ratio, and significantly increased the cross sectional area, maximum depth, and mean bankfull depth for both riffles and pools within the project area. The monitoring activities we conducted on this section of Young Creek since the initial project construction have been directed at determining if the stream channel maintained the pattern and dimensions relative to as built conditions in 2003.

The changes that occurred in the stream channel dimensions within the Young Creek State Lands Restoration Project area between 2004 and 2009 were relatively small. We measured the cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio within each riffle that existed within the project area before (2002), during (2003; as built), and after (2004-2009) project construction (Table 14). We established the transect location at each riffle at the longitudinal mid-point of each riffle. The total number of riffles within this section of Young Creek has remained relatively similar since the project was constructed, varying by no more two riffles between years. Mean cross sectional area, mean bankfull width, maximum bankfull depth, and width to depth ratio have also remained relatively similar to the constructed stream channel dimensions, within changes generally less than 10% between years (Table 14). However, the mean bankfull width and width to depth ratio in 2009 remained substantially lower than existed in 2002 prior to the project, and mean and maximum bankfull depth remained about double and half again deeper in 2009 (Table 14). We did not perform any statistical tests on these data because these surveys were a complete census of all riffles within the project area. Therefore, given the data collected since project completion, it appears that the channel dimensions are being maintained within the riffle habitats of this project since initial construction in 2003.

The Young Creek State Lands Restoration Project also increased the quality and quantity of pool habitat for resident salmonids, and these changes are being sustained five years after the project was completed. The total number of pools, total pool area and total pool volume, remain 750, 348, and 941% higher than existed in this section of Young Creek prior to the restoration work (Table 15). The large woody debris stems and root wads used during project construction also likely increased cover available to rearing and migrating salmonids within this reach of Young Creek. We measured the same 5 parameters that we measured at each riffle transect in addition to pool length. We established the transect location within each pool at the location of maximum depth. The results from our pool monitoring were similar to the results we observed in riffles. The total number of pool increased from 8 in 2003 to 14 in 2004 to 15 in 2005, and 17 in 2006 - 2009 (Table 15), primarily as a result of the formation of several new pools that formed within several of the meanders. However, the pool dimensions changed relatively little between years after the project construction, especially during the past four years.

Stream channel dimensions with the pool changes within the past four years were generally relatively small (Table 15). However, total pool area and volume increased slightly in 2009 (9.0 and 8.3%, respectively), which was the result of a slight increase in mean width, depth, and length (data not presented). The constructed pool habitat continues to provide an improvement in the amount of depth and cover that existed prior to the project (Table 15). As was the case with the riffle surveys, we did not perform any statistical tests on these data due to the fact that these surveys were a complete census of all riffles within the project area.

The stream restoration techniques we employed on this section of Young Creek increased channel diversity and stability, stream length, and sinuosity within the project area. Although we did not present a figure that displays the stream plan for this section of Young Creek, it has changed little since the project was completed in 2003. This project continues to meet the original objectives (Dunnigan et al. 2005) set forth for this project.

Table 14. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for the total number of riffles 2002-2009 for the Young Creek State Lands Stream Restoration Project. The project was constructed in the fall of 2003. Variance estimates for annual mean values are presented in parentheses. The percent change between years is also presented.

Year	Number Of Riffles	Cross Sectional Area (ft^2)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Width to Depth Ratio
2002 (Existing)	4	16.8 (1.6)	27.9 (22.7)	0.60 (0.01)	1.05 (0.02)	48.3 (239.6)
2003 (As Built)	10	22.0 (10.1)	16.3 (9.2)	1.24 (0.05)	1.99 (0.09)	13.7 (21.2)
2004	11	18.7 (6.3)	14.8 (3.6)	1.28 (0.07)	1.85 (0.13)	12.3 (17.3)
2005	11	21.9 (22.0)	16.1 (4.4)	1.37 (0.08)	1.79 (0.09)	12.3 (11.4)
2006	10	19.7 (14.1)	15.6 (4.7)	1.29 (0.12)	1.89 (0.14)	13.0 (22.5)
2007	10	19.1 (15.5)	14.8 (4.0)	1.32 (0.14)	1.72 (0.12)	14.4 (25.1)
2008	10	20.0 (9.4)	16.0 (5.4)	1.25 (0.02)	1.75 (0.07)	13.0 (7.1)
2009	8	18.0 (6.2)	15.2 (5.7)	1.19 (0.02)	1.59 (0.11)	13.1 (9.9)
Percent Change						
2002/2005	175%	30.9%	-42.1%	128.3%	129.4%	-74.5%
2002/2009	100%	7.3%	-45.5%	99.4%	51.2%	-73.0%
2003/2009	-20.0%	-18.3%	-6.8%	-3.9%	-20.0%	-4.7%
2004/2009	-27.3%	-6.8%	0.3%	-7.4%	-15.0%	4.3%
2005/2009	-27.3%	18.0%	-5.8%	-13.1%	-11.4%	5.8%
2006/2007	0%	-3.2%	-4.8%	2.3%	-8.8%	-4.9%
2006/2008	0%	1.4%	2.6%	-3.2%	-7.4%	-0.5%
2006/2009	-20.0%	-8.8%	-2.5%	-7.9%	-15.8%	0.1%
2007/2008	0%	4.7%	7.7%	-5.4%	1.5%	4.6%
2007/2009	-20.0%	-5.8%	2.4%	-10.0%	-7.7%	5.2%
2008/2009	-20.0%	-10.0%	-5.0%	-4.9%	-9.0%	0.6%

Table 15. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, width to depth ratio, and total area and volumes of pools (n) 2002-2008 for the Young Creek State Lands Stream Restoration Project. The project was constructed in the fall of 2003. Variance estimates for annual mean values are presented in parentheses. The percent change between years is also presented.

Year	Number of Pools	Cross Sectional Area (ft^2)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Total Area (ft^2)	Total Volume (ft^3)
2002 (Existing)	2	19.3 (3.1)	23.5 (24.5)	0.79 (0.005)	2.35 (0.13)	1,998	1,578
2003 (As Built)	8	37.7 (65.1)	21.8 (18.0)	1.73 (0.084)	3.23 (0.42)	8,480	14,671
2004	14	31.8 (37.0)	19.2 (24.7)	1.73 (0.23)	3.63 (0.53)	8,602	14,881
2005	15	29.1 (48.6)	17.8 (12.8)	1.71 (0.28)	3.08 (0.67)	8,218	14,053
2006	17	30.1 (135.6)	17.4 (9.8)	1.74 (0.32)	3.12 (0.40)	10,667	17,923
2007	17	28.7 (54.4)	16.8 (10.0)	1.75 (0.26)	3.04 (0.22)	10,090	16,544
2008	17	30.0 (44.2)	15.9 (7.8)	1.94 (0.35)	3.12 (0.26)	8,231	15,751
2009	17	30.8 (54.0)	16.6 (9.3)	1.99 (0.46)	2.98 (0.25)	8,972	17,052
Percent Change							
2002/2005	650.0%	51.0%	-24.5%	116.5%	31.1%	311.4%	790.6%
2002/2009	750.0%	59.8%	-31.9%	152.4%	26.7%	348.4%	941.4%
2003/2009	112.5%	18.4%	-26.6%	15.2%	-8.1%	8.3%	21.3%
2004/2009	21.4%	-6.4%	-16.8%	12.8%	17.0%	-8.8%	0.6%
2005/2009	13.3%	5.8%	-9.8%	16.4%	-3.4%	6.4%	26.0%
2006/2007	0%	-4.6%	-3.7%	0.6%	-2.6%	-5.4%	-7.7%
2006/2008	0%	0.2%	-8.8%	11.6%	0%	-22.8%	-12.2%
2006/2009	0%	2.3%	-8.1%	14.5%	-4.5%	-15.9%	-4.9%
2007/2008	0%	2.7%	-5.3%	10.9%	2.7%	-18.4%	-4.7%
2007/2009	0%	7.3%	-4.6%	13.8%	-1.9%	-11.1%	3.1%
2008/2009	0%	2.5%	0.8%	2.6%	-4.5%	9.0%	8.3%

Therriault Creek Restoration Project

MFWP partnered with The Kootenai River Network (KRN), the USFWS Partners for Wildlife and the local landowner to complete the Therriault Creek Restoration Project during the summer of 2005. Prior to the restoration work, the lower section of Therriault Creek was extensively modified through land cover disturbance, riparian vegetation clearing, and physical stream straightening prior to the mid-1900s. These past activities resulted in an incised stream channel, accelerated bank erosion, channel degradation, and poor fish habitat. This project reconstructed a total of 9,100 feet of entirely new stream channel that will restore the proper dimension, pattern, and profile of the channel, which approximately doubled the stream length by increasing meander frequency. Cooperators for this project initiated restoration work in 2004 and completed the stream channel restoration work during the summer 2005. The goals for this restoration project were to 1. To reduce nonpoint source pollution to Therriault Creek and the Tobacco River through mitigation of chronic instream sources of sediment, 2. Eliminate an existing partial fish barrier (perched culvert), 3. Restore and create approximately 55 acres of prior converted wetland, and 4. Improve and increase fish habitat for resident fish species.

The stability of the channel is tied to the structure and composition of riparian vegetation, which provides rooting structure to maintain lateral channel stability by preventing accelerated lateral erosion. Initial revegetation efforts associated with the restoration work in 2005 included the installation of 5,000 riparian shrubs, 10,000 dormant willow cuttings and seeding of disturbed areas. However, poor survival of the plants installed in the initial phase of the restoration project prompted further work. MFWP implemented several vegetation treatments in the fall of 2007 intended to restore site conditions capable of supporting native riparian woody vegetation along the restored Therriault Creek channel. The specific actions implemented in the fall of 2007 (Phase I) included those actions are described in detail in Dunnigan et al. 2009, and Geum Environmental Consulting (2007). This activities included residual shrub protection of 250 existing plants (initially planted in 2004 and 2005), an additional planting of 1,028 containerized shrubs, 8,120 square feet of solarization treatment intended to control weeds, 120 feet of vegetated soil lifts to stabilize and revegetate streambanks, 800 feet of willow fascines, installation of five woody debris jams, installation of 400 feet of coir logs, and two herbicide applications, once in the summer and fall of 2008 along 4,000 feet of stream channel. In 2008 Geum Environmental Consulting completed monitoring of prior riparian vegetation efforts (Geum Environmental 2008b), and developed an adaptive management plan for the revegetation of this site. The Phase II portion of the riparian restoration effort included additional monitoring, maintenance and supplemental revegetation treatments summarized below.

Riparian Vegetation Monitoring

Geum Environmental Consulting completed riparian vegetation monitoring at this site in July 2009, and a detailed discussion of the monitoring results is presented in Geum Environmental 2009. The highlights of those results are briefly discussed below. Observations made in 2009 were similar to those made in 2008 and indicate that protecting residual shrubs remains a relatively simple and cost-effective treatment for reducing browse and allowing shrubs to grow. Most protected residual shrubs continue to show increased new growth, with some growth of more than three feet observed. No difference in new growth between shrubs with mulch mats and those without was observed. This indicates that the root systems of surviving residual shrubs are established enough to withstand competition from pasture grasses. However, browse is occurring on portions of protected shrubs growing outside of browse protectors. The results of 2009 effectiveness monitoring showed continued high survival rates for containerized shrubs and trees planted in 2007. Containerized plant survival was 89 percent overall (overall plant survival was 96 percent in 2008) and remains above 80 percent for most species installed in 2007. Only three species fell below 80 percent survival; water birch, mountain alder and Engelmann spruce. Of these three species, Engelmann spruce had the lowest survival (18 percent) and is not recommended for future plantings until site conditions are more suitable for the species. Many leaves and stems extending beyond the height or width of browse protectors are being browsed. No sign of stem girdling was observed on planted shrubs or protected residual shrubs in 2008 or 2009 by voles or other animals. Because vole damage was identified as a primary cause of initial poor survival of planted shrubs at the site, new plants installed should include vole protectors. Although a few planting units showed an increase in native sedge and forbs cover in 2009, pasture grasses continue to dominate the understory in the planting units. However, brush blankets are effectively controlling grass cover immediately adjacent to installed plants. Based on these results and observations, planting additional containerized shrubs and trees should be part of Phase III revegetation efforts.

Planted solarization plots in 2008 and 2009 showed comparable survival with other planting units. Plant growth was also monitored in solarization plots and some species showed a high level of growth between 2008 and 2009.

Vegetated soil lifts have provided stable areas within the high stress land-water interface, allowing the dormant willows used in this treatment to take root and sprout. Willow cutting survival is good but new shoot growth and overall percent cover of willows is not as high as expected at either site. The vegetated soil lifts are creating stable areas for woody vegetation to establish and therefore achieving the desired function. Willow cutting survival is variable but within the expected range of survival for dormant willow cuttings. Poor survival is primarily in sections of the soil lift where willows placed under the lift are inundated for most of the year. Willow cover increased at both sites between 2008 and 2009, but remains patchy.

The willow fascine treatment has been variable in terms of achieving the intended function of increasing root mass and providing long term bank stability. Willow cutting survival and percent cover is low at all observed sites, but nonetheless, fascines are functioning as debris and sediment traps but little natural recruitment of desirable species was observed in 2008 or 2009. Location where willow fascines were placed within the channel appears to have the most influence on survival and growth of the willows in the fascines.

The five woody debris structures installed in 2007 may be improving floodplain hydrology at this site including trapping sediments and prolonging floodplain inundation. Non-native pasture grasses remain the dominant species along each transect, although inclusions of hydrophytic species such as sedges and rushes are increasing.

Coir logs appear to be creating a suitable environment on outer meander bends for the establishment of willow cuttings and natural recruitment of wetland shrubs and forbs. Willow survival is within the range of expected survival for this treatment (50 to 79%).

Maintenance and Supplemental Revegetation Treatments

All containerized plants and protected residual shrubs were watered with a minimum of five gallons of water on September 2 and 3, 2009. A Montana Conservation Corps crew watered approximately one-third of planted shrubs and trees on August 19, 2009. Browse protectors were expanded, re-secured and straightened in all planting units and residual shrub protection areas, and some protectors were for all shrubs that had out-grown the current browse protector. Approximately 700 of the 1,028 plants installed were retro-fitted with larger diameter browse protectors. Approximately 200 of the 250 residual shrubs were retro-fitted with larger browse protectors. Sixty additional residual shrubs were protected using four-foot tall by 16-inch diameter browse protectors. Based on observations made during the effectiveness monitoring it was determined that the grass treated by solarization fabric in a temporary solarization plot had been effectively heat killed. The fabric was removed, and a native seed mix consisting of shrubs, grasses, and forbs was applied to the exposed surface. Fabric removed from the plot was placed along the edges of the plot to create a buffer around the newly exposed bare soil, which resulted in treating 2,370 new square feet of reed canarygrass.

Maintenance was completed in two temporary solarization plots and in two additional planted solarization plots. Maintenance included re-securing staples and fabric edges, weeding. A total of 115 supplemental willow cuttings were installed in areas of poor willow cutting survival at Coir Log sites 1-7. Herbicide applications were completed twice in 2009 (August and October). Both treatments targeted reed canarygrass, Canada thistle, yellow toadflax, sulfur cinquefoil and houndstongue. Herbicide is effectively reducing the infestations and densities of target species.

Stream Channel Monitoring

The existing stream channel prior to restoration consisted of an entrenched F4 /G4 Rosgen channel type (Rosgen 1996), and the restoration work converted the stream back to an E4 channel type that has access to the historic floodplain. This restoration project approximately doubled the stream length within the project area due to the increased meander frequency resulting from project construction. The stream pattern and total length have not changed substantially since it was constructed. A detailed and rigorous evaluation of changes to the stream channel dimensions, pattern, and profile that resulted from this restoration effort are presented in Dunnigan et al. (2008). The results of monitoring reported within this document therefore focus on evaluating whether these changes have been maintained through time.

We stratified Therriault Creek within the project area into two reaches based on changes in valley slope. Reach 1 included the upper 3,750 feet of constructed stream channel, where valley slope measured 1.44%. The valley slope of Reach 2 measured 0.75%, and included the lower 5,350 feet of constructed stream channel. In order to evaluate the immediate physical changes to the stream channel as a result of the restoration work and the long-term sustainability of these changes, we completed cross sectional surveys before and after project implementation.

Prior to project construction, we surveyed 10 riffles and 10 pools within the existing stream channel. Within the riffle habitats, we established each transect at the longitudinal mid-point of the first 10 riffles downstream of the upper project boundary. Within the pool habitats, we established the cross section transects within each pool where the maximum depth occurred. We also selected the first ten pools downstream of the upper project boundary. Upon completion of the project, we established permanent cross sections within 10 pool and 10 riffle/run habitats that were distributed throughout the entire project area, and surveyed them annually since project completion, measuring mean bankfull width, depth, cross sectional area, maximum bankfull depth and width to depth ratio at each. However, in 2009, we were only able to relocate 8 of each of the cross section locations. We used an analysis of variance to test each of these parameters for significant differences between years. Multiple comparisons were performed using the Tukey Test.

This restoration project changed the stream channel type, pattern, profile and channel dimensions of Therriault Creek within the project area (Dunnigan et al. 2008), and these changes appear to be self-sustaining since the project was completed. Stream channel type, length, and pattern have not changed since the project was completed. Stream channel dimensions also significantly changed as a result of the project, but stream channel dimensions have not changed significantly after project construction (Tables 16-19). Stream channel dimensions for riffle/run habitats within Reach 1 changed little between 2008 and 2009, with changes less than 10%, with the exception that mean bankfull width increased by 0.4 feet (13.3%; Table 16). Both mean and maximum bankfull depth of riffles in Reach 1 increased slightly (4% and 7%, respectively). However, riffle/run habitat dimensions in Reach 2 remained very similar between 2008 and 2009, with changes less than 5% between years (Table 17). Riffles in both reaches remained narrower and deeper (mean and maximum) in 2009 than prior to the reconstruction (Tables 16 and 17). Pool habitat dimensions within Reaches 1 and 2 were not significantly different from 2008 to 2009, with most annual changes generally less than 5% (Table 18). Cross sectional area and mean bankfull width of pools in 2009 in both reaches remained lower than existed in 2003. Mean pool depth in Reach 2 in 2009 was slightly higher than existed in 2003, but mean maximum pool depth decreased slightly in both reaches, as did mean bankfull pool depth in Reach 1 (Tables 18 and 19). Despite the relatively small changes in pool habitat dimension from 2003 to 2009, the approximate two fold increase in stream length outweighs these small changes. This section of Therriault Creek is maintaining in a state of relative dynamic equilibrium, in which case depositional and erosion are occurring at approximately equal rates within the project area, and the stream plan form has remained nearly identical since it was originally constructed.

Table 16. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio for riffle/run-type habitats in Reach 1 of the Therriault Creek Restoration Project area. The project was constructed in the fall of 2004-2005. The range for annual mean values is presented in parentheses. The percent change between years is also presented. Cross sectional surveys from 2003 were not stratified by reach. Analysis of variance was preformed for each parameter, and the P value is presented. Multiple comparisons were performed using Tukey's Test. Significant comparisons are indicated via * (alpha < 0.05).

	# Runs	Cross Sectional Area (ft^2)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	W/D Ratio
2003 (Existing)	10	13.9 (8.2-20.5)	12.6 (8.3-17.2)	1.1 (1.0-1.2)	1.5 (1.1-1.8)	11.5 (7.4-15.0)
2004 (As Built)	4	11.2 (8.6-12.1)	8.3 (7.9-9.0)	1.3 (1.0-1.5)	1.8 (1.2-2.0)	6.4 (5.2-8.3)
2005	4	13.8 (11.9-16.7)	9.6 (8.0-13.0)	1.5 (1.3-1.6)	1.9 (1.7-2.3)	6.7 (5.4-10.0)
2006	4	12.8 (9.3-15.5)	10.0 (8.0-12.7)	1.3 (1.0-1.7)	1.9 (1.4-2.2)	8.2 (4.7-12.3)
2007	4	13.2 (9.1-20.4)	10.5 (8.0-15.1)	1.2 (1.0-1.6)	1.6 (1.1-2.0)	8.7 (5.0-11.2)
2008	4	13.0 (10.7-14.5)	10.5 (8.3-14.4)	1.3 (1.0-1.7)	1.7 (1.3-2.2)	8.8 (4.9-14.4)
2009	4	14.7 (11.4-18.3)	10.9 (7.9-17.2)	1.4 (1.2-1.7)	1.8 (1.4-2.2)	8.3 (5.1-11.9)
P-Value		0.774	0.165	0.152	0.197	0.047
Percent Change						
2003/2004		-19.7%	-34.0%	22.2%	17.8%	-44.5%*
2003/2005		-1.3%	-23.9%	32.1%	27.9%	-41.4%
2003/2006		-8.1%	-20.6%	18.5%	29.6%	-28.7%
2003/2007		-5.6%	-16.4%	13.1%	7.7%	-24.1%
2003/2008		-6.6%	-16.6%	16.0%	13.0%	-22.9%
2003/2009		5.8%	-13.2%	24.2%	22.9%	-27.8%
2004/2005		3.8%	10.0%	-6.7%	4.5%	5.7%
2004/2006		-8.3%	11.1%	20.0%	-9.1%	28.7%
2004/2007		17.6%	26.7%	-7.4%	-8.6%	36.9%
2004/2008		16.2%	26.4%	-5.0%	-4.1%	39.0%
2004/2009		31.7%	31.5%	1.7%	4.3%	30.2%
2005/2006		-11.7%	10.1%	14.3%	-13.4%	21.8%
2005/2007		-4.3%	9.8%	-14.4%	-15.8%	29.5%
2005/2008		-5.4%	9.6%	-12.2%	-11.7%	31.6%
2005/2009		7.2%	14.0%	-6.0%	-3.9%	23.2%
2006/2007		2.8%	5.3%	-4.6%	-16.9%	6.4%
2006/2008		1.6%	5.1%	-2.1%	-12.9%	8.1%
2006/2009		15.2%	9.3%	4.8%	-5.2%	1.2%
2007/2008		-1.1%	-0.2%	2.6%	4.8%	1.6%
2007/2009		12.0%	3.8%	9.8%	14.1%	-4.9%
2008/2009		13.3%	4.0%	4.0%	8.8%	-6.4

Table 17. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio for riffle/run-type habitats in Reach 2 of the Therriault Creek Restoration Project area. The project was constructed in the fall of 2004-2005. The range for annual mean values is presented in parentheses. The percent change between years is also presented. Cross sectional surveys from 2003 were not stratified by reach. Analysis of variance was preformed for each parameter, and the P value is presented. Multiple comparisons were performed using Tukey's Test. Significant comparisons are indicated via * (alpha < 0.05).

	# Runs	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**W/D Ratio**
2003 (Existing)	10	13.9 (8.2-20.5)	12.6 (8.3-17.2)	1.1 (1.0-1.2)	1.5 (1.1-1.8)	11.5 (7.4-15.0)
2004 (As Built)	6	14.5 (10.2-16.6)	8.3 (7.9-9.0)	1.7 (1.3-2.1)	2.2 (1.7-2.5)	4.9 (4.3-6.1)
2005	6	15.1 (11.7-18.9)	8.3 (7.5-9.0)	1.8 (1.6-2.1)	2.2 (1.8-2.4)	4.6 (4.3-5.0)
2006	6	14.7 (10.5-17.0)	8.4 (7.9-8.9)	1.7 (1.3-2.0)	2.2 (1.6-2.6)	4.9 (4.2-5.9)
2007	6	16.3 (13.3-19.2)	8.2 (7.7-8.8)	2.0 (1.7-2.3)	2.3 (1.9-2.8)	4.1 (3.8-4.5)
2008	6	12.8 (10.7-14.5)	8.3 (7.8-9.0)	1.5 (1.3-1.7)	2.0 (1.5-2.4)	5.4 (4.8-6.2)
2009	4	13.1 (10.3-15.6)	8.6 (8.0-9.5)	1.5 (1.2-1.7)	1.9 (1.5-2.2)	5.8 (4.6-6.9)
P-Value		0.384	<0.001	<0.001	<0.001	<0.001
Percent Change						
2003/2004		4.4%	-33.7%*	57.0%*	45.9%*	-57.3%*
2003/2005		8.6%	-33.9%*	63.5%*	45.9%*	-59.5%*
2003/2006		5.7%	-33.0%*	57.9%*	48.1%*	-57.0%*
2003/2007		17.3%	-35.0%*	80.3%*	57.1%*	-63.8%*
2003/2008		-8.2%	-34.4%*	39.9%*	32.4%*	-52.9%*
2003/2009		-5.7%	-31.4%*	37.6%*	28.8%	-49.4%*
2004/2005		-3.0%	1.1%	-5.3%	-16.1%	-5.2%
2004/2006		-11.8%	9.8%	-21.1%	-19.4%	0.8%
2004/2007		12.4%	-1.7%	14.8%	7.7%	-15.2%
2004/2008		-12.1%	-0.8%	-10.9%	-9.2%	10.3%
2004/2009		-9.7%	3.7%	-12.4%	-11.7%	18.5%
2005/2006		-9.1%	-8.6%	-16.7%	-3.8%	6.3%
2005/2007		8.6%	-1.6%	10.3%	7.7%	10.6%
2005/2008		-15.0%	-0.8%	-14.4%	-9.2%	16.3%
2005/2009		-12.8%	3.8%	-15.6%	-11.7%	24.9%
2006/2007		11.0%	-2.9%	14.2%	6.1%	-15.9%
2006/2008		-13.2%	-2.1%	-11.4%	-10.6%	9.4%
2006/2009		-10.1%	2.4%	-12.9%	-13.1%	17.5%
2007/2008		-21.7%	0.9%	-22.4%*	-15.7%	30.2%
2007/2009		-19.7%	5.5%	-23.7%*	-18.0%	39.8%
2008/2009		2.7%	4.6%	-1.7%	2.8%	7.4%

Table 18. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio for pool-type habitats in Reach 1 of the Therriault Creek Restoration Project area. The project was constructed in the fall of 2004-2005. The range for annual mean values is presented in parentheses. The percent change between years is also presented. Cross sectional surveys from 2003 were not stratified by reach. Analysis of variance was preformed for each parameter, and the P value is presented. Multiple comparisons were performed using a Tukey Test. Significant comparisons are indicated via * (alpha < 0.05).

	Number Of Pools	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**
2003 (Existing)	10	18.9 (13.8-27.2)	13.4 (7.8-19.5)	1.5 (0.9-1.8)	2.5 (1.9-3.0)
2004 (As Built)	4	13.2 (9.3-16.6)	9.0 (8.0-10.0)	1.5 (1.2-1.7)	2.2 (1.7-2.8)
2005	4	13.7 (10.7-17.6)	9.9 (8.9-11.9)	1.4 (1.2-1.9)	2.3 (1.9-2.6)
2006	4	12.1 (8.7-16.1)	10.0 (9.7-10.5)	1.2 (0.8-1.7)	2.0 (1.4-2.5)
2007	4	12.1 (8.5-14.1)	10.0 (9.6-10.5)	1.2 (0.9-1.4)	2.1 (1.7-2.5)
2008	4	12.9 (10.3-14.4)	10.3 (9.9-10.8)	1.3 (1.0-1.4)	2.2 (1.8-2.5)
2009	4	13.4 (9.6-18.1)	10.8 (9.9-12.2)	1.2 (0.9-1.5)	2.2 (1.8-2.5)
P-Value		0.007	0.047	0.533	0.338
Percent Change					
2003/2004		-30.3%	-33.0%	-1.0%	-11.3%
2003/2005		-27.5%	-26.5%	-5.6%	-8.8%
2003/2006		-35.8%*	-25.4%	-17.2%	-19.4%
2003/2007		-35.8%*	-25.4%	-19.9%	-14.3%
2003/2008		-31.7%	-25.0%	-13.4%	-12.3%
2003/2009		-29.1%	-19.7%	-15.6%	-11.8%
2004/2005		23.2%	15.7%	15.4%	5.6%
2004/2006		14.3%	20.5%	0%	5.6%
2004/2007		-7.9%	11.4%	-17.0%	-3.4%
2004/2008		-2.1%	12.0%	-12.6%	-1.1%
2004/2009		1.7%	19.9%	-14.8%	0.5%
2005/2006		-7.2%	4.2%	-13.3%	0%
2005/2007		-11.3%	1.5%	-13.0%	-6.1%
2005/2008		-5.8%	2.1%	-8.3%	-3.9%
2005/2009		-2.1%	9.3%	-10.7%	-3.3%
2006/2007		0.1%	0%	0.8%	6.3%
2006/2008		6.4%	0.6%	4.5%	8.7%
2006/2009		10.5%	7.7%	2.7%	2.9%
2007/2008		6.3%	0.5%	5.4%	2.4%
2007/2009		10.4%	7.7%	2.7%	2.9%
2008/2009		3.8%	4.3%	-2.6%	0.6%

Table 19. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio for pool-type habitats in Reach 2 of the Therriault Creek Restoration Project area. The project was constructed in the fall of 2004-2005. The range for annual mean values is presented in parentheses. The percent change between years is also presented. Cross sectional surveys from 2003 were not stratified by reach. Analysis of variance was preformed for each parameter, and the P value is presented. Multiple comparisons were performed using a Tukey Test. Significant comparisons are indicated via * (alpha < 0.05).

	Number Of Pools	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**
2003 (Existing)	10	18.9 (13.8-27.2)	13.4 (7.8-19.5)	1.5 (0.9-1.8)	2.5 (1.9-3.0)
2004 (As Built)	6	16.9 (12.6-21.5)	9.2 (8.7-10.3)	1.9 (1.2-2.4)	3.1 (2.3-3.7)
2005	6	16.4 (11.2-20.7)	9.3 (8.2-10.4)	1.8 (1.3-2.3)	2.6 (1.9-3.2)
2006	6	14.9 (9.8-19.4)	10.1 (8.4-12.8)	1.5 (0.9-1.8)	2.5 (1.8-3.0)
2007	6	18.1 (14.6-23.1)	9.2 (8.2-10.9)	2.0 (1.6-2.2)	2.7 (2.2-3.1)
2008	6	15.7 (11.9-17.3)	9.9 (8.3-13.0)	1.6 (1.3-1.9)	2.4 (2.0-2.8)
2009	4	16.1 (9.8-27.2)	10.3 (9.3-11.5)	1.6 (0.9-2.4)	2.2 (1.8-3.7)
P-Value		0.249	0.005	0.045	0.075
Percent Change					
2003/2004		-10.4%	-31.4%*	26.1%	23.0%
2003/2005		-14.4%	-30.9%*	19.3%	6.2%
2003/2006		-21.1%	-24.8%	1.7%	2.2
2003/2007		-3.9%	-31.3%*	34.1%	8.2%
2003/2008		-16.8%	-26.3%	9.7	-1.5%
2003/2009		-14.8%	-23.5%	6.9%	-9.8%
2004/2005		4.1%	0%	5.9%	0%
2004/2006		1.4%	1.2%	0.0%	0%
2004/2007		7.0%	0.2%	6.3%	-12.0%
2004/2008		-7.3%	7.4%	-13.0%	-19.9%
2004/2009		-5.1%	11.6%	-15.3%	-26.6%
2005/2006		-2.6%	1.2%	-5.6%	0%
2005/2007		12.2%	0.5%	12.4%	11.9%
2005/2008		-2.8%	6.7%	-8.0%	-7.3%
2005/2009		-0.5%	10.8%	-10.4%	-15.0%
2006/2007		21.8%	-8.6%	31.8%	5.9%
2006/2008		5.5%	-2.0%	7.9%	-3.6%
2006/2009		8.1%	1.8%	5.1%	-11.7%
2007/2008		-13.4%	7.2%	-18.1%	-9.0%
2007/2009		-11.3%	11.3%	-20.3%	-16.6%
2008/2009		2.4%	3.9%	-2.6%	-8.4%

Deep Creek Irrigation Fish Screen Project

Deep Creek is third order 17.7 km long tributary that enters the Tobacco River at Rkm 32.8, draining approximately 48 km^2 of the Whitefish Mountains. The largest irrigation diversion on Deep Creek is located approximately 1.7 miles upstream from the confluence (Figure 7). Deep Creek provides habitat for westslope cutthroat trout resident bull trout and non-native brook and rainbow trout, but bull trout and westslope cutthroat trout are the primary species upstream of the irrigation diversion, which diverts a maximum of approximately 4 cubic feet per second of water from Deep Creek. This system prior to replacement did not have a functional fish screen and represented the largest single loss of fish due to entrainment within the drainage.

Montana FWP worked with the landowner to develop a cost share project to upgrade the existing system in order to improve ease of operation, eliminate fish entrainment and decrease maintenance at the point of diversion. The system was designed by the Montana FWP Libby staff and was installed in the spring of 2010. The system was designed by the Montana FWP Libby staff, manufactured by Roscoe Steel Company, and was installed in the spring of 2010. The original system consisted of a concrete diversion structure, headgate, approximately 700 feet of 18" corrugated metal pipe (CMP) and 1.5 miles of open ditch. This project installed a new trash rack in front of the existing headgate (Figure 8), removed 26 feet of existing 18 inch diameter CMP (approximately 70 feet from the headgate), and installed the prefabricated fish screen and 16 feet of new 18 inch diameter CMP. The fish screen structure consisted of a 4-foot diameter turbulent fountain fish screen with a 20 mesh per inch screen size, and was buried at ground level (Figure 9). A 12-inch diameter fish return line routed screened fish back into Deep Creek approximately 40 feet away from the screen structure. The screen was also fitted with a hinged cover for safety purposes. The new screen and associated system prevents fish entrainment and requires less maintenance.

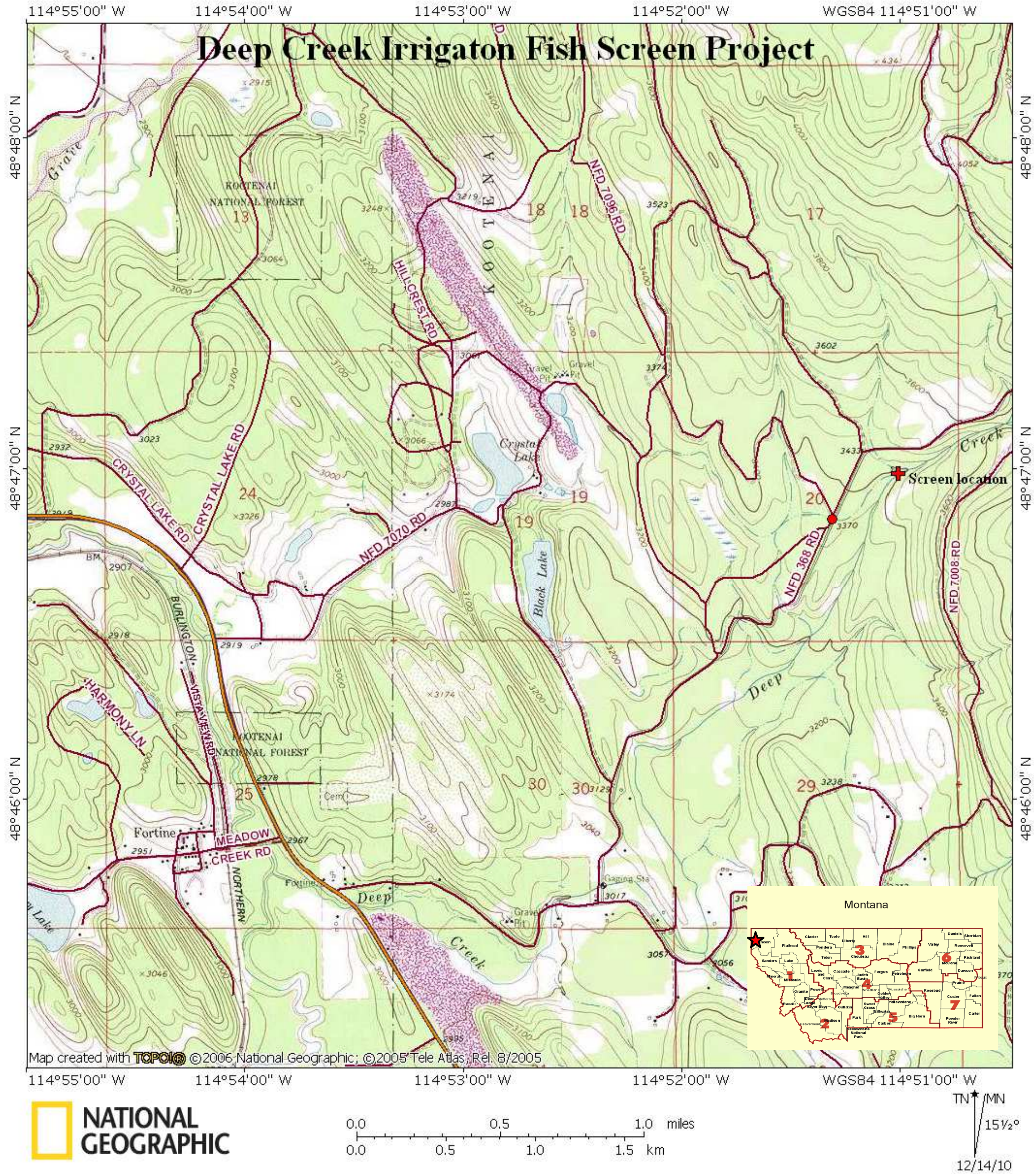


Figure 7. Location of the Deep Creek Irrigation Fish Screen Project.

Figure 8. A photograph of the existing diversion structure, headgate on Deep Creek. The trash rack was installed as part of this project.

Figure 9. Photographs of the Deep Creek irrigation fish screen. The top photo describes the intake, fish bypass, and conveyance pipes and the hinged cover. The bottom photo shows the screen in operation at the exact moment a cutthroat trout passed over the screen.

Boulder Lake and Creek Fish Removal Project

Upper and Lower Boulder lakes are located approximately 15 miles southwest of Eureka, Montana, and are accessed from the Boulder Creek Road (Forest Service #337). Upper Boulder Lake has surface area of 6.9 acres and a maximum depth of approximately 10 feet, and Lower Boulder Lake has a surface area of 6.0 acres and a maximum depth of approximately 13 feet. Boulder Creek begins at the outlet of Lower Boulder Lake and flows approximately 8 miles across public land (USFS) before flowing into Lake Koocanusa (Figure 10). The Boulder Creek watershed was likely historically fishless due primarily to the presence of a natural falls barrier located approximately 1.7 miles upstream from the Forest Development Road (USFS Road # 228; Figure 11). Montana FWP stocked Upper Boulder Lake in 1953 with an undesignated strain of cutthroat trout, and Lower Boulder Lake was stocked the following year with a similar group of fish. Boulder Creek was stocked with rainbow trout in 1944 and once with an undesignated strain of cutthroat trout in 1946. Upper Boulder Lake is currently fishless prior to the proposed fish removal project, and therefore did not require rotenone treatment. Montana FWP does not propose stocking the upper lake with trout as part of this project. Limited water and steep gradient prevent fish in the lower lake from migrating into the upper lake. Prior to this project, the fish residing in Boulder Creek and Lower Boulder Lake are a hybridized population with individuals containing characteristics from Yellowstone, westslope cutthroat and rainbow trout ancestry. Relatively few anglers fish Lower Boulder Lake and Boulder Creek each year. MFWP conducts annual statewide fishing pressure estimates, and a review of these estimates since 1993 found that Lower Boulder Lake appeared only in 2007, with an estimated 37 angler days per year. Boulder Creek was not listed in any of the statewide fishing estimates searched.

The objectives of this project were to expand the current distribution within the historic range of westslope cutthroat trout in the Kootenai River Subbasin while continuing to provide angling opportunity within the Boulder Creek watershed. The goals of this project were to remove all fish residing in lower Boulder Lake and Boulder Creek from the lake outlet downstream to the existing natural barrier falls located approximately 1.2 miles upstream from Koocanusa Reservoir. Historically, westslope cutthroat trout were likely the dominant salmonid species in the Montana portion of the Kootenai River Subbasin upstream of the present location of Libby Dam. Prior to this project, genetically pure populations only existed in the headwater regions of Dodge, Young and Grave creeks.

Montana FWP began implementation of the fish removal project on September 1, 2009 with the treatment of Lower Boulder Lake. We airlifted a 12-foot long aluminum boat, motor, piscicide and dispersal equipment into the lake using a helicopter operated by a Montana FWP pilot (Figure 12). We distributed 10.5 gallons of CFT-Legumine, a commercial formulation that contains 5% rotenone as the active ingredient, to Lower Boulder Lake using a venturi pump system from the motor boat to achieve 1 part per million (ppm) concentration within the lake (Figure 12). We used a continuous drip device (drip station; Figure 13) to deliver the rotenone formulation to the inlet stream, and we placed a 400 g packet of powdered rotenone in the inlet stream to prevent fish from seeking refuge in this area.

We began treating Boulder Creek on September 2, 2009 using a combination of eight drip stations and backpack sprayers to achieve a target concentration of 1 ppm. We also placed packets containing powdered rotenone at the following locations; 2 in the North Fork of Boulder Creek, 2 in the inlet of boulder Lake, 1 at the outlet of Boulder Lake, 1 in the mainstem of Boulder Creek above its confluence with the North Fork, 2 in the North Fork of Boulder Creek and 2 in Fan Creek above its confluence with Boulder Creek in order to prevent fish from seeking refuge in these areas. Treatment of Boulder Lake was completed early in the day on September 3, 2009. We used caged cutthroat trout to measure the toxicity of the water in the lake and creek to ensure the objectives were met.

There are three ways in which rotenone can be detoxified; natural oxidation, dilution by freshwater and introduction of a neutralizing agent such as potassium permanganate. We would relied on natural detoxification for the lake and used potassium permanganate to detoxify Boulder Creek prior to it entering Koocanusa Reservoir. We installed a detoxification station approximately 0.1 miles upstream from Koocanusa Reservoir. The system consisted of a 3,000 gallon water reservoir provided and filled by the USFS, an electric powered auger to meter the potassium permanganate, a gasoline powered generator, and several hundred feet of 1 inch diameter poly-pipe used to gravity feed the aqueous solution of permanganate to the creek (Figure 14). We operated the station from 10:00 on 9/2/09 until 17:00 on 9/3/09, delivering a total of 19.8 kilograms of potassium permanganate to Boulder Creek. Concentrations of potassium permanganate ranged from 1.5 ppm to 2.5 ppm in Boulder Creek downstream of the detoxification site. We also used caged cutthroat trout directly above and below the detoxification station to determine if active rotenone had reached the site and to ensure that all rotenone was neutralized, respectively. However, we determined from the health of the caged fish that detoxification efforts were totally precautionary and that no active rotenone had reached this site.

During the planning phase of this project, we anticipated that a single application of rotenone may not kill all the fish within the project area due to the multiple small tributaries and hiding refugia present within the watershed. However, effectiveness monitoring in June 2010 that included electrofishing in the creek and gillnetting in the lake, indicated that the single application achieved a complete removal of all fish within the project area. Libby Mitigation project staff assisted MFWP hatchery personnel restock the lake and creek with westslope cutthroat trout fry in July 2010. Stocking will continue for at least two to three additional years. We will continue to monitor and evaluate growth and relative survival of the hatchery over the next several years. This project expanded the distribution of genetically pure westslope cutthroat trout in the Montana portion of the Kootenai watershed upstream of Libby Dam by approximately twenty percent. However, it will probably be several years until the stocked hatchery cutthroat trout fry become large enough to support a viable recreational fishery in both the lake and the creek.

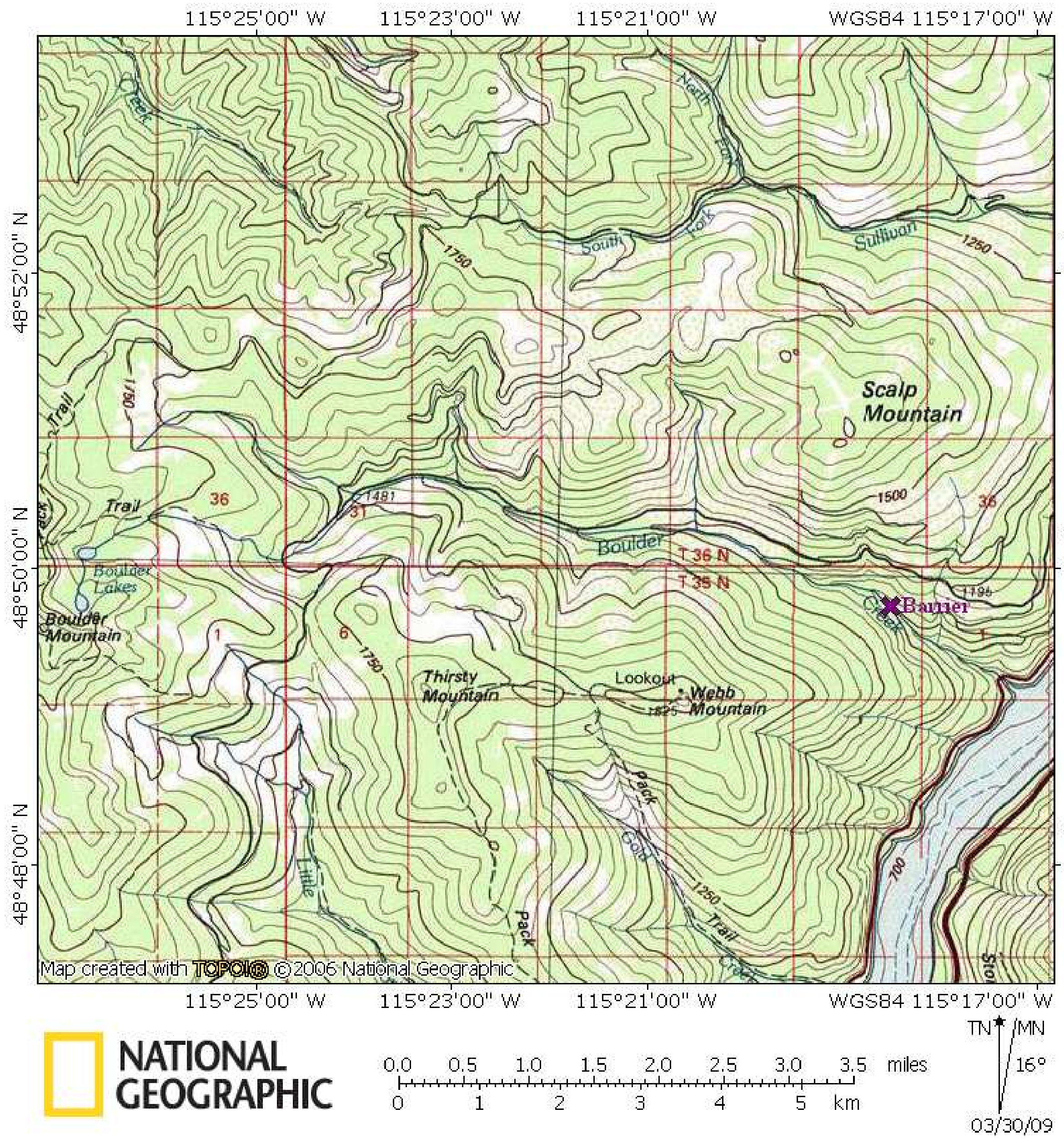


Figure 10. Location of the Lower Boulder Lake and Boulder Creek Restoration project area, located approximately 15 miles southwest of Eureka, Montana.

Figure 11. A photograph of the natural barrier falls on Boulder Creek located approximately 1.1 miles upstream from Koocanusa Reservoir.

Figure 12. The photograph on the left shows the Montana FWP helicopter used to transport the equipment into Lower Boulder Lake. The photograph on the right was taken during the application of rotenone to Lower Boulder Lake using a venture pump system (smaller photograph insert).

Figure 13. Photograph of a drip station used to deliver the liquid rotenone formulation to the inlet stream to Lower Boulder Lake. Similar apparatus were used on Boulder Creek.

Figure 14. Photographs of the detoxification station used on Boulder Creek located approximately 0.1 miles upstream from Koocanusa Reservoir. The upper left photo shows the water reservoir used to store water used for the water delivery system. The upper right photograph shows the inside of the electric powered auger that metered the potassium permanganate into the water delivery system. The lower two photos shows the delivery system used to gravity feed the aqueous solution to the creek.

Discussion

Within this report, we presented physical monitoring from eight stream restoration projects on four separate streams ranging from four to nine years after completion. Restoration techniques were generally similar between projects, consisting primarily of stream channel reconstruction with the use of large rock, woody debris and bioengineered structures to stabilize previously unstable stream banks and create pool-type habitats. Each of the three streams had generally similar in stream channel type (Rosgen 1996), with the exception of Therriault Creek. These streams did however differ in discharge capacity.

These restoration projects unequivocally changed the pattern, profile and dimension of the stream within the project areas. Within the riffle habitats several conditions were generally evident for each restoration project. We were generally able to show a significant increase in mean bankfull depth and a decrease in stream bankfull width, and change in channel dimensions were generally less than 10% annually. Pool-type habitats generally changed more so than riffle habitats after construction. All the restoration projects presented within this document demonstrated substantial increases in the quantity, depth and spacing of pools within the project areas. Total pool numbers and total pool area and volume increased by several fold for all projects after construction. However, we have observed a slight annual loss of the total number of pools, and mean pool depth through time up to three years after construction, but despite these reductions, pool depth, quantity and quality still exceeded conditions that existed prior to project construction.

The stream restoration activities that we have undertaken as part of the Libby Mitigation Project differ fundamentally from those typically reported in the literature. Most of the stream restoration activities that others report either the successes (Binns 1994; Binns and Remmick 1994; Burgess and Bider 1980; Hunt 1976; House and Boehne 1986) or failures (Frissell and Nawa 1992; Pattenden et al. 1998; Hamilton 1989) typically implemented what we would consider habitat enhancement activities rather than stream channel reconstruction as was the case with each of the projects we completed. Frissell and Nawa (1992) and Pattenden et al. (1998) agreed that the risk of failure of stream restoration activities is highest in streams with recent watershed disturbance, high instream sediment budgets, and unstable stream channels. It seems ironic however, that many of the stream systems that fit within these characterizations are those most important to fisheries populations and in the most need of restoration. Grave, Libby, Young and Therriault creeks are good examples of streams that fit both sets of circumstances. Frissell and Nawa (1992) and Pattenden et al. (1998) also noted that when failure or impairment occurred in stream restoration projects, it generally was a result of watershed driven aspects of stream channel dynamics rather than internal structural failures, and that rain on snow events produced some of the highest incidences of structure failure. In fact, when such failures occur, one may argue that the restoration efforts were likely focused at an inappropriate scale.

In order for the stream restoration projects we completed to be successful over the long term, the changes to the quantity and quality of the habitat will need to be sustained through time. All of the restoration projects discussed in this report have sustained the changes through time, with almost every metric of habitat quantity and quality remaining substantially higher several years after these projects were completed. However, the work we performed relies on the physical structures to maintain streambank stability through time, but we acknowledge these structures have a limited life expectancy, and that riparian vegetation will ultimately be the glue that holds these projects together in the long-term. The monitoring data for the revegetation efforts on Therraiult Creek (see above), and Grave Creek (Geum Environmental Consulting 2009) indicate these efforts are succeeding at reestablishing a healthy riparian community. Therefore, many of our recent efforts have been to promote recovery of healthy riparian areas associated with our restoration projects, as is case with the Therriault and Grave Creek projects. We believe these efforts will provide long-term benefits and we are committed to continuing this important work. However, this commitment is an expensive and long-term process due to adaptive management strategies employed and the relatively long length time it takes for vegetation to mature.

The number of cases reported in the literature where stream restoration work has increased fish abundance at the population level is relatively small and somewhat dated relative to the overall effort expended to improve fisheries habitat (Frissell and Nawa 1992; Roper et al. 1997). Habitat enhancement has been shown to increase the abundance of resident salmonids in streams (Binns 1994; Binns and Remmick 1994; Hunt 1976; Saunders and Smith 1962; House and Boehne 1986). Many restoration efforts do not monitor the fish population response to the habitat manipulations. This project does monitor fish populations (see Chapter 1), but the results are sometimes contradictory and generalizations between projects is difficult. For example, we were able to demonstrate an increase in the abundance of rainbow trout at the Libby Creek Demonstration Project, but similar trends on the three projects within the upper Libby Creek watershed have shown an opposite trend (see Chapter 1). The Therriault Creek Restoration Project monitoring results were ambiguous depending upon the method used to assess changes in abundance within the project area and which control section these results were compared to. The Young Creek Restoration Project increased the abundance of brook trout, but westslope cutthroat trout abundance decreased. In this situation, it seems likely that ecological interactions between the two species are confounding the results of the improved habitat conditions. Many investigators (Hunt 1976; Binns 1994; Binns and Remmick 1994) argue that several years are needed for fish populations to fully respond to habitat enhancement. Binns and Remmick (1994) lobby for a minimum of several years of pretreatment data be collected and at least 4-8 years post treatment data collection is necessary for a valid evaluation of fish populations to habitat restoration work. The life histories of the fish species inhabiting these streams dictates that they will not sexually mature until age 3-5, and in the case of bull trout, the age at maturity is as long as 5-8 years. We attribute the lack of fish response to the limited time since the restoration work was completed. Given these relatively long life cycles and the high disturbance regimes of many of the streams where the restoration work was completed, it seems likely that recovery will be a lengthy process. We are however confident that the physical changes to the habitat will translate into real and substantial increases at the local population level, but that these changes may take many years to realize. We feel our monitoring components associated with the Libby Mitigation stream restoration projects will be adequate to detect these changes through time.

References

Binns, N.A. 1994. Long-term responses of trout and macrohabitats to habitat management in a Wyoming headwater stream. North American Journal of Fisheries Management 14:87-90.

Binns, N.A., and R. Remmick. 1994. Response of Bonneville cutthroat trout and their habitat to drainage-wide habitat management at Huff Creek, Wyoming. North American Journal of Fisheries Management 14(4):669-680.

Burgess, S.A., and J.R. Bider. 1980. Effects of stream habitat improvements on invertebrates, trout populations, and mink activity. Journal of Wildlife Management 44:871-880.

Chisholm, I.M., M.E. Hensler, B. Hansen, D. Skaar. 1989. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries. Methods and Data Summary 1983-1987. Prepared for Bonneville Power Administration by Montana Department of Fish, Wildlife and Parks. Kalispell, Montana.

Daley, R.J., E.C. Carmack, C.B. Gray, C.H. Pharo, S. Jasper, and R.C. Wiegland. 1981. The effects of upstream impoundments of Kootenay Lake, British Columbia, Canada Inland Waters Directorate, Research Institute, Scientific Series, British Columbia, Canada.

Dunnigan, J.L, B. Marotz, J. DeShazer, L. Garrow, and T. Ostrowski. 2003. Mitigation for the construction and operation of Libby Dam: Annual report 2001-2002. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L, B. Marotz, J. DeShazer, L. Garrow, and T. Ostrowski. 2004. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2003 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L,, J. DeShazer, L. Garrow, B. Marotz, T. Ostrowski, and C. Sinclair. 2005. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2004 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L., J. DeShazer, L. Garrow, T. Ostrowski, and M. Benner, and B. Marotz. 2007. Mitigation for the construction and operation of Libby Dam: Libby Mitigation Program, 2005 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Dunnigan, J.L., J. DeShazer, L. Garrow, T. Ostrowski, and M. Benner, and B. Marotz. 2008. Mitigation for the construction and operation of Libby Dam: Libby Mitigation

Program, 2006 annual progress report. Bonneville Power Administration. Portland, Oregon. Project Number 199500400

Dunnigan, J., J. DeShazer, L. Garrow, T. Ostrowski M. Benner, R. Leary, J. Tohtz, and D. Neeley. 2009. Libby Mitigation Program, 2007 Annual Progress Report: Mitigation for the Construction and Operation of Libby Dam. BPA Project Number 199500400.

Dunnigan, J., J. DeShazer, L. Garrow, T. Ostrowski M. Benner, J. Lampton, and J. Tohtz. 2010. Libby Mitigation Program, 2008 Annual Progress Report: Mitigation for the Construction and Operation of Libby Dam. BPA Project Number 199500400.

Frissell, C.A., and R.K. Nawa. 1992. Incidence and causes of physical failure of artificial habitat structures in streams of western Oregon and Washington. North American Journal of Fisheries Management 12:182-197.

Geum Environmental Consulting, Inc. 2007. Therriault Creek Riparian Revegetation Plan. Prepared for: Kootenai River Network. Libby, Montana.

Geum Environmental Consulting, Inc. 2008a. Grave Creek riparian revegetation and monitoring plan. Prepared for: Kootenai River Network. Libby, Montana.

Geum Environmental Consulting, Inc. 2008b. Therriault Creek riparian revegetation 2008 monitoring report. Prepared for: Kootenai River Network. Libby, Montana.

Geum Environmental Consulting, Inc. 2008c. Grave Creek riparian revegetation and monitoring plan. Prepared for: Kootenai River Network. Libby, Montana.

Geum Environmental Consulting, Inc. 2009. Grave Creek riparian revegetation 2008 as-built and 2009 monitoring report. Prepared for: Kootenai River Network. Libby, Montana.

Hamilton, J.B. 1989. Response of juvenile steelhead to instream deflectors in a high gradient stream. Pages 149-157 *in* R.E. Gresswell, B.A. Barton, and J.L. Kershner, editors. Practical approaches to riparian resources management. American Fisheries Society, Montana Chapter, Bethesda, Maryland.

Hauer, R., J. Stanford. 1997. Kootenai river zoobenthos investigation: Kootenai River Fisheries Investigations - Montana. Montana Department of Fish, Wildlife and Parks, Region 1. Annual Report to Bonneville Power Administration, Contract , Project 83-467

House, R.A., and P.L. Boehne. 1986. Effects of instream structures on salmonid habitat and populations in Tobe Creek, Oregon. North American Journal of Fisheries Management 6:38-46.

Hunt, R.L. 1976. A long-term evaluation of trout habitat development and its relation to improving management-related research. Transactions of the American Fisheries Society 150(3):361-364.

Jenkins, R.M. 1967. The influence of some environmental factors on standing crop and harvest of fishes in U.S. reservoirs. Pages 298-321 in Reservoir fishery resources symposium. Southern Division American Fisheries Society, Bethesda MD, U.S.A.

Kootenai Tribe of Idaho (KTOI) and Montana Fish, Wildlife & Parks (MFWP). 2004. Kootenai Subbasin Plan. Available on CD from the Kootenai Tribe of Idaho, Bonners Ferry, ID and Montana Fish, Wildlife & Parks, Kalispell. Also available at: http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan/

Marotz, B.L., D. Gustafson, C. Althen and B. Lonen. 1996. Model development to establish integrated operational rule curves for Hungry Horse and Libby Reservoirs - Montana. Montana Department of Fish, Wildlife and Parks - Region 1. Prepared for U.S. Department of Energy - BPA. Project number 83-467

May B. and Joe Huston 1983. Kootenai river investigations final report: Fisheries investigations. Montana Department of Fish, Wildlife and Parks in cooperation with U.S. Army Corps of Engineers.

Montana Fish, Wildlife & Parks (MFWP), Confederated Salish and Kootenai Tribes, and the Kootenai Tribe of Idaho. 1998. Fisheries mitigation and implementation plan for losses attributable to the construction and operation of Libby Dam. Authored by: Marotz, B.L., S.R. Dalbey, C. Muhlfeld, S. Snelson, G. Hoffman, J. DosSantos and S. Ireland. Montana Fish, Wildlife and Parks, Kalispell, MT., Confederated Salish and Kootenai Tribes, Pablo, Montana, and Kootenai Tribe of Idaho, Bonners Ferry, Idaho.

Pattenden, R., M. Miles, L. Fitch, G. Hartman, R. Kellerhals. 1998. Can instream structures effectively restore fisheries habitat? Pages 1-11 *in* M.K. Brewin and D.M.A. Monita, technical coordinators Forest-fish conference: land management practices affecting aquatic ecosystems. Proceedings Forest-Fish Conference, May 1-4, 1996, Calgary Alberta. Natural resources Canada, Canadian Forest Service. North Forest Centre, Edmonton, Alberta. Information report NOR-X-356.

River Design Group (RDG). 2003. Supplemental design report for the Grave Creek Phase 2 Restoration Project near Eureka, Montana. RDG Project Number 03-002. Prepared for: The Kootenai River Network, Libby, Montana.

Roper, B.B, J.J. Dose, and J.E. Williams. 1997. Stream restoration: Is fisheries biology enough? Fisheries 22(5):6-11.

Rosgen, D.L. 1996. Applied River Morphology. Printed Media Companies, Minneapolis, Minnesota. 343 pp.

Sato, S. 2000. Upper Libby Creek stabilization analysis and recommendations. Master of science thesis report, University of Montana, Missoula. 131 pp.

Saunders, J.W., and M.W. Smith. 1962. Physical alteration of stream habitat to improve brook trout production. Transactions of the American Fisheries Society 91:185-188.

Snyder, E.B. and G.W. Minshall. 1996 Ecosystem metabolism and nutrient dynamics in the Kootenai river in relation to impoundment and flow enhancement for fisheries management. Annual Report. Stream Ecology Center, Idaho State University, Pocatello.

U.S. Fish and Wildlife Service. 2002. Chapter 4, Kootenai River Recovery Unit, Oregon. 89 pages *in* U.S. Fish and Wildlife Service. Bull Trout (*Salvelinus confluentus*) Draft Recovery Plan. Portland, Oregon.

Voelz, N.J. and J.V. Ward. 1991. Biotic responses along the recovery gradient of a regulated stream. Canadian Journal of Fisheries and Aquatic Sciences. 48: 2477-2490.

Woods, P.F., and C.M. Falter. 1982. Annual nutrient loadings, primary productivity, and trophic state of Lake Koocanusa, Montana and British Columbia, 1972-80. Geological Survey Professional Paper 1283, United States Government Printing Office.

Zar, J.H. 1996. Biostatistical analysis. Third edition. Prentice-Hall Inc. Englewood Cliffs, New Jersey

Chapter 3

Investigations of Angler Catch and Harvest of Fish Below Libby Dam

Abstract

Montana FWP designed and implemented a creel survey to estimate fishing effort, catch and harvest of trout in the Kootenai River downstream of Libby Dam during the 2009/2010 fishing season which included the period June 1, 2009 to March 31, 2010. This creel survey targeted the rainbow and bull trout fishery, and was conducted during the night and crepuscular hours. We conducted angler interviews to estimate angling success, and we conducted visual counts of boat and bank anglers to estimate fishing effort (pressure). Visual counts were conducted by Libby Dam operators (US Army Corps of Engineers) and Montana FWP visual counts made during angler interview surveys. We also supplemented catch and harvest information for boat anglers using angler log books from seven volunteer anglers that frequently fished at this location. The majority of the fishing effort was concentrated near Libby Dam downstream to David Thompson Bridge, followed in decreasing order by the Dredge Cut Area, the Dunn Creek boat ramp area, and the Alexander Creek Campground area. The most common type of terminal gear used by bank anglers were lures, followed in descending order by bait, combination bait and lure, and artificial fly. The vast majority of the bank anglers were residents of Lincoln County. Bank angler effort differed by month, with the highest effort occurring in July, and the lowest effort occurring during November. The total effort for the season was 4,079 hours (1,467 trips). Bank angler catch rates of rainbow trout > 24 inches were low, averaging only 0.007 fish/hour (151 hours/fish). Harvest rates of rainbow trout > 24 inches were similar to catch rates, indicating most fish angled in this size class by bank angler were harvested. Bank angler bull trout catch rates were relatively high, and averaged 0.045 bull trout/hour (22 hours/fish). We estimated that bank anglers caught a total of 27 rainbow trout >24 inches and 185 bull trout during the season. Boat angler effort was substantially lower than bank effort, but generally showed a similar pattern. Boat effort was lowest from September through December, but increased to the highest effort in January to the end of the season in March. Total boat effort for the season was 262 boat hours (411 boat angler hours), which represented 74 boat trips. Boat angler catch rates of rainbow trout > 24 inches averaged 0.020 fish per boat hour (77 hours/fish). The estimated total catch and harvest for the season of rainbow trout > 24 inches was relatively low (5 and 3 fish, respectively). Bull trout catch rate for boats averaged 0.151 fish per boat hour (11 hours/fish). We estimated boats angler caught 39 bull trout during the season.

Methods

Data Collection

Montana FWP manages the Libby Dam tailrace section of the Kootenai River for trophy rainbow trout. The current Montana State record rainbow trout (33.1 pounds) was captured below Libby Dam in August 1997, and is especially known to produce trophy class rainbow trout. The current fishing regulations on the Kootenai River from Libby Dam downstream to the Fisher River confluence (3.5 miles) allow angling between June 1 to March 31, harvest of four combined trout including 3 under 13 inches and 1 over 24 inches. The limit applies to both the daily and possession limits. Intentional angling that targets bull trout is not allowed. Montana FWP designed and implemented a creel survey to estimate fishing effort, catch and harvest of trout in the Kootenai River downstream of Libby Dam during the 2009/2010 fishing season which included the period between June 1, 2009 to March 31, 2010.

Anecdotal information suggested that the majority of the angling pressure occurred during the nighttime hours for this unique fishery, presumably because catch rates were highest during the nighttime. Therefore, we limited our investigations to one half hour before sunset and one half hour after sunrise. Montana FWP collaborated with the US Army Corps of Engineers that operate Libby Dam to conduct angler counts in order to estimate fishing effort (pressure). Libby Dam operators used a HurleyIR Model MRTVI Forward Looking Infrared (FLIR) camera with 36X zoom capability mounted on top of Libby Dam to count boat and bank anglers within randomly selected time blocks. From June through December, counts were conducted nightly from one of two randomly selected time blocks that were approximately evenly distributed between one half and hour before sunset to 01:00. A second count was conducted during seven randomly selected days of each month from one of three randomly selected time blocks from 01:00 to one half and hour after sunrise. During each count Libby Dam operators recorded the number bank anglers and the number of boats observed. The FLIR camera was capable of performing counts from Libby Dam downstream to Alexander Creek (1.2 miles). Montana FWP also conducted interviews to estimate success rate (see below), during which time we also conducted ten counts from randomly selected days during the period one half hour before sunset to 01:00 and three randomly determined counts from one of the seven periods between 01:00 and one half hour after sunrise. However, in early January 2010, the FLIR function on the camera malfunctioned, which required us to modify our sampling protocol to compensate for this malfunction. From January to March 31, 2010, the ACOE was only able to use the camera during the daylight hours to conduct two daily counts of boat and bank anglers below Libby Dam. The first count was conducted between dawn to one half hour after dawn, and the second count was conducted between one half hour before sunset to sunset. Montana FWP increased our interview and count schedule to include daily surveys from one of two randomly selected time blocks that were approximately evenly distributed between one half and hour before sunset to 01:00, during which time angler counts and interviews were conducted.

Montana FWP personnel conducted interviews to estimate angling success according to the schedule described above, during which we drove a vehicle along the Kootenai River including known access points within the study area to look for anglers and boats. We attempted to interview each angler and recorded the number of anglers and boats that we were not able to interview. For each angler interviewed we collected the following information: location of the interview, boat or shore angler, residence (classified as Lincoln County, Montana, or non-resident), trip status (complete or incomplete), time the angler began, the time the angler quit angling or the time which the interview was conducted, the type of gear used (classified as lure, bait, fly, or combination), and the number of fish caught and harvested. Catch and harvest information was broken down by species (rainbow trout, cutthroat trout, bull trout, and other species) according to the following size classes. Rainbow and cutthroat trout were each divided into: less than 13 inches, 13-18 inches, 18-24 inches and greater than 24 inches. Bull trout were divided into: less than 13 inches, 13-24 inches, and greater than 24 inches. We collected a scale and tissue sample (fin clip) from each harvested rainbow trout greater than 24 inches to be used for aging and genetic analysis, respectively. A sample interview data form used for this study is included in Appendix Exhibit A. In an effort to supplement the interview data for boat anglers, Montana FWP also recruited the help of seven boat anglers that volunteered to record similar information that we collected from interviews in log books that we provided to them.

Data Analyses

We estimated boat and bank angler fishing effort from the count data according to the methods presented by Sigler and Sigler (1984). Specifically, we estimated fishing effort for each month using the following formula.

$$F_i = h_i \times \overline{X}_i$$

Where F_i = fishing effort in hours for the ith month, h_i = the number of possible fishing hours for the month, and $\overline{X}_i$ = the mean number of anglers per count for that month. We estimated the number of angler trips for the ith month by dividing F_i by the mean duration (hours) of completed angler interviews (see below). The variance (VAR) of F_i was calculated from the following formula.

$$\text{VAR } (F_i) = h_i^{\,2} \times VAR(\overline{X}_i)$$

Where $VAR(\overline{X}_i)$ = the sample variance divided by n (number of angler counts in the ith month). Total fishing effort (F_T) is estimated from $\sum F_i$, and the variance of F_T is calculated from the following formula.

$$\text{VAR } (F_T) = \text{VAR } F_1 + \text{VAR } F_2 + \ldots\ldots \text{VAR } F_k$$

Where *k* is the number of groups. The standard error (SE) of the total fishing effort is calculated from the following formula.

$$SE(F_T) = \sqrt{VAR(F_T)}$$

The 95% confidence intervals (C.I.) for estimates of fishing effort were calculated using the following formula.

$$95\% C.I. = F_T \pm t_{(1-0.025,v)} \times SE(F_T)$$

Where *t* is the student t-score with *v* degrees of freedom equal to $n_1 + n_2 + \ldots . n_k - k$.

We estimated the rate of angler catch and harvest (*r*) from the interview data for each interview conducted as catch or harvest (respectively) divided by effort (hours) for each size class and species of fish. We limited this analysis to only those interviews with a minimum effort of half an hour. We evaluated differences in mean monthly *r* using the Generalized Linear Model (GLM) in SAS statistical software, which is analogous to an analysis of variance. However, the GLM allows investigators to specify the type of distribution. We specified the Poisson distribution, since *r* has a high frequency of zero values and does not conform to a normal distribution. We pooled monthly estimates of *r* that did not differ significantly in order to increase sample size. We estimated the variance of *r* using the following formula.

$$VAR(\bar{r}) = \frac{s^2}{n}$$

Where s^2 is equal to the sample variance of *r*, and *n* is equal to the number of observations. We estimated catch and harvest (*H*) for each species and size class using the following formula.

$$H = \bar{r} \times F_i$$

Where $\bar{r}$ = the rate of success for the i^{th} month, and F_i = fishing effort in hours for the i^{th} month. The variance of *H* was estimated with the following formula.

$$VAR(H) = \bar{r}^2 \times VAR(F_i) + F_i^2 \times VAR(\bar{r}_i)$$

The standard error of H is $= SE(H) = \sqrt{H}$ and was used to calculate the 95% C.I. for *H* using the following formula.

$$95\%C.I. = H \pm t_{(1-0.025,v)} \times SE(H)$$

Where *t* is the student t-score with *v* degrees of freedom equal to $n_1 + n_2 + \ldots n_k - k$.

Results

Montana FWP personnel conducted 151 interview surveys from June 1, 2009 to March 31, 2010, of which 93 surveys (61.6%) at least one angler interview was conducted. We completed a total of 422 angler interviews for the season with effort of at least one half hour, for an overall mean number of interviews per survey of 2.8 interviews/survey. The mean number of interviews per survey when anglers were present and an interview was conducted was 4.5 anglers/survey. We also completed 58 surveys (38.4%) in which anglers were not present or unable to be interviewed.

The average duration of a completed bank angler trip was 2.8 hours. The average time interviewed bank anglers started angling varied by month (Table 1), was influenced by time of sunset (and therefore interview schedules), and averaged 19:00 throughout the study. The majority of the fishing effort was concentrated near Libby Dam (from Libby Dam downstream to David Thompson Bridge; 76.1%), followed in decreasing order by the Dredge Cut Area (13.3%), the Dunn Creek boat ramp area (6.9%), and the Alexander Creek Campground Area (3.7%). The most common type of terminal gear used by bank anglers were lures (52.5%), followed in descending order by bait (37.9%), combination bait and lure (8.7%), and artificial fly (1.0%). The vast majority of the bank anglers were residents of Lincoln County (72.4%), followed by non-resident anglers (17.0%), and lastly Montana residents other than Lincoln County (10.6%).

Table 1. Average monthly bank angler start times from interviews conducted one half hour before sunset to one half hour after sunrise.

	Month										
	6	7	8	9	10	11	12	1	2	3	Overall Average
Mean Angler Start Time	7:55 PM	7:14 PM	8:18 PM	8:26 PM	9:30 PM	5:30 PM	2:30 PM	5:52 PM	6:23 PM	6:58 PM	7:00 PM

Bank angler effort differed by month (Figure 1), with the highest effort occurring in July (851 hours or 306 trips), and the lowest effort occurring during November (32 hours or 11 trips). The total effort for the season was 4,079 hours (1,467 trips). The 95% C.Is were 4,713-3,446 hours and 1,695-1,240 trips, respectively.

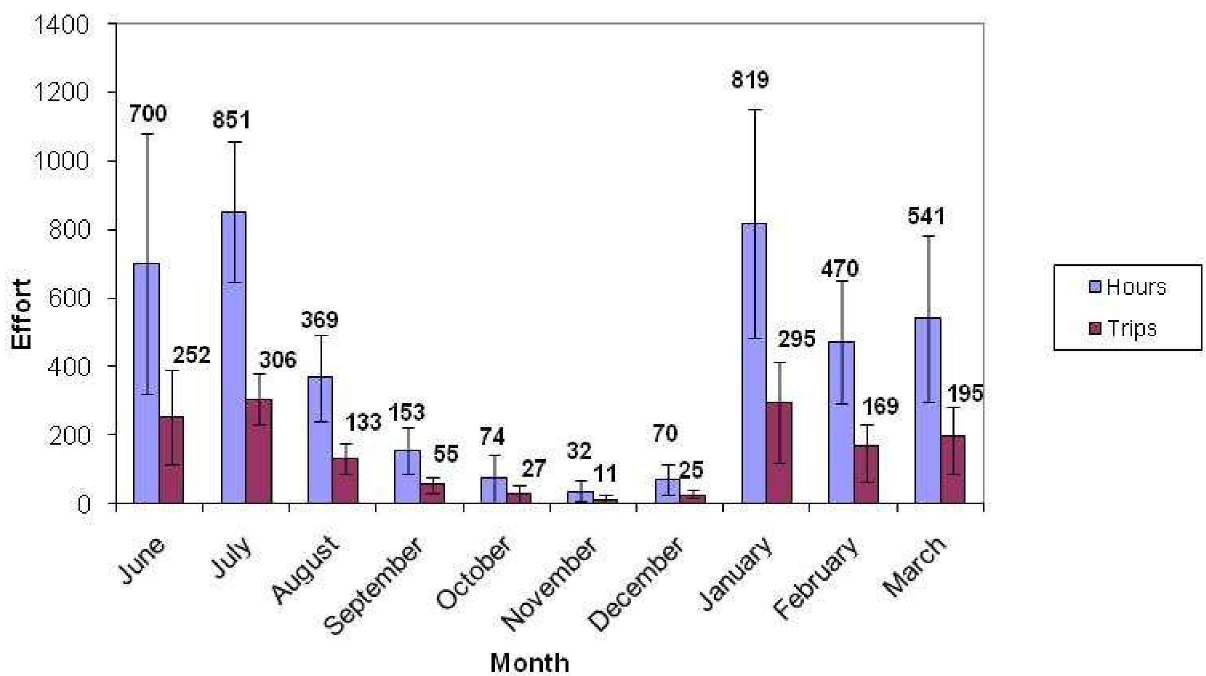


Figure 1. Estimated total monthly bank angler effort (hours and angler trips) in the Kootenai River Libby Dam tailrace between June 2009 and March 2010. The total monthly value is labeled above each bar, and the whisker bars represent 95% confidence intervals.

We found little evidence that catch or harvest rates for bank anglers varied by month ($p > 0.05$), so we pooled catch and harvest rates across all months of the survey for each species and size class of interest. We also were unable to detect significant differences ($p > 0.05$) of catch or harvest rates between complete and incomplete trip types for any species or size class of fish, so we pooled trip types. We estimated catch rate for bank angler for rainbow trout <13 inches to be 0.044 fish/hour (95% C.I. = 0.011-0.077 fish/hour). Harvest rates was substantially lower than catch rates averaging only 0.006 fish per hour (95% C.I. = 0.002-0.011 fish/hour; Table 2). The overall mean catch and harvest rates yielded estimates of 182 (95% C.I. = 44-319) and 23 (11-47) rainbow trout caught and harvested, respectively (Table 2). Catch rates for rainbow trout 13-18 inches were slightly lower, averaging 0.039 fish/hour (95% C.I. = 0.018-0.059 fish/hour). We did interview two anglers that illegally harvested rainbow trout within this size class, which enabled us to estimate an average harvest rates for this size class of fish of 0.001 fish/hour. The total catch and harvest estimates for the season were 158 and 5 fish, respectively (Table 2). Catch rates for rainbow trout 18-24 inches averaged 0.018 fish/hour for bank anglers (95% C.I. = 0.008-0.029), which equated to a total catch of 75 fish (Table 2). We did not observe any illegal harvest of rainbow trout within the 18-24 inch size class. Catch rates of rainbow trout > 24 inches were low, averaging only 0.007 fish/hour (95% C.I. = 0.004-0.012 fish/hour; Table 2). Harvest rates of rainbow trout > 24 inches were similar to catch rates (0.006 fish/hour; Table 2), indicating most fish angled in this size class by bank angler were harvested. Bull trout catch rates were relatively high, and averaged 0.045 bull trout/hour (95% C.I. = 0.027-0.064 fish/hour). We did observe an angler illegally harvest two bull trout during this survey, which enabled us to estimate harvest rate for protected bull trout. Harvest rate of bull trout averaged 0.003 fish/hour of effort (95% C.I. = 0.0005-0.0101; Table 2). Total annual catch was estimated to be 185 bull trout (95% C.I. = 104-266), and the harvest estimate was 14 fish (95% C.I. = 2-43; Table 2). We also estimated catch and harvest for total (combined) trout. Catch rates averaged 0.154 fish/hour (95% C.I. = 0.103-0.204). Overall total trout harvest rates were approximately an order of magnitude lower than catch rates, and averaged 0.013 fish/hour (95% C.I. = 0.005-0.021). Total catch for the season was 626 total trout (95% C.I. = 400-853), and total harvest for the season was 52 fish (95% C.I. = 21-87; Table 2).

We were unable to detect significant differences of catch or harvest rates between bank angler gear types ($p > 0.05$). However, several trends were apparent. Bank anglers using a combination of bait and lures had the highest catch rates for rainbow trout < 13 inches, averaging 0.079 fish/hour (95% C.I. = 0.046-0.112; Table 3), but the sample size was limited (n=35). Bait anglers had the second highest catch rates of 0.062 fish/hour (95% C.I. = 0.002-0.121; Table 3). Bank anglers using lures had approximately half the catch rates of those using bait or combination bait/lures, with average catch rates equaling 0.035 fish/hour (95% C.I. = 0-0.082; Table 3). These trends were reversed for larger fish. Bank anglers using lures had slightly higher catch rates of rainbow trout 13-18 inches and 18-24 inches than did anglers using bait (Table 3). Lure anglers were the only group we interviewed that captured rainbow trout > 24 inches, and anglers that captured bull trout using lures had approximately three fold higher catch rates than those anglers using bait or combination bait/lure (Table 3). We only interviewed four anglers during the survey using flies, and none captured any fish.

We did not present catch or harvest data for cutthroat trout because cutthroat trout constituted only 1.7% of the total catch for bank and boat anglers combined. Rainbow trout constituted the majority (65.1%) of the catch and bull trout constituted 33.2% of the catch.

Table 2. Estimated bank angler catch and harvest rates (fish/hour and hour/fish) for rainbow (RBT), bull and total trout (rainbow, cutthroat, and bull trout) in the Kootenai River from Libby Dam downstream to the Fisher River. 95% confidence intervals are presented in parentheses.

	Species and Size Class					
	RBT < 13”	RBT 13-18”	RBT 18-24”	RBT > 24”	Bull Trout	Total Trout
Mean Catch Rate (fish/hour)	0.044 (0.011-0.077)	0.039 (0.018-0.059)	0.018 (0.008-0.029)	0.007 (0.004-0.012)[1]	0.045 (0.027-0.064)	0.154 (0.103-0.204)
Mean Catch Rate (hours/fish)	22 (13-86)	26 (17-55)	54 (34-133)	151 (82-272)1	22 (16-37)	7 (5-10)
Mean Harvest Rate (fish/hour)	0.006 (0.002-0.011)[1]	0.001 (0.0005-0.0.003)[1,2]	0	0.006 (0.004-0.011)[1]	0.003 (0.0005-0.0101)[1]	0.013 (0.005-0.021)[1,2]
Mean Harvest Rate (hours/fish)	180 (87-371)[1]	158 (70-245)[1,2]	0	169 (88-272)[1]	291 (95-2040)	78 (48-194)[1,2]
Total Catch	182 (44-319)	158 (70-245)	75 (29-121)	27 (15-50)[1]	185 (104-266)	626 (400-853)
Total Harvest	23 (11-47)[1]	5[2] (2-14)[1,2]	0	24 (15-46)[1]	14[2] (2-43)[1]	52 (21-87)[1,2]

[1]Lower bound of 95% confidence interval set at the known minimum values from interviews conducted.
[2]Includes illegal harvest.

Table 3. Estimated bank angler catch rates (fish/hour) for rainbow (RBT), and bull trout in the Kootenai River from Libby Dam downstream to the Fisher River for different gear types. 95% confidence intervals are presented in parentheses.

	Sample Size	Species and Size Class				
		RBT < 13"	RBT 13-18"	RBT 18-24"	RBT > 24"	Bull Trout
Bait Mean Catch Rate	153	0.062 (0.002-0.121)	0.036 (0.011-0.061	0.012 (0.001-0.023)	0	0.033 (0.004-0.061)
Lure Mean Catch Rate	212	0.035 (0-0.082)	0.043 (0.006-0.080)	0.026 (0.005-0.046)	0.011 (0.0002-0.022)	0.092 (0.019-0.164)
Combined Mean Catch Rate	35	0.079 (0.046-0.112)	0.049 (0.022-0.076)	0	0	0.025 (0.012-0.037)
Fly Mean Catch Rate	4	0	0	0	0	0

Boat effort was substantially lower than bank effort, but generally showed a similar pattern. Boat effort was lowest from September through December, but increased to the highest effort in January to the end of the season in March (Figure 2). January had the highest total estimated boat effort (75 hours). Total effort for the season was 262 hours (95% confidence interval = 176 – 384 hours). The average duration of a completed boat angler trip was 3.53 hours. We estimated a season total of 74 boat trips (95% confidence interval = 50 – 98 total trips). We did not test for significant differences in boat effort between months due the relatively low sample sizes. The average number of anglers per boat was 1.57 anglers and ranged from 1-3 anglers. When we adjusted total season boat effort by the mean number of anglers per boat, we estimated that there were approximately 411 boat angler hours (95% confidence interval = 276 – 603 boat angler hours) for the total season.

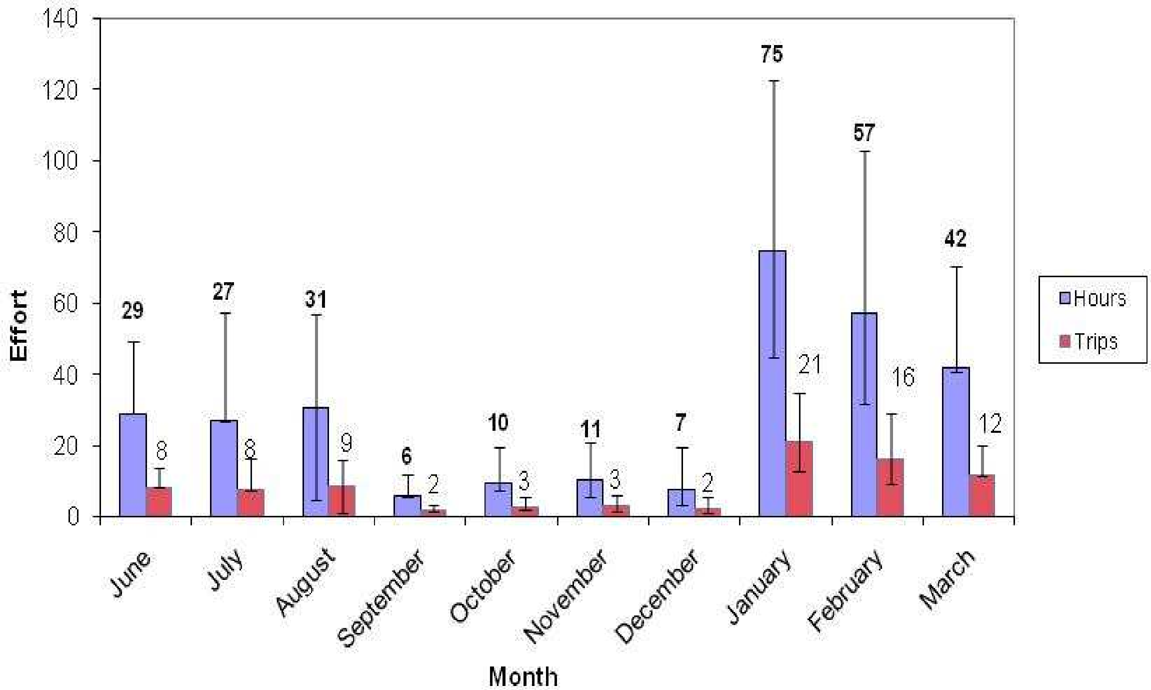


Figure 2. Estimated total monthly boat effort (hours and angler trips) in the Kootenai River Libby Dam tailrace between June 2009 and March 2010. The total monthly value is labeled above each bar, and the whisker bars represent 95% confidence intervals.

We conducted a total of 16 boat angler interviews, which comprised only 4% of the total interviews for this study. During the creel interview, FWP personnel collected information separately from individual anglers within a boat. However, the boat angler volunteers recorded information for each respective boat trip. Therefore, we pooled effort, catch and harvest information for all boat anglers at the boat level. Only two of the seven boat angler volunteers returns creel logs books. The two volunteers provided information from 39 boat trips (creel entries), which we combined with the boat interviews to estimate catch and harvest rates for all boat anglers. From the combined creel log books and interviews, we estimated the average number of anglers per boat to be 1.57 (range 1-3 anglers per boat). Lures were the most popular gear type used by boat anglers, constituting 94.6% from the interviews and creel log books. Flies and bait were used by 2.7% (each) of all boat anglers. We did not estimate catch or harvest for different gear types since the majority of the boat anglers used lures, and the sample size was small

Due to the fact that we were unable to determine catch per unit of effort on an individual angler basis for the volunteer creel log book anglers, we were unable to estimate variance associated with catch and harvest rates of boat anglers. We did not compare catch or harvest rates on a monthly basis due to the limited sample size. We estimated mean catch rate of rainbow trout < 13 inches to be 0.120 fish per boat hour (95% confidence interval = 0.045-0.196; Table 4), and 0.076 fish per hour per boat angler (Table 5). Total estimated catch of rainbow trout > 13 inches for the ten month season was 32 fish (95% confidence interval 10-53 fish; Table 4). Mean overall harvest rate of rainbow trout < 13 inches was an order of magnitude lower than catch rates, averaging only 0.012 fish per boat hour (95% confidence interval = 0.001-0.364; Table 4), and 0.008 fish per boat angler (Table 5). Estimated harvest was low (4 fish; Table 4). Catch rates of rainbow trout 13-18 inches was similar to the smaller size class (< 13 inches), averaging 0.110 fish per boat hour (95% confidence interval = 0.066-0.176; Table 4), and 0.070 fish per angler hour (Table 5). The catch rate for rainbow trout 18-24 inches was substantially lower and averaged 0.038 fish per boat hour (95% confidence interval = 0.007-0.069; Table 4), and 0.024 fish per angler hour (Table 5). We did not observe any illegal harvest of rainbow trout within the protected size slot (13-24 inches). Catch rates of rainbow trout > 24 inches were variable, and averaged 0.020 fish per boat hour (95% confidence interval = 0.001-0.045; Table 4) and 0.013 fish per boat angler hour (Table 5). We interviewed only one angler that harvested a rainbow trout > 24 inches, and none of the volunteer creel log boat owners harvested a rainbow trout > 24 inches. The estimated total catch for the season of rainbow trout > 24 inches was relatively low (5 fish), with 95% confidence interval ranging from 3 – 12 fish (Table 4). We estimated harvest rate of rainbow trout > 24 inches to be half that of catch rates for boat anglers, averaging 0.010 fish per boat hour (95% confidence interval = 0.001-0.031; Table 4), and 0.006 fish per boat angler hour (Table 5). We estimated total season harvest of rainbow trout > 24 inches to be only 3 fish (95% confidence interval = 2-8; Table 4). Bull trout catch rate for boats were similar to the boat catch rates of small (13-18 inch rainbow trout), and averaged 0.151 fish per boat hour (95% confidence interval 0.080-0.221; Table 4) and 0.096 fish per boat angler hour (Table 5). We estimated boats angler caught 39 bull trout during the season, with 95% confidence intervals ranging from 18-61 fish. We did not observe any illegal harvest of bull trout by boat anglers during this study.

Table 4. Estimated boat catch and harvest rates (fish/boat hour and boat hour/fish) for rainbow (RBT), bull and total trout (rainbow, cutthroat, and bull trout) in the Kootenai River from Libby Dam downstream to the Fisher River. 95% confidence intervals are presented in parentheses.

	Species and Size Class					
	RBT < 13"	RBT 13-18"	RBT 18-24"	RBT > 24"	Bull Trout	Total Trout
Mean Catch Rate (fish/boat hour)	0.120 (0.045-0.196)	0.110 (0.066-0.176)	0.038 (0.007-0.069)	0.020 (0.001-0.045)[1]	0.151 (0.080-0.221)	0.458 (0.321-0.596)
Mean Catch Rate (boat hours/fish)	8 (5-22)[1]	9 (6-23)	26 (15-139)[1]	49 (22-1,335)[1]	7 (5-12)	2 (1.7-3.1)
Mean Harvest Rate (fish/boat hour)	0.012 (0.001-0.364)[1]	0	0	0.010 (0.001-0.031)[1]	0	0.025 (0.002-0.061)[1]
Mean Harvest Rate (boat hours/fish)	83 (27-1,001)[1]	0	0	98 (33-2,002)[1]	0	39 (16-572)[1]
Total Catch	32 (10-53)	29 (9-48)	10 (7-19)[1]	5 (3-12)[1]	39 (18-61)	120 (67-173)
Total Harvest	4 (4-9)[1]	0	0	3 (2-8)[1]	0	7 (7-16)[1]

[1]Lower bound of 95% confidence interval set at the known minimum values from interviews conducted.

Table 5. Estimated boat angler catch and harvest rates (fish/hour and hour/fish) for rainbow (RBT), bull and total trout (rainbow, cutthroat, and bull trout) in the Kootenai River from Libby Dam downstream to the Fisher River. We were unable to calculate 95% confidence intervals for these data.

	Species and Size Class					
	RBT < 13"	RBT 13-18"	RBT 18-24"	RBT > 24"	Bull Trout	Total Trout
Mean Catch Rate (fish/angler hour)	0.076	0.070	0.024	0.013	0.096	0.292
Mean Catch Rate (angler hours/fish)	12.5	14	41	77	11	3
Mean Harvest Rate (fish/boat hour)	0.008	0	0	0.006	0	0.016
Mean Harvest Rate (angler hours/fish)	130	0	0	154	0	61

References

W.F. Sigler, and J.W. Sigler. 1984. Recreational fisheries: management, theory and application. University of Nevada Press, Reno, Nevada.

Chapter 4

Kootenai River Resident Fish Monitoring During the 2010 Spill Test at Libby Dam

Abstract

The Federal Action Agencies conducted a spill test in June 2010 at Libby Dam that lasted seven days which was intended to benefit the Kootenai River white sturgeon. Discharge from the turbines at Libby Dam was held constant at 27,000 cubic feet per second (cfs) throughout the spill test. Spill discharge peaked at 9,000 cfs on June 15, 2010 from 9:00 to 11:00 for a total discharge of 36,000 cfs. Total mean hourly discharge from Libby Dam during the spill test averaged 33,700 cfs. Montana FWP conducted monitoring to evaluate the effects of elevated total dissolved gas on resident fish in the Kootenai River immediately downstream of Libby Dam. We conducted day and night visual searches for dead or dying fish, expending a total effort of 103.5 boat-hours (233 man-hours). We did not observe any fish mortality attributable to elevated gas levels. However, we did recover 3 bull trout, 287 kokanee salmon, 1 mountain whitefish, and 5 suckers, whose deaths using our visual criteria could not be attributed to gas-related injuries. In an effort to estimate search efficiency of dead or morbid fish, we released a total of 39 dead and individually marked bull trout in the Kootenai River. We recovered a total of 12 (30.8%) bull trout during our search efforts. The mean distance and time traveled of all recovered marked bull trout was 1.53 RM and 17.1 hours. The spatial recovery pattern of the test fish was not randomly distributed, 9 out of 12 (75%) of the relocated test fish were recovered on the river bottom of the back eddy associated with the pool located near Big Bend (RM 217.4). The visual recovery of test fish was likely biased towards larger individuals during daylight hours. Montana FWP captured fish via jetboat electrofishing on two occasions after spill had ceased in order to determine if fish exhibited symptoms of gas bubble trauma (GBT). The day after spill had ceased, we estimated that 26.5% of the mountain whitefish examined had GBT symptoms. We also captured two rainbow trout, but none of these fish exhibited GBT symptoms. Almost six days after spill activities had ceased at Libby Dam, we captured and examined 8 rainbow trout, 2 bull trout, 21 mountain whitefish, 5 kokanee salmon, and 1 brook trout. However, none of these fish exhibited readily apparent external GBT symptoms. We also present fish population estimates derived from mark recapture electrofishing for rainbow trout on three sections of the river and bull trout from a single section located immediately downstream of Libby Dam.

Background

The U.S. Fish and Wildlife Service (USFWS) issued their Biological Opinion on the effects of the Operation of Libby Dam on Kootenai River White Sturgeon (KRWS) and Bull Trout and Kootenai Sturgeon Critical Habitat (BiOp) to the U.S. Army Corps of Engineers (Corps) and Bonneville Power Administration (BPA) on February 18, 2006. The BiOp reached a jeopardy conclusion for KRWS, an adverse modification conclusion for KRWS critical habitat and a non-jeopardy conclusion for bull trout. In the 2006 BiOp, the USFWS developed Reasonable and Prudent Alternatives (RPAs) designed to achieve habitat attributes/measures that some think are necessary to adequately provide for successful KRWS spawning and natural in-river reproduction in the Kootenai River near Bonners Ferry, Idaho. A regional team of biologists collaborated to develop and assess seasonal physical and biological conditions with the objective of: (1) providing peak augmentation flows during periods the team determines appropriate based on sturgeon spawning condition (generally May into July); (2) providing post-peak augmentation flows to optimize conditions for sturgeon via the descending limb of a normalized hydrograph; and, (3) optimizing the temperature of releases using the selective withdrawal system at Libby Dam during the sturgeon flow augmentation period.

In May 2006, the USFWS was sued over the BiOp by the Center for Biological Diversity, with interveners including the State of Montana and the Kootenai Tribe of Idaho. The U.S. Army Corps of Engineers was added as a defendant to this suit on September 2007. In September 2008, a settlement agreement between the parties occurred, and the Federal Court in Missoula dismissed the case. According to the terms of the settlement agreement, the Action Agencies would attempt to achieve these desired physical and biological attributes in 2008 and 2009 without spilling additional water at Libby Dam, but if operations in 2008 and 2009 were not successful, then the Action Agencies would add additional discharge from Libby Dam by spilling water. The settlement agreement included the following suite of criteria by which the 2008 and 2009 operations were evaluated:

i. Migration of 40% of the tagged F4 KRWS in the river to the Hwy 95 Bridge or above; and

ii. Presence of those fish in the reach of river at or above the Hwy 95 Bridge for 5 or more days; and

iii. Capture of > 5 unmarked juveniles of the same cohort in 2009 from 2006 or 2007 year classes, when improved temperature control and a descending limb were integral components of KRWS operations at Libby Dam.

The USFWS determined that in 2008 that only criterion *i* was achieved, and that criterion *iii* was not applicable, and in 2009, the USFWS determined that none of the criteria were achieved. The settlement agreement also stipulated that if the 2008 and 2009 Libby Dam operations were not successful according to the specified criteria, the Action Agencies would conduct spill tests at Libby Dam on the Kootenai River in 2010-2012.

Introduction

Spilling water at hydroelectric projects can cause supersaturated gas conditions in waters downstream. Water and air become mixed when water passes over the spillway, and can be carried to substantial depths in the plunge basin where hydrostatic pressure increases the solubility of the atmospheric gases. The air can then pass into solution in sufficient quantities to promote supersaturated conditions with respect to surface or atmospheric pressure. These conditions can cause gas bubble disease in aquatic organisms. Bouck (1980) defines gas bubble disease as "a noninfectious, physically induced process caused by uncompensated, hyperbaric total dissolved gas pressure, which produces primary lesions in blood (emboli) and in tissues (emphysema) and subsequent physiological dysfunctions. The severity of gas bubble disease depends on concentration of total dissolved gas and exposure time with effects ranging from bubbles or blisters under the skin, between fin rays, on the head and in the lining of the mouth or gills, exopthalmia, loss of equilibrium and even death (Weitkamp and Katz 1980).

Spill at Libby Dam has been an infrequent event since the fifth turbine went online in 1976. The first spill test associated with white sturgeon recovery efforts at Libby Dam occurred in June 2002, in an effort to learn more about the gas exchange processes, particularly dissolved gas production from spill releases and dissolved gas dissipation downstream from Libby Dam. U.S. Army Corps of Engineers (2003) detailed the results of gas exchange, dissipation and mixing associated with the 2002 spill event. Agencies learned that at full power house capacity, spill would need to be limited to discharge levels far lower than those called for by the USFWS in 2010 in order to remain in compliance with the Montana Total Dissolved Gas standard of 110% (U.S. Army Corps of Engineers 2003). In June 2006, the surface elevation of Koocanusa Reservoir in northwestern Montana approached full pool elevation (2459 ft msl) and inflows to the reservoir remained in excess of Libby Dam turbine discharge capacity (approx. 24 kcfs when surface elevation approaches full pool), resulting in a spill operation at Libby Dam that extended for 20 consecutive days, caused elevated total dissolved gas (TDG) and resulted in a total discharge from Libby Dam that has been unprecedented since its construction. Montana Fish, Wildlife and Parks was the lead agency responsible for fish monitoring during the 2002 and 2006 spill events at Libby Dam. The results of these monitoring efforts are fully described in Dunnigan et al. (2003) and Marotz et al. (2007), respectively. Montana Fish, Wildlife and Parks is especially concerned about the unique tailrace fishery. The three mile section of the Kootenai River directly downstream of Libby Dam supports a unique abundance of trophy size rainbow trout (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*), that congregate in this location likely due to the abundant rich food source of kokanee salmon (*Oncorhynchus nerka*) that are entrained through Libby Dam.

The Montana Department of Environmental Quality issued a temporary waiver of Montana's Total Dissolved Gas Standard of 110% for the 2010 spill event at Libby Dam (see Appendix Exhibit B). However this temporary waiver specified several conditions in order to prevent substantial damage to the State's aquatic resources inhabiting the Kootenai River downstream of Libby Dam. Two of the conditions specified by the State of Montana were contingent upon resident fish monitoring activities conducted by Montana FWP during the spill test. This report summarizes the results of resident fish monitoring that occurred in the Kootenai River below Libby Dam during the spill event in June 2010.

Methods

Visual Surveys

Montana FWP conducted two 6-hour shifts (one daylight, one nighttime) daily during the 2010 spill event at Libby Dam to search for fish killed, injured or distressed resulting from elevated total dissolved gas. During each search effort 1-2 jetboats operated on the Kootenai River between Libby Dam (RM 221.7) and the city of Libby (RM 220), with the majority of the effort occurring from Libby Dam downstream to the Osprey Landing boat ramp (RM 208.9). Search activities were concentrated in relatively low velocity areas (e.g. pools, back eddies, and river margins) where dead or moribund fish were most likely to be located. Each jetboat was equipped with 1-2 observers, a driver, spotlights (for night searches), and dipnets.

Montana FWP personnel attempted to capture all dead or morbid fish observed and determine the cause of mortality. We gave all captured fish an external physical examination immediately following capture to look for visible symptoms of gas bubble trauma (GBT). A dead, distressed, or injured fish exhibiting external symptoms of GBT (i.e., bubbles in gill filaments, eyes, fins, lateral line, beneath the skin, hemorrhages due to tissue rupture, or split fins) was classified as a GBT related mortality. Dead or morbid fish that exhibit physical damage other than GBT symptoms (e.g. lacerations or abrasions from turbulence, passage over the spillway, or other injuries) were not be classified as a GBT-related mortality. Each captured fish was identified to species, measured, weighed examined for previous marks/tags, photographed, removed from the river, and disposed of according to state protocol.

In an effort to estimate search efficiency of dead or morbid fish, we released a total of 39 dead bull trout collected from Koocanusa Reservoir during our Montana FWP annual gillnetting conducted on May 17, 2010, hereafter referred to as test fish. All test fish were frozen until the spill test. We removed the otoliths from all test fish and marked each with a 134.2 KHz (ISO) passive integrated transponder (PIT) tag to allow individual identification, we marked 9 of these fish with radio tags (Table 2). We recorded the date, time, location and PIT tag number of each test fish released. We surveyed telemetry relocations independently of the visual search efforts so as not to bias the results. We estimated visual search efficiency by dividing the number of test fish released by the number of recovered test fish. We evaluated the effect fish length had on recovery success using two statistical analyses. We used logistic regression to evaluate if fish length influenced the probability of recovery and we compared the mean length of all test fish released to the mean length of all recovered test fish using a student's t-test. We also investigated the effect fish length had on length of time it required to recover a fish using non-linear regression techniques. In similar analyses we evaluated the effect fish length had on distance (river miles) traveled prior to recovery and the relationship between distance traveled to hours to recovery using linear regression techniques. All statistical analyses were performed using SPSS version 7.5 Software.

Electrofishing Surveys

Montana FWP conducted two surveys after spill activities at Libby Dam had ceased in order to determine if fish in the LDT section of the Kootenai River exhibited symptoms of GBT. We conducted the first survey on June 18th during daylight hours, and a second survey on June 22nd during nighttime hours. We collected fish using a boom mounted electrofishing gear consisting of a Coffelt model Mark 22 electrofishing unit operating with an electrical output ranging from 200-350 volts at 5-8 amps powered by a 5,000 watt gasoline powered generator. We attempted to capture all fish observed, placing them in a live well for a period no longer than 10-15 minutes, until we gave all captured fish an external physical examination to look for visible symptoms of GBT. We examined the fins, eyes, and gills for the presence of gas emboli, and then recorded the total proportion of each fin or anatomical feature that contained emboli.

Fish Population Estimates

Montana FWP conducts fish population estimates using a mark and recapture techniques to assess long-term trends in resident fish populations within three sections of the Kootenai River. We target bull trout at the Libby Dam Tailrace (LDT), which extends from Libby Dam (River mile [RM] 221.7) downstream to the confluence of the Fisher River (RM 218.2) in April/May. We have conducted this survey annually since 2004, with the exception of 2005. We divided the 3.5 mi. (5.63 km) reach of Kootenai River into two sections, and sampled the two sections on consecutive evenings during the marking session and approximately seven days later during the recapture session. We compared the mean length of bull trout captured during our 2010 sampling to the mean length of bull trout captured during similar sampling conducted annually from 2004 to 2010 using ANOVA and subsequent Tukey multiple comparisons. We used the Petersen Estimator as modified by Chapman (Ricker 1958) to estimate absolute abundance of bull trout within the LDT section using the following formula.

$$N = \frac{(M+1)\bullet(C+1)}{R+1} - 1 + Morts$$

Where:
N = population estimate,
C = total fish captured in the recapture sample(s),
M = number of marked fish at the start of recapture sample period and
R = number of marked fish in the recapture sample(s)
Morts = number unmarked mortalities captured during the marking sessions.

We used the following formula to calculate bounds (B) for 95% confidence intervals for N:

$$B = 1.96 \times \sqrt{\frac{N^2 \bullet (C-R)}{(C+1)\bullet(R+2)}}$$

As advised by Robson and Regier (1964), we performed a validity test of the population estimates to determine if our estimates were heavily biased. If the estimate meets the following condition, then the estimate is not strongly biased (valid).

$$M \times C > 4 \times N$$

Montana FWP also conducts population estimates in three sections of the Kootenai River to monitor rainbow and cutthroat trout abundance (*Oncorhynchus spp.*). We have sampled the LDT section in September in 1992-1994 and 2008-2010.

Montana FWP targets *Oncorhynchus spp.* within the "Rereg" section of the Kootenai River, which extends from RM 210.5 downstream to the Osprey Landing boat ramp (RM 208.9). Montana FWP has surveyed this section during early spring (February/March) annually since 2001, with the exception of 2002 when high turbid flows from the Fisher River limited visibility and reduced capture efficiency. *Oncorhynchus spp.* are also targeted in the Flower-Pipe section of the Kootenai River, which extends from the confluence of Flower Creek (RM 204.0) downstream to the confluence of Pipe Creek (RM 201.0). This section has been surveyed approximately annually since 1973, and although the sampling date has varied throughout this period, sampling since 2001 has occurred in August or September. A single mark and recapture session is conducted approximately seven days apart in the LDT, Flower-Pipe and Rereg sections for *Oncorhynchus spp*. estimates. Population estimates are calculated using a partial log-likelihood estimator (Fisheries Analysis + © 2004, MFWP).

Fish collected for the four population estimates were captured during nighttime electrofishing using two jet boats. Each boat contained a driver and two netters. The electrofishing unit on each boat consisted of a Coffelt model Mark 22 electrofishing unit operating with an electrical output ranging from 200-350 volts at 5-8 amps powered by a 5,000 watt gasoline powered generator. We recorded the total time (minutes) that electrical current was generated in the water as a measure of effort. We examined all fish for marks, collected scale samples, measured total length (mm) and weight (g), and then released all fish near their capture location. All bull trout were marked with PIT tags (see above) and an adipose fin clip was removed to evaluate PIT tag retention. Rainbow and cutthroat trout within the Flower-Pipe and Rereg sections were marked with a non-permanent fin clip.

Results

Visual Surveys

The spill test in June 2010 at Libby Dam lasted seven days (Table 1). Discharge from the turbines at Libby Dam was held constant at 27,000 cubic feet per second (cfs) throughout the spill test. Spill discharge peaked at 9,000 cfs on June 15, 2010 from 9:00 to 11:00 for a total discharge of 36,000 cfs (Table 1). Total mean hourly discharge from Libby Dam during the spill test averaged 33,700 cfs (Table 1). We expended a total effort of 103.5 boat-hours (233 man-hours) of effort visually searching for dead or morbid fish in the Kootenai River. We did not observe any fish mortality attributable to elevated gas levels. However, we did observe 3 bull trout mortalities that were either entrained through the turbines or over the spillway. We also recovered 287 kokanee salmon, 1 mountain whitefish (*Prosopium williamson)*, and 5 suckers (*Catostomus spp.*) whose deaths using our visual criteria could not be attributed to gas-related injuries.

We released 39 test fish in four general release groups with release locations ranging from RM 218.5 to 221.3 (Table 2; Figure 1). We recovered a total of 12 of the 39 marked bull trout during our search efforts, for an overall efficiency of 30.8%. The mean distance traveled of all recovered marked bull trout was 1.53 RM (range 0.02-3.99), and the mean travel time was 17.1 hours (range 2.7-71.3). Total discharge at Libby Dam was 34,000 cubic feet per second when most (n = 9) of the test fish were recovered (range 33,500-35,000 cubic feet per second; Table 2). Only one (8.3%) of the 12 test fish was recovered during the nighttime (after sunset and before sunrise) search efforts (Table 1), even though approximately half of the effort occurred during nighttime hours. The spatial recovery pattern of the test fish was not randomly distributed, 9 of 12 (75%) of the relocated test fish were recovered on the river bottom of the back eddy associated with the pool located near Big Bend (RM 217.4; Table 2; Figure 1). However, we recovered test fish ranging from RM 217.4 to 220.6 (Table 2; Figure 1).

The visual recovery of test fish was likely biased towards larger individuals. The mean length of all test fish was 497 mm, and the mean size of all recovered test fish was slightly larger (mean = 561 mm), although the difference was not significant (p = 0.221; two tailed t-test). Furthermore, the estimated probability of detecting a test fish (P_d) was positively correlated with fish length (p = 0.089), and logistic regression yielded the following equation to predict probability of a fish given the length.

$$P_d = \frac{e^{(-2.797 \times Length \times 0.0039)}}{1 + e^{(-2.792 \times Length \times 0.0039)}}$$

Fish length was also significantly negatively correlated to the length of time until recovery (p = 0.007), and was best fit with a natural logarithmic transformation of the data (Figure 2). However, we found no evidence that distance traveled of the test fish was correlated to either hours at large (r^2 = 0.130; p = 0.249) or fish length (r^2 = 0.048; p = 0.492).

We located two radio tagged (49.661 and 49.720) test bull trout during visual searches (Table 3) on June 12 and June 13, respectively. We removed these fish from the river at that time. On June 16, we attempted to relocate the remaining seven radio tagged test fish between the Osprey Boat Ramp (RM 213) upstream to Libby Dam (RM 221.4). Discharge was similar during the telemetry search effort to most dam operations during the spill test, averaging 6.5 kcfs spill (33.5 kcfs total discharge; Table 1). We triangulated the location of six radio tagged test fish to within an estimated 5-10 m based on radio strength and directionality. However, we were unable to visually locate any of these fish. With the exception of one radio tagged test fish (radio tag 49.482), most of the radio tagged fish were located within the general vicinity of the non-radio tagged fish that were visually located (Figures 3 and 1, respectively). Radio tag 49.482 was relocated just upstream of the Osprey Landing boat ramp (RM 213.16). One of the radio tagged bull trout (radio tag 49.581) was never relocated within the search area.

Table 1. Start and end times and dates of different flow regimes out of Libby Dam during the June 2010 spill test. Discharge rates are expressed in thousands of cubic feet per second (kcfs).

Date and Time		Discharge (kcfs)			
Start	End	Turbine	Spill	Total	Duration (hours)
6/10/10 8:00	6/10/10 15:00	27	5	32	7
6/10/10 15:00	6/10/10 16:00	27	6.5	33.5	1
6/10/10 16:00	6/10/10 18:00	27	7	34	2
6/10/10 18:00	6/10/10 22:00	27	7.3	34.3	4
6/10/10 22:00	6/11/10 17:00	27	7	34	19
6/11/10 17:00	6/11/10 20:00	27	6.7	33.7	3
6/11/10 20:00	6/13/10 14:00	27	7	34	42
6/13/10 14:00	6/13/10 15:00	27	6.7	33.7	1
6/13/10 15:00	6/13/10 22:00	27	6.5	33.5	7
6/13/10 22:00	6/14/10 8:00	27	7	34	10
6/14/10 8:00	6/14/10 12:00	27	8	35	4
6/14/10 12:00	6/14/10 13:00	27	7	34	1
6/14/10 13:00	6/15/10 8:00	27	6.5	33.5	19
6/15/10 8:00	6/15/10 9:00	27	7	34	1
6/15/10 9:00	6/15/10 11:00	27	9	36	2
6/15/10 11:00	6/15/10 19:00	27	6.5	33.5	8
6/15/10 19:00	6/15/10 22:00	27	7	34	3
6/15/10 22:00	6/16/10 21:00	27	6.5	33.5	23
6/16/10 21:00	6/16/10 22:00	27	6	33	1
6/16/10 22:00	6/17/10 7:00	27	5	32	9
6/17/10 7:00	6/17/10 8:00	27	2.5	29.5	1
Minimum		27	2.5	29.5	1
Maximum		27	9	36	42
Hourly Mean		27	6.7	33.7	

Table 2. Release and recovery information for 39 marked test bull trout released in the Kootenai River during the June 2010 spill test at Libby Dam. Those PIT tag numbers marked with an * were also radio tagged. See Table 3 for additional information regarding those fish.

		Release		Recovery					
PIT Tag Number	Length	Date & Time	RM	Date & Time	RM	Distance (miles)	Time at large (hr)	Travel Speed (mph)	Spill Discharge (KCFS)
985161000109879*	766	6/10/10 12:15	221.48						
985161001244178*	466	6/10/10 12:15	221.48						
985161001279500*	565	6/10/10 12:15	221.48						
985161000126094	263	6/10/10 12:28	221.41						
985161000127241	720	6/10/10 12:28	221.05						
985161000103244a	324	6/10/10 12:28	221.04	6/13/10 11:44	220.57	0.47	71.3	0.01	7
985161000096592	637	6/10/10 12:29	221.05						
985161000093805	316	6/10/10 12:30	221.05						
985161000110330*	470	6/12/10 10:34	219.15						
985161000139239*	575	6/12/10 10:36	219.26	6/12/10 13:30	217.37	1.89	2.9	0.65	7
985161000103769*	735	6/12/10 10:37	219.30	6/13/10 00:12	217.40	1.90	13.6	0.14	7
985161000217313	790	6/12/10 10:46	219.25	6/12/10 20:30	217.39	1.86	9.7	0.19	7
985161000099324	230	6/12/10 10:47	219.31						
985161000082973	262	6/12/10 10:48	219.31						
985161000085375	305	6/12/10 10:49	219.31						
985161000137632	730	6/12/10 10:50	219.23	6/12/10 13:30	217.38	1.85	2.7	0.69	7
985161000120891	461	6/12/10 10:51	219.23	6/12/10 21:00	218.81	0.42	10.2	0.04	7
985161000103244b	324	6/13/10 12:33	221.41						
985161000120773	500	6/13/10 12:35	221.35	6/13/10 21:15	217.36	3.99	8.7	0.46	6.5
985161000060651	285	6/13/10 12:38	221.28						

Table 2. (continued)									
		Release		Recovery					
PIT Tag Number	Length	Date & Time	RM	Date & Time	RM	Distance (miles)	Time at large (hr)	Travel Speed (mph)	Spill Discharge (KCFS)
985161000192993	430	6/13/10 12:40	221.18						
985161000099128	653	6/13/10 12:42	220.94						
985161000126580	295	6/13/10 12:44	220.78						
985161000119016	305	6/13/10 12:45	220.53						
985161000084364	467	6/13/10 12:48	220.54	6/14/10 20:36	220.52	0.02	31.8	0.00	6.5
985161000110168	450	6/13/10 12:52	220.47	6/14/10 11:40	217.38	3.09	22.8	0.14	8
985161000103130*	730	6/15/10 10:00	218.54						
985161000138650	471	6/15/10 10:01	218.54						
985161000108202*	310	6/15/10 10:02	218.54						
985161000070526	577	6/15/10 10:04	218.54						
985161000062831	473	6/15/10 10:05	218.54						
985161000101552a	520	6/15/10 10:06	218.54	6/15/10 20:43	217.63	0.91	10.6	0.09	7
985161000108211	523	6/15/10 10:07	218.54						
985161000104235	571	6/15/10 10:08	218.54						
985161000016859a	508	6/15/10 10:09	218.53	6/15/10 20:43	217.65	0.88	10.6	0.08	7
985161000099194a	674	6/15/10 10:10	218.53	6/15/10 20:30	217.41	1.12	10.3	0.11	7
985161000099194b	674	6/15/10 20:30	217.45						
985161000016859b	508	6/15/10 20:43	217.70						
985161000101552b	520	6/15/10 20:43	217.68						
Mean	**497.0**	**6/13/10 7:49**	**219.8**	**6/14/10 00:19**	**217.8**	**1.53**	**17.1**	**0.22**	**7.0**

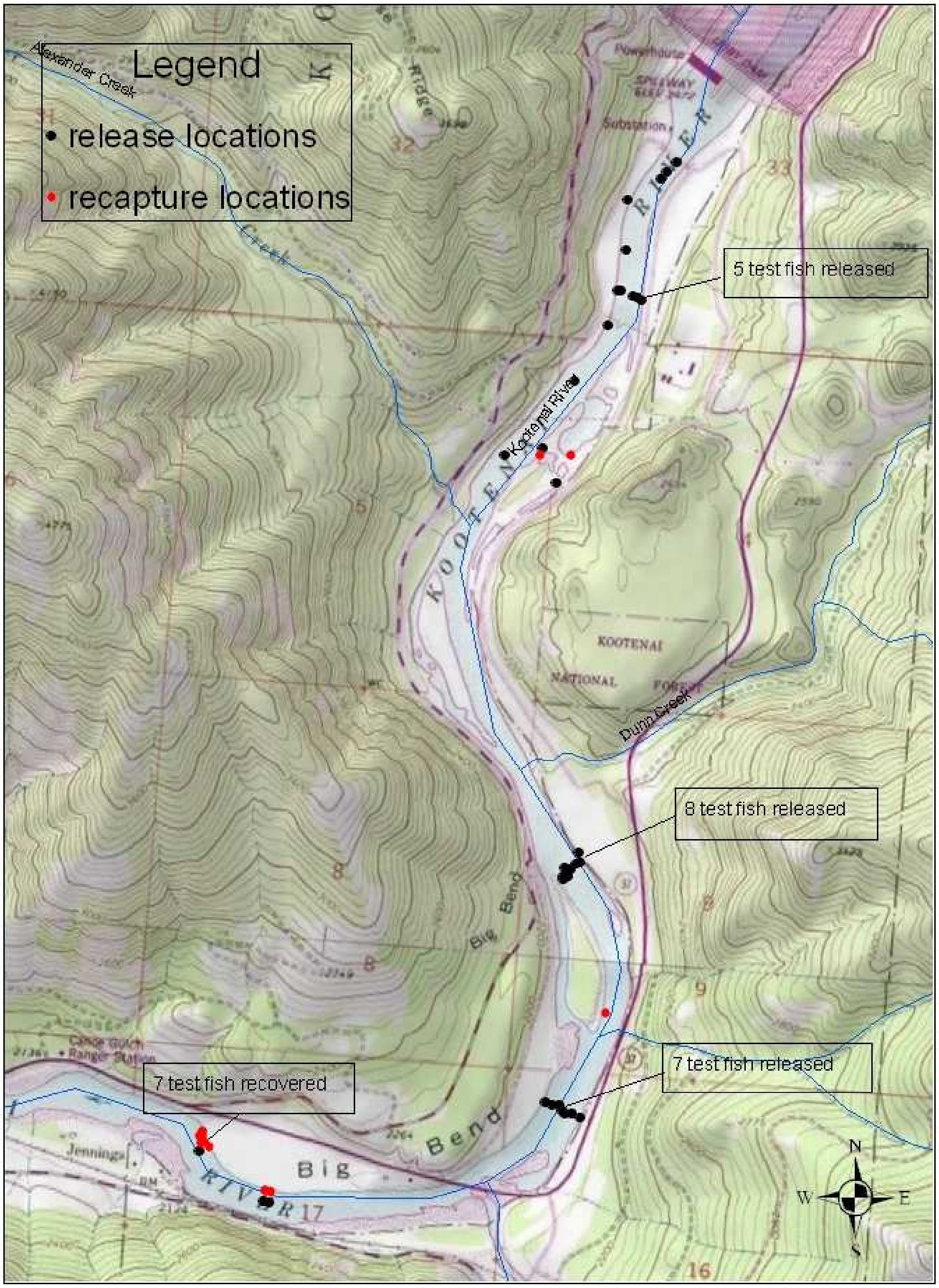


Figure 1. Release and recapture locations of 39 marked bull trout during the June 2010 spill test at Libby Dam.

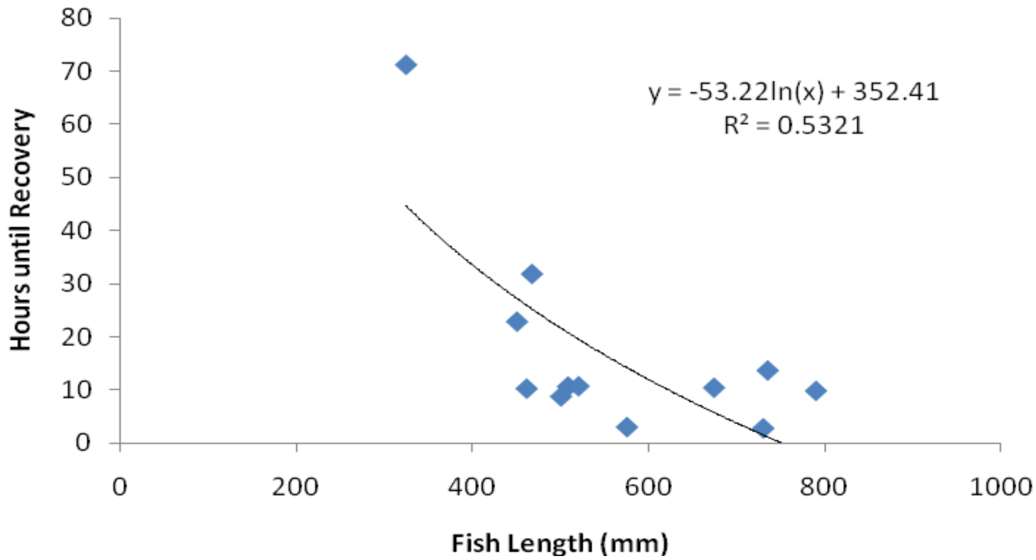


Figure 2. Relationship between fish length and hours until recovery for marked test fish released in the Kooenai River near Libby Dam during the 2010 spill test.

Table 3. Release and relocation information for 9 radio tagged test bull trout released in the Kootenai River during the June 2010 spill test at Libby Dam.

			Release		Recovery				
PIT Tag Number	Radio Tag #	Length	Date & Time	RM	Date & Time	RM	Distance (miles)	Time at large (hr)	Travel Speed (mph)
985161000138650	49.401	471	6/15/10 10:01	218.54	6/16/10 13:50	216.72	1.82	27.8	0.07
985161000110330	49.411	470	6/12/10 10:34	219.15	6/16/10 14:30	218.87	0.28	99.9	0.00
985161000108202	49.421	310	6/15/10 10:02	218.54	6/16/10 13:45	216.76	1.78	27.7	0.06
985161001244178	49.482	466	6/10/10 12:15	221.48	6/16/10 13:20	213.16	8.32	145.1	0.00
985161000103130	49.501	730	6/15/10 10:00	218.54	6/16/10 14:20	217.35	1.19	28.3	0.04
985161000109879	49.581	766	6/10/10 12:15	221.48					
985161000139239*	49.661*	575	6/12/10 10:36*	219.26*	6/12/10 13:30*	217.37	1.89	2.9	0.65
985161001279500	49.680	565	6/10/10 12:15	221.48	6/16/10 14:55	220.80	0.68	146.7	0.06
985161000103769*	49.720*	735	6/12/10 10:37*	219.30*	6/13/10 0:12*	217.40	1.90	13.6	0.14
Mean with *		**565.3**	**6/12/10 18:57**	**219.8**	**6/15/10 15:17**	**217.3**	**2.23**	**61.5**	**0.13**
Mean without *		**539.7**	**6/12/10 21:20**	**219.1**	**6/16/10 14:06**	**217.3**	**2.35**	**79.3**	**0.04**

*Two bull trout marked with radio tags were located during visual searches and removed from the river prior to attempts to relocate using radio telemetry.

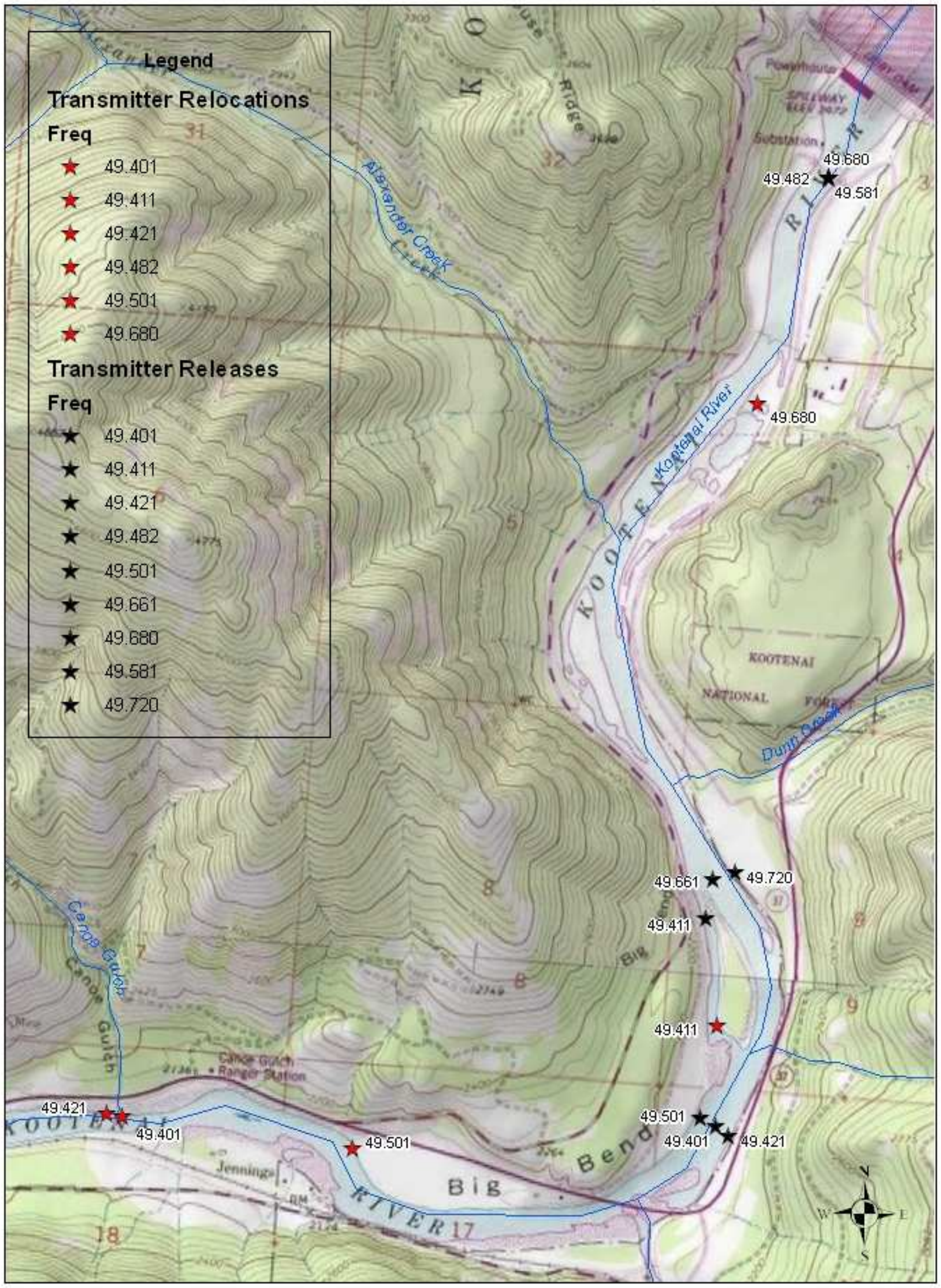


Figure 3. Release and relocations of 9 radio tagged bull trout during the June 2010 spill test at Libby Dam. Radio tag number 49.482 relocation is not depicted on this figure due to spatial limitation. This radio tag was located at RM 213.16 near Osprey Landing boat ramp, approximately 8.5 miles downstream of Libby Dam.

Electrofishing Surveys

On June 18th we captured fish using electrofishing gear on the Kootenai River from Libby Dam downstream to the Highway 37 Bridge. However, we had difficulty capturing fish due to fish avoidance during the daylight. We restricted our electrofishing efforts to the east bank of the Kootenai River, which is the same side of the river as the spillway, in order to maximize the probability of observing impacted fish. Mountain whitefish dominated the catch, constituting 89.5% (n = 34) of the total daily catch (38 fish). GBT symptoms were observed on 26.5% (n = 9) of the mountain whitefish examined. The most common GBT symptom observed were emboli on the gill filaments ranging from 2-10% coverage. Slight hemorrhaging was also observed to a lesser degree than gill emboli on 8.8% (n = 3) of these fish. We also captured two rainbow trout and a course scale sucker (*Catostomus macrocheilus*), but none of these fish exhibited GBT symptoms.

On the evening of June 22, almost six days after spill activities had ceased at Libby Dam, we captured additional fish in the LDT Section and examined them for GBT symptoms. We restricted our electrofishing efforts from Libby Dam downstream to Alexander Creek (RM 220.5). We captured 8 rainbow trout, 2 bull trout, 21 mountain whitefish, 5 kokanee salmon, 1 brook trout (*Salvelinus fontanalis*) , 1 redside shiner (*Richardsonius balteatus*), 1 peamouth chub (*Mylocheilus caurinus*), and 4 longnose suckers (*Catostomus catostomus*). However, none of these fish exhibited readily apparent external GBT symptoms.

Population Estimates

Montana FWP marked a total of 55 bull trout in the LDT on April 7, 2010. Six days later, we captured 34 bull trout, of which 3 were marked (Table 4). Our efforts yielded an estimate of 489 bull trout within this section prior to spill activities in 2010. However, this estimate failed the validity check (Robson and Regier 1964). Therefore, we believe this estimate to be invalid due to excessive bias. We will attempt to conduct a bull trout estimate in early 2011 prior to any spill event planned for 2011. Bull trout abundance at this site has ranged from approximately 920 fish in 2004 to a low of 180 fish in 2009 (Figure 4). The mean total length of the bull trout in 2010 was 659 mm (range = 402-873), which was similar to most years since we began this work in 2004 (Table 5). Bull trout length in 2010 (mean = 659.8 mm) differed significantly only from fish collected in 2008 (mean = 607.9 mm; Table 5).

We marked a total of 188 *Oncorhynchus spp.* in the LDT section of the Kootenai River on September 2, 2010. We captured 285 fish six days later, of which 27 were marked. The majority (98.3%) of the catch consisted of rainbow trout and the remainder (1.7%) were cutthroat trout. We estimated 114 fish per 1,000 feet were present in this section of the Kootenai River, which was the lowest abundance on record for this section (Table 6; Figure 5), representing a 62% reduction from our 2009 estimate of 298 fish per 1,000 feet (Table 6). However, the trend since 2008 has been one of declining total abundance, and especially a decline in larger size class individuals (Table 6). Trout abundance within this section decreased by 41.2% from 2008 to 2009 (Table 6).

We conducted the mark recapture population estimate within the Rereg section of the Kootenai River in March 2010, prior to the spill test in June. We marked 217 fish on the evening of March 24, 2010 and recaptured 36 fish one week later. The recapture rate was 17.4%, producing a population estimate of 153 fish per 1,000, which represented the second lowest estimated abundance at this site since 2001 (Figure 6). Fish abundance since 2001 at this site peaked in 2007 with an estimated 432 fish per 1,000 feet, but has declined annually since (Table 7). Rainbow trout comprised the entire catch at this site in 2010. Montana FWP will attempt to conduct a population estimate in the Rereg section in spring 2011, which will represent the first sampling session after the June 2010 spill test.

Montana FWP marked 494 *Oncorhynchus spp.* during the mark run for the Flower-Pipe population estimate on September 1, 2010, and completed the recapture run on the evening of September 7, 2010, capturing 371 fish. The recapture rate was 11.1%, yielding a population estimate of 330 fish per 1,000 feet (Figure 7; Table 8). This represented the second lowest population estimate over the previous ten years (Table 8). Fish abundance at this site peaked in 2006 with an estimated 813 fish per 1,000 feet (Figure 8). Species composition at this site was dominated by rainbow trout (93.8%) and cutthroat trout (6.2%) in 2010, which was similar to the past several years.

Table 4. The sampling dates for the number of adult bull trout marked, recaptured, and the estimated total population and number of fish per mile in the Kootenai River from Libby Dam downstream to the Fisher River confluence. The 95 percent confidence intervals (CI) are presented in parentheses.

Date	Bull Trout Marked	Bull Trout Recaptured	Population Estimate (95% CI)	Fish Per Mile (95% CI)	Valid (Y/N)
April 2004	109	13	918 (511-1,326)	262 (146-379)	Yes
April 2006	19	5	176 (73-279)	50 (21-80)	Yes
April/May 2007	37	4	417 (120-714)	119 (34-204)	Yes
April 2008	73	7	381 (158-605)	109 (43-175)	Yes
April 2009	44	7	180 (78-282)	51 (23-80)	Yes
April 2010	55	3	N/A	N/A	No

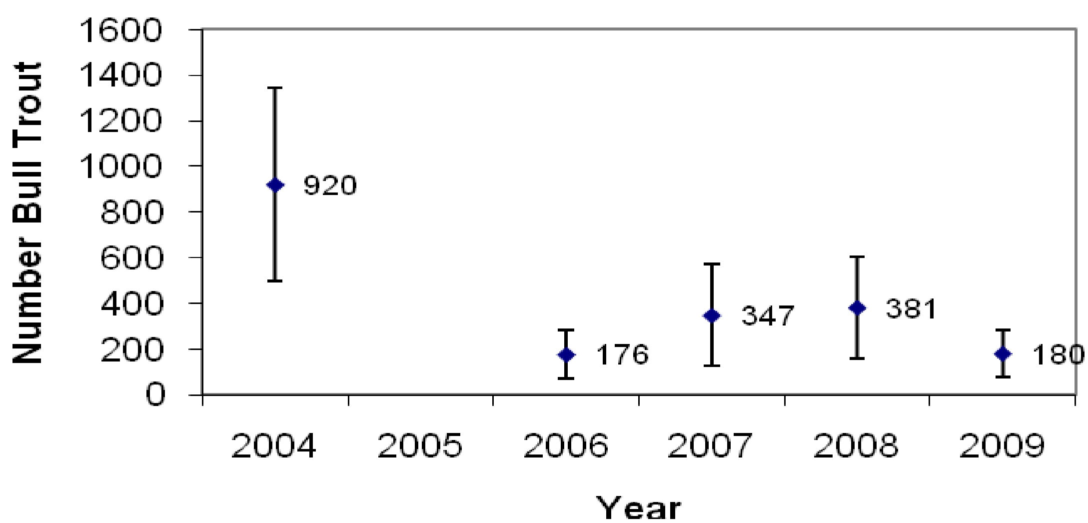


Figure 4. Estimated number of bull trout obtained from mark recapture population estimates in the Libby Dam tailrace section from 2004 to 2009. The whisker bars represent 95% confidence intervals.

Table 5. Bull trout length summary of fish collected during mark recapture population estimates in the Libby Dam Tailrace area of the Kootenai River 2004-2010. Statistical comparisons between years were made using an analysis of variance and subsequent Tukey's multiple comparisons.

Year	Mean	Range	Standard Deviation	Median	Mode	Significantly Different than (P<0.05)
2004	648.9	343-861	113.3	646.5	647	2008
2006	692.3	425-870	105.2	701	625	2008 & 2009
2007	655.1	308-875	137.0	672.5	658	none
2008	602.9	237-900	158.8	613	795	2004, 2006 & 2010
2009	613.1	319-855	125.1	611	514	2006
2010	659.8	402-873	117.7	680.5	746	2008

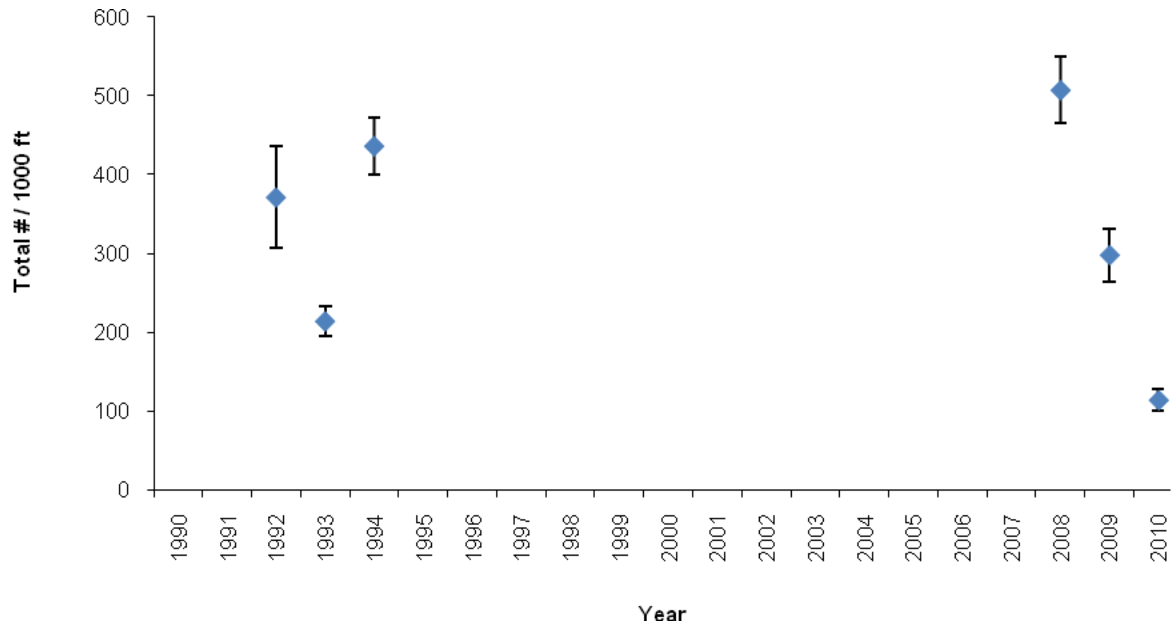


Figure 5. Estimated number of trout (rainbow and cutthroat) per 1,000 feet obtained from mark recapture population estimates in the Libby Dam tailrace section of the Kootenai River from 1992-1994 and 2008-2010. The whisker bars represent one standard deviation.

Table 6. Estimated number of fish (*Oncorhynchus spp*.) per 1,000 feet by length group in the Libby Dam Tailrace Section from 1992-1994 and 2008-2010 using mark-recapture techniques and partial log-likelihood estimator methods. An * indicates a lumped estimate for fish equal to or greater than the length category shown.

Length Category (mm)	1992	1993	1994	2008	2009	2010
75-99	7	0	0	0	0	0
100-124	35	2	47	2	2	2
125-149	61	30	87	62	23	8
150-174	84	55	98	148	46	16
175-199	55	48	92	106	60	27
200-224	33	29	64	46	63	24
225-249	96*	13	19	41	41	7
250-274		9	6	39	35	6
275-299		8	6	30	38*	24*
300-324		5	5	16		
325-349		3	3	19*		
350-374		1	2			
375-399		3	0			
400-424		3	1			
425-449		1	1			
450-474		2	6*			
475-499		2*				
500-524						
Total per 1,000 ft	**371**	**214**	**436**	**507**	**298**	**114**

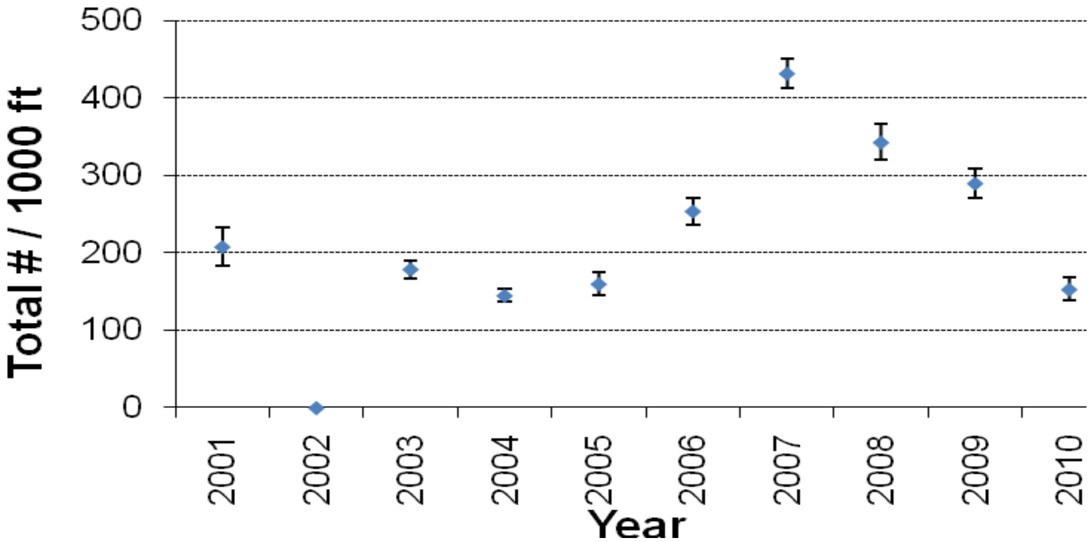


Figure 6. Estimated number of trout (rainbow and cutthroat) per 1,000 feet obtained from mark recapture population estimates in the Rereg section of the Kootenai River from 2001-2010. The whisker bars represent one standard deviation.

Table 7. Estimated number of fish (*Oncorhynchus spp*.) per 1,000 feet by length group in the Rereg Section from 2001 to 2010 approximately 8 miles downstream from Libby Dam using mark-recapture techniques and partial log-likelihood estimator methods. No population estimate was completed in 2002 due to high water. An * indicates a lumped estimate for fish equal to or greater than the length category shown.

Length Category (mm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
75-99	0		0	1	0	0	0	0	2	5
100-124	4		8	19	0	15	26	4	1	6
125-149	36		1	18	3	16	24	5	26	10
150-174	38		35	8	4	16	79	37	74	23
175-199	49		40	17	14	37	99	46	71	26
200-224	23		50	25	20	55	80	59	53	25
225-249	20		22	16	27	37	36	56	28	15
250-274	2		8	10	25	25	26	41	15	15
275-299	4		4	7	19	18	19	44	7	28*
300-324	10		2	10	17	19	17	27	11*	
325-349	10		2	14*	31*	16*	16	23*		
350-374	5		7*				10*			
375-399	3									
400-425	4*									
Total per 1,000 ft	**208**		**179**	**145**	**160**	**254**	**432**	**343**	**290**	**153**

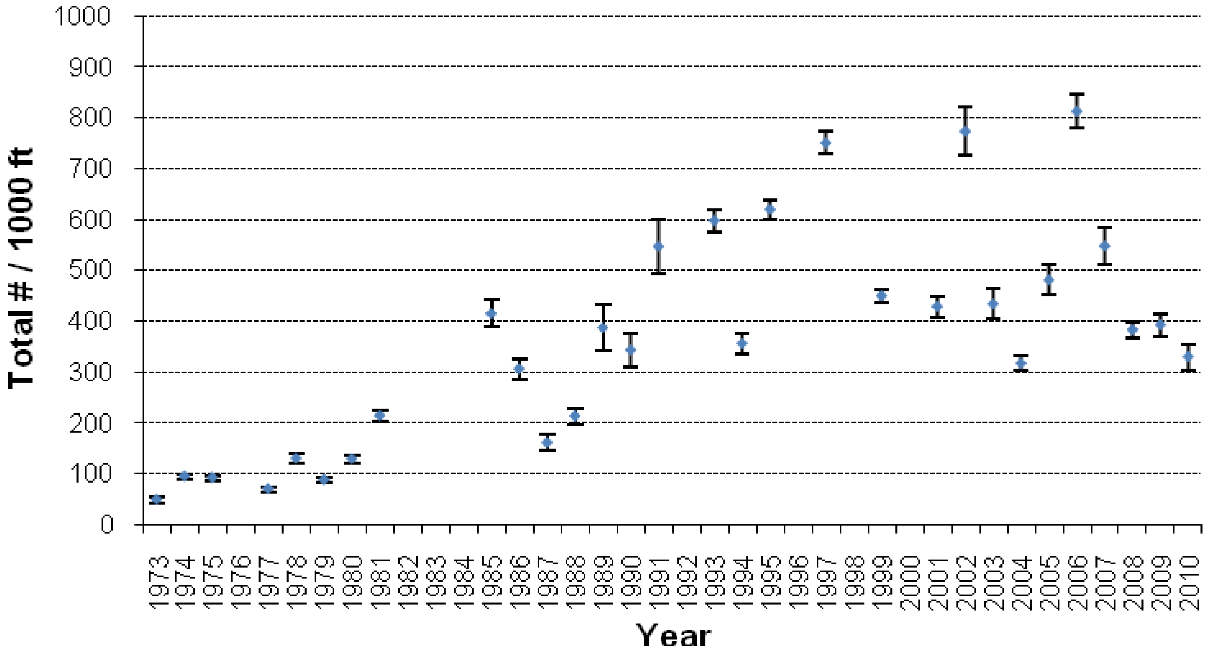


Figure 7. Estimated number of trout (rainbow and cutthroat) per 1,000 feet obtained from mark recapture population estimates in the Flower-Pipe section of the Kootenai River from 2001-2010. The whisker bars represent one standard deviation.

Table 8. Estimated number of fish (*Oncorhynchus spp*.) per 1,000 feet by length group in the Flower-Pipe Section from 2001 to 2010 approximately 15 miles downstream from Libby Dam using mark-recapture techniques and partial log-likelihood estimator methods. An * indicates a lumped estimate for fish equal to or greater than the length category shown.

Length Category (mm)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
100-124	27	0	2	2	1	5	3	4	6	3
125-149	87	33	14	2	6	55	12	58	44	30
150-174	99	252	36	23	47	162	50	117	94	59
175-199	69	264	126	34	135	269	119	90	99	85
200-224	58	143	108	69	137	171	155	37	64	58
225-249	33	46	58	86	65	54	103	28	45	44
250-274	19	18	46	53	31	32	49	17	21	20
275-299	13	9	26	20	26	19	57*	14	10	16
300-324	9	4	11	12	19	16		18*	5	6
325-349	15*	2	8*	16*	14*	29*			2	3
350-374		5*							1	5*
375-399									1*	
Total per 1,000 ft	**429**	**774**	**434**	**317**	**481**	**813**	**548**	**383**	**393**	**330**

References

Bouck, G.R. 1980. Etiology of gas bubble disease. Transactions of the American Fisheries Society 109:703-707.

Dunnigan, J.L, B. Marotz, J. DeShazer, L. Garrow, and T. Ostrowski. 2003. Mitigation for the construction and operation of Libby Dam: Annual report 2001-2002. Bonneville Power Administration. Portland, Oregon. Project Number 199500400.

Marotz, B, R., Sylvester, J. Dunnigan, T. Ostrowski, J. DeShazer, J. Wachsmuth, M. Benner, M. Hensler, and N. Benson. 2007. Incremental analysis of Libby Dam operation during 2006 and gas bubble trauma in Kootenai River fish resulting from spillway discharge. Montana Fish, Wildlife and Parks, Libby.

Ricker, W.E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin 119.

Robson, D.S., and H.A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Transactions of the American Fisheries Society 93:215-226.

U.S. Army Corps of Engineers. 2003. Total dissolved gas exchange at Libby Dam, Montana: June-July 2002. U.S. Army Engineer District, Seattle, Washington.

Weitkamp, D.E., and M. Katz. 1980. Dissolved Gas supersaturation-A review. Transactions of the American Fisheries Society 109(6):659-702.

Appendix

Table A1. Therriault Creek depletion population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis. If the upper confidence interval is not presented, it was not able to be calculated because all fish were captured on the first pass of the depletion. Therriault Creek was not sampled during the 2000 or 2002 field seasons, and only Section 2 was sampled in 2001.

Year	1997	1998	1999	2001	2003	2004	2005	2006	2007	2008
Section 1										
Rainbow Trout	123 (261)	130 (151)	82 (89)		56 (57)	108 (111)	106 (119)	121 (124)	53 (n/a)	135 (139)
Cutthroat Trout	0	0	0	Not	0	0	0	0	0	4 (n/a)
Brook Trout	41 (47)	49 (56)	60 (64)	Sampled	59 (66)	11 (13)	66 (73)	114 (120)	101 (104)	49 (55)
Bull Trout	0	0	0		0	92 (95)	10 (n/a)	48 (54)	28 (31)	4 (n/a)
Total Population[A]	149 (214)	182 (207)	141 (149)		115 (122)	200 (203)	175 (201)	235 (241)	154 (157)	187 (193)
Section 2										
Rainbow Trout	36 (41)	79 (82)	76 (83)	93 (102)	84 (n/a)	102 (107)	32 (34)	42 (43)	11 (n/a)	33 (34)
Cutthroat Trout	0	0	0	0	0	0	0	0	2 (n/a)	0
Brook Trout	56 (58)	125 (137)	72 (80)	82 (87)	58 (61)	24 (27)	67 (91)	46 (48)	40 (42)	37 (39)
Bull Trout	47 (49)	15 (16)	3 (n/a)	2 (n/a)	40 (42)	49 (53)	4 (n/a)	4 (n/a)	2 (n/a)	4 (n/a)
Total Population[A]	92 (96)	205 (217)	149 (163)	180 (193)	144 (151)	153 (160)	95 (107)	123 (125)	53 (55)	70 (73)
Section 3										
Rainbow Trout	54 (58)	164 (170)	177 (205)		99 (104)	112 (117)	99 (109)	28 (29)	15 (n/a)	54 (55)
Cutthroat Trout	0	0	0	Not	0	0	0	0	0	0
Brook Trout	74 (77)	82 (88)	110 (117)	Sampled	67 (72)	41 (45)	82 (90)	46 (48)	57 (59)	48 (51)
Bull Trout	0	0	0		10 (n/a)	3 (n/a)	15 (17)	2 (n/a)	4 (n/a)	7 (10)
Total Population[A]	66 (93)	248 (257)	284 (308)		170 (180)	118 (124)	183 (201)	74 (76)	72 (74)	102 (105)

A) Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.

Table A1 (Continued). Therriault Creek depletion population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis. If the upper confidence interval is not presented, it was not able to be calculated because all fish were captured on the first pass of the depletion. Therriault Creek was not sampled during the 2000 or 2002 field seasons, and only Section 2 was sampled in 2001.

Year	2009
Section 1	
Rainbow Trout	113 (115)
Cutthroat Trout	0
Brook Trout	134 (140)
Bull Trout	34 (42)
Total Population[A]	247 (252)
Section 2	
Rainbow Trout	29 (33)
Cutthroat Trout	0
Brook Trout	54 (55)
Bull Trout	7 (n/a)
Total Population[A]	83 (86)
Section 3	
Rainbow Trout	57 (60)
Cutthroat Trout	0
Brook Trout	59 (62)
Bull Trout	59 (62)
Total Population[A]	116 (120)

A) Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.

Table A2. Grave Creek Demonstration Project population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	2000[A]	2001[B]	2002[C]	2003	2004	2005	2006	2007	2008
Westslope Cutthroat	4	18	3	13 (n/a)	4 (n/a)	14 (15)	16 (17)	12 (13)	6 (n/a)
Rainbow Trout	1	17	26	25 (29)	41 (45)	63 (66)	25 (27)	10 (12)	14 (16)
Brook Trout	1	10	5	9 (18)	1(n/a)	3 (7)	4 (n/a)	3 (n/a)	0
Bull Trout	9	33	5	41 (144)	63 (67)	63 (66)	84 (87)	72 (84)	40 (43)
Mountain Whitefish	54	3	33	21 (22)	70 (73)	60 (62)	47 (48)	51 (52)	48 (50)

Year (Continued)	2009
Westslope Cutthroat	5 (7)
Rainbow Trout	3 (5)
Brook Trout	0
Bull Trout	80 (86)
Mountain Whitefish	10 (11)

A) Four bull trout ≥ 490 mm were likely lacustrine - adfluvial fish from Libby Reservoir moving into Grave Creek to spawn. Three bull trout < 75 mm were also included in the total.

B) Four bull trout ≥ 470 mm were likely lacustrine - adfluvial fish from Libby Reservoir moving into Grave Creek to spawn.

C) Due to the presence of approximately 2,000 mature kokanee, the section was snorkeled rather than electrofished. Two adult bull trout were observed that were likely lacustrine - adfluvial fish from Libby Reservoir moving into Grave Creek to spawn.

Table A3. Young Creek depletion population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Section 1 (Tooley)												
Cutthroat Trout[B]	3	36 (37)	139 (148)	Not	55 (64	88 (96)	Not	68 (70)	66 (72)	61 (63)	47 (51)	87 (95)
Rainbow Trout[B]	19 (23)	62 (70)	3 (n/a)	Sampled	2 (n/a)	14 (19)	Sampled	8 (n/a)	2 (n/a)	2 (n/a)	2 (n/a)	2 (n/a)
Brook Trout	11 (17)	120 (124)	102 (105)		36 (39)	30 (31)		20 (n/a)	72 (80)	30 (36)	20 (24)	41 (44)
Mountain Whitefish	0	0	0		0	2 (n/a)		2 (n/a)	4 (n/a)	2 (n/a)	0	0
Total Population [A]	36 (40)	220 (228)	248 (258)		96 (107)	148 (158)		96 (98)	86 (96)	95 (101)	67 (71)	130 (138)
Section 4 (303 Rd.)												
Westslope Cutthroat	100 (114)	439 (500)	352 (367)	Not	130 (142)	222 (237)	Not	218 (228)	327 (351)	323 (337)	165 (170)	382 (398)
Rainbow Trout	0	0	0	Sampled	0	0	Sampled	0	0	2 (n/a)	0	0
Brook Trout	0	0	3 (n/a)		6 (12)	4 (n/a)		10 (12)	12 (17)	26 (30)	5 (11)	38 (43)
Bull Trout	0	0	0		0	0		0	0	0	1 (n/a)	0
Total Population [A]	100 (114)	439 (500)	358 (373)		136 (148)	232 (249)		230 (241)	338 (364)	351 (366)	169 (174)	423 (440)
Section 5 (State)												
Westslope Cutthroat	Not	216 (227)	256 (290)	126 (153)	153 (174)	268 (290)	178 (183)	115 (118)	151 (164)	137 (143)	57 (60)	174 (191)
Rainbow Trout	Sampled	0	0	0	0	0	0	0	0	0	0	0
Brook Trout		62 (71)	52 (65)	19 (22)	25 (27)	46 (49)	35 (n/a)	60 (63)	142 (147)	93 (96)	57 (60)	71 (77)
Bull Trout		0	0	0	0	2 (n/a)	0	3 (n/a)	2 (n/a)	3 (5)	2 (n/a)	0
Total Population [A]		280 (294)	314 (353)	113 (119)	176 (195)	315 (335)	213 (183)	230 (241)	296 (309)	115 (122)	115 (122)	245 (265)

A) Includes rainbow, rainbow x cutthroat hybrids, westslope cutthroat, and brook trout. Bull trout were not included in the total population estimate.
B) Sampling crew did not distinguish between westslope cutthroat trout and rainbow trout.

Table A3 (Continued). Young Creek depletion population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	2009[C]
Section 1 (Tooley)	
Cutthroat Trout[B]	38 (42)
Rainbow Trout[B]	21 (23)
Brook Trout	45 (46)
Mountain Whitefish	0
Total Population [A]	104 (108)
Section 4 (303 Rd.)	
Westslope Cutthroat	339 (349)
Rainbow Trout	0
Brook Trout	33 (37)
Bull Trout	0
Total Population [A]	374 (384)
Section 5 (State)	
Westslope Cutthroat	90 (98)
Rainbow Trout	0
Brook Trout	64 (82)
Bull Trout	2 (n/a)
Total Population [A]	154 (170)

[A] Includes rainbow, rainbow x cutthroat hybrids, westslope cutthroat, and brook trout. Bull trout were not included in the total population estimate.
[B] Sampling crew did not distinguish between westslope cutthroat trout and rainbow trout.
[C] .An estimated 23 bull trout were also estimated (per 1,000 feet) in Section 1.

Table A4. Libby Creek depletion population estimates for fish $\geq$ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	1998	1999[A]	2000[A]	2001	2002	2003	2004	2005	2006	2007	2008
Section 1 – below Hwy 2											
Rainbow Trout	81 (127)	26	125	46 (51)	117 (130)	84 (96)	113 (118)	169 (191)	271 (293)	174 (422)	80 (88)
Brook Trout	6 (8)	6	13	10 (12)	16 (24)	5	9 (15)	57 (64)	26 (27)	19 (n/a)	20 (29)
Bull Trout	0	0	0	0	3	0	1 (n/a)	1 (n/a)	0	0	0
Mountain Whitefish	0	0	0	0	3	1	0	0	0	1 (n/a)	0
Total Population [B]	90 (116)	32	138	57 (64)	138 (153)		138 (144)	227 (256)	296 (317)	261 (615)	102 (113)
Section 2 –above Hwy 2											
Rainbow Trout	203 (225)	Not	Not	148 (193)	Not	100 (108)	120 (128)	76 (92)	117 (122)	98 (120)	132 (142)
Brook Trout	7	Sampled	Sampled	2	Sampled	2	30 (34)	25 (28)	19 (20)	23 (25)	9 (11)
Bull Trout	5 (6)			0		2.08	0	2 (n/a)	2 (n/a)	0	4 (n/a)
Total Population [B]	208 (228)			160 (213)			150 (160)	105 (116)	135 (141)	123 (139)	141 (151)
Section 3 – upper Cleveland											
Rainbow Trout	Not	Not	170 (194)	172 (182)	163 (183)	112.3 (127)	88 (104)	63 (75)	105 (110)	30 (34)	199 (227)
Brook Trout	Sampled	Sampled	0	0	0	0	0	0	0	0	0
Bull Trout			3	8 (11)	7	11 (14)	2 (n/a)	2 (n/a)	3 (n/a)	0	0
Mountain Whitefish			0	0	1	0	0	0	0	0	0
Total Population [B]			170 (194)	172 (182)	163 (183)		88 (104)	63 (75)	105 (110)	30 (34)	199 (227)

[A] Section 1 population estimates in 1999 and 2000 were single pass catch–per-unit-effort estimates due to high escapement rates. Actual population is higher than reported.

[B] Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.

Table A4 (Continued). Libby Creek depletion population estimates for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	2009
Section 1 – below Hwy 2	
Rainbow Trout	87 (96)
Brook Trout	39 (42)
Bull Trout	11 (n/a)
Mountain Whitefish	0
Total Population [B]	131 (141)
Section 2 –above Hwy 2	
Rainbow Trout	78 (86)
Brook Trout	17 (21)
Bull Trout	2 (n/a)
Total Population [B]	97 (107)
Section 3 – upper Cleveland	
Rainbow Trout	207 (239)
Brook Trout	0
Bull Trout	0
Mountain Whitefish	0
Total Population [B]	207 (239)

[A] Section 1 population estimates in 1999 and 2000 were single pass catch–per-unit-effort estimates due to high escapement rates. Actual population is higher than reported.
[B] Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.

Table A4 (Continued). Libby Creek depletion population estimates for fish > 75 mm per 1,000 feet using 95 % confidence intervals. Upper confidence intervals are in parenthesis.

Year	2004	2005	2006	2007	2008	2009
Section 4 – below lower Cleveland						
Rainbow Trout	352 (365)	273 (283)	314 (324)	141 (148)	289 (305)	351 (374)
Brook Trout	0	2 (n/a)	2 (n/a)	1 (n/a)	4 (n/a)	4 (n/a)
Bull Trout	5 (n/a)	0	0	1 (n/a)	2 (n/a)	2 (n/a)
Total Population[A]	355 (368)	276 (286)	316 (326)	143 (150)	291 (306)	356 (379)
Section 5 –above lower Cleveland						
Rainbow Trout	172 (185)	173 (183)	170 (177)	129 (144)	406 (431)	201 (213)
Brook Trout	0	0	0	0	0	2 (n/a)
Bull Trout	6 (n/a)	0	0	2 (n/a)	0	6 (9)
Total Population[A]	172 (185)	173 (183)	170 (177)	129 (144)	406 (431)	203 (215)
Section 6 – lower Cleveland						
Rainbow Trout	218 (234)	221 (250)	273 (298)	133 (158)	213 (235)	209 (219)
Brook Trout	1 (n/a)	0	0	6 (9)	2 (n/a)	2 (n/a)
Bull Trout	0	4 (n/a)	0	0	2 (n/a)	0
Total Population [A]	219 (235)	221 (250)	273 (298)	141 (169)	215 (237)	213 (226)

[A] Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.

Table A5. Pipe Creek depletion population estimate for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals surveyed directly downstream of the Bothman Road Bridge. Upper confidence intervals are in parenthesis.

Year	2001	2002[B]	2003	2004	2005	2006	2007	2008	2009
Rainbow Trout	42 (46)	73 (85)	39 (43)	25 (27)	21 (25)	69 (73)	54 (59)	69 (73)	119 (133)
Brook Trout	0	3	7 (8)	4 (n/a)	6 (10)	15 (n/a)	5 (n/a)	0	5 (n/a)
Bull Trout	0	0	0	0	0	2 (n/a)	0	0	0
Total Population [A]	42 (46)	73 (85)	0	27 (29)	27 (31)	83 (85)	59 (64)	69 (73)	121 (133)

[A] Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.
[B] Also captured were 43 mountain whitefish ranging from 51 to 105 millimeters and one pumpkinseed sunfish 74 millimeters long.

Table A6. Mean zooplankton densities (no./l) (top line) and variances (bottom line) estimated from 10-20 m. vertical tows made in the Tenmile area of Libby Reservoir during 2009. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**Sample Size**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclop***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	3	0.05	0.06	0.01	2.10	0.00	1.41	0.00
		0.00	0.00	0.00	2.87	0.00	5.99	0.00
May	3	0.77	0.72	0.68	36.98	0.47	174.47	0.00
		0.11	1.54	0.26	614.30	0.66	24,080.52	0.00
June	3	0.98	4.45	0.08	23.53	3.77	0.00	0.01
		0.02	15.11	0.01	144.09	6.19	0.00	0.00
July	3	1.94	0.23	1.04	8.83	3.06	195.97	0.12
		0.16	0.01	0.11	4.80	1.16	20,670.57	0.01
August	3	0.21	0.02	0.58	6.09	0.00	128.45	0.04
		0.02	0.00	0.01	5.19	0.00	3,579.88	0.00
September	3	1.68	0.40	0.99	7.08	0.24	58.47	0.11
		6.20	0.28	1.19	15.62	0.17	3,212.52	0.03
October	3	0.57	0.76	0.63	4.78	0.00	7.92	0.01
		0.03	0.27	0.10	3.05	0.00	188.34	0.00
November	3	0.40	1.92	0.32	4.35	0.00	12.64	0.01
		0.01	2.07	0.00	2.12	0.00	142.96	0.00

Table A7. Mean zooplankton densities (no./l) (top line) and variances (bottom line) estimated from 10-20 m. vertical tows made in the Rexford area of Libby Reservoir during 2009. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**Sample Size**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclop***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	3	0.08	0.60	0.01	7.98	0.00	0.00	0.00
		0.00	0.23	0.00	8.65	0.00	0.00	0.00
May	3	0.27	2.40	0.45	16.40	5.38	445.39	0.01
		0.01	0.77	0.11	32.85	75.88	52,302.46	0.00
June	3	2.32	7.27	0.08	9.31	6.60	43.38	0.04
		1.29	8.43	0.00	37.95	0.66	372.93	0.00
July	3	2.48	0.10	0.75	7.15	6.37	85.47	0.30
		0.44	0.00	0.00	32.94	0.50	3,641.00	0.02
August	3	0.16	0.01	0.51	2.63	0.24	68.84	0.00
		0.00	0.00	0.03	0.13	0.17	1,803.82	0.00
September	3	2.43	0.66	1.24	7.20	0.00	16.55	0.17
		0.21	0.14	0.01	1.08	0.00	214.64	0.00
October	3	0.23	1.45	0.40	3.65	0.00	0.00	0.00
		0.00	1.70	0.01	0.03	0.00	0.00	0.00
November	3	0.40	1.67	0.38	2.96	0.00	0.00	0.00
		0.08	1.71	0.03	0.33	0.00	0.00	0.00

Table A8. Mean zooplankton densities (no./l) (top line) and variances (bottom line) estimated from 10-20 m. vertical tows made in the Canada area of Libby Reservoir during 2009. *Epischura* and *Leptodora* were measured as number per m^3. The Canada area was not sampled in April 2009.

Month	**Sample Size**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclop***	***Leptodora***	***Epischura***	***Diaphanosoma***
May	3	0.01	0.73	0.03	1.51	0.00	59.42	0.01
		0.00	1.37	0.00	6.12	0.00	9,133.74	0.00
June	3	9.17	3.81	0.49	13.61	7.77	0.86	0.12
		59.65	31.77	0.19	169.94	12.25	2.20	0.02
July	3	0.51	0.01	0.02	0.31	0.00	0.00	0.15
		0.56	0.00	0.00	0.07	0.00	0.00	0.06
August	3	0.33	0.00	0.59	2.83	0.47	167.40	0.01
		0.01	0.00	0.02	0.04	0.17	10,931.39	0.00
September	3	3.16	0.28	0.98	4.04	0.67	15.66	0.12
		5.76	0.00	0.04	0.72	1.36	281.96	0.01
October	3	0.63	0.92	0.72	3.36	2.12	1.70	0.00
		0.04	0.52	0.10	5.60	9.51	8.64	0.00
November	3	4.37	1.53	2.51	5.83	0.47	11.73	0.02
		25.25	2.90	5.95	14.54	0.66	160.73	0.00

Table A9. Yearly mean total zooplankton densities (no./l) (top line) and variances (bottom line) estimated from 10-20 m. vertical tows made in Libby Reservoir. *Epischura* and *Leptodora* were measured as number per m^3.

Year	(N)	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epishura***	***Diaphanosoma***
1997	69	2.80	0.07	0.80	6.10	4.34	57.24	0.08
		11.30	0.01	0.88	50.87	108.72	6,013.80	0.02
1998	72	2.17	0.64	2.22	9.35	3.99	131.58	0.36
		4.00	1.80	9.17	64.33	80.92	47,113.37	0.43
1999	57	2.19	0.77	0.51	9.57	6.63	89.41	0.15
		4.53	1.39	2.35	107.88	148.11	14,367.63	0.05
2000	69	1.07	0.51	0.36	8.04	2.72	51.20	0.05
		0.97	1.06	0.20	80.04	14.05	7,153.52	0.01
2001	72	1.58	0.46	0.46	8.39	2.72	63.72	0.22
		2.77	0.46	0.21	59.53	21.18	11,153.71	0.13
2002	56	1.82	0.65	0.39	8.89	4.88	77.96	1.02
		6.85	1.29	0.22	57.44	139.73	9,041.90	3.62
2003	72	3.42	0.83	1.79	11.34	2.24	98.02	0.90
		20.29	1.93	4.46	64.61	19.74	19,825.83	1.68
2004	72	2.10	1.63	1.38	10.26	3.39	95.06	0.53
		6.70	8.72	3.21	169.71	29.53	37,077.33	0.88
2005	72	1.50	2.62	0.51	7.74	2.43	91.36	0.30
		4.05	37.88	0.59	80.18	26.13	15,412.56	0.19
2006	63	1.81	1.09	1.37	9.10	2.78	121.03	0.23
		2.65	3.42	2.24	69.20	16.67	28,439.64	0.16
2007	54	1.48	0.87	0.68	8.84	1.83	139.38	0.10
		2.19	2.53	0.92	112.66	12.33	50,542.01	0.06
2008	72	1.90	2.23	0.64	11.83	2.25	52.03	0.06
		6.30	10.10	1.11	124.81	13.14	6,960.08	0.02
2009	69	1.44	1.30	0.59	7.94	1.64	65.03	0.05
		7.02	5.04	0.54	98.31	9.44	14,266.98	0.01

Table A10. Mean annual fine sediment (<6.35 mm) in eight Montana bull trout spawning tributaries of the Kootenai River. 95% confidence intervals are presented in parenthesis.

Stream	Year	Sample Size	Mean % Fine Sediment
N. Fork Keeler Crk.	1998	12	32.7 (23.6 - 42.4)
N. Fork Keeler Crk.	1999	0	N/A
N. Fork Keeler Crk.	2000	11	22.8 (17.5 – 28.5)
N. Fork Keeler Crk.	2001	12	29.5 (25.9 – 33.3)
N. Fork Keeler Crk.	2002	12	31 (26.4 – 35.8)
N. Fork Keeler Crk.	2003	12	36.7 (28.1 – 45.7)
N. Fork Keeler Crk.	2004	12	36.2 (30.1 – 42.6)
N. Fork Keeler Crk.	2005	12	30.3 (25 – 36)
N. Fork Keeler Crk.	2006	12	23.9 (14.4 – 34.9)
N. Fork Keeler Crk.	2007	12	28.4 (20.2 – 37.3)
N. Fork Keeler Crk.	2008	12	18.0 (14.2– 22.1)
N. Fork Keeler Crk.	2009	12	20.6 (18.1 - 23.2)
N. Fork Keeler Crk.	2010	12	15.4 (12.0 – 19.1)
O’Brien Crk.	1998	12	42.1 (38.5 – 45.7)
O’Brien Crk.	1999	0	N/A
O’Brien Crk.	2000	0	N/A
O’Brien Crk.	2001	12	34 (30.4 – 37.8)
O’Brien Crk.	2002	12	39.8 (35.3-44.4)
O’Brien Crk.	2003	12	43 (37.9 – 48.2)
O’Brien Crk.	2004	12	43.3 (40.6 – 45.9)
O’Brien Crk.	2005	12	46.1 (41.9 – 50.3)
O’Brien Crk.	2006	12	40 (35.4-44.9)
O’Brien Crk.	2007	12	36.8 (30.7-43.2)
O’Brien Crk.	2008	12	21.6 (15.7 – 28.1)
O’Brien Crk.	2009	12	29.2 (26.7 – 31.7)
O’Brien Crk.	2010	12	27.6 (23.6 – 31.9)
W. Fork Quartz Crk.	1998	8	37.5 (30.7 – 44.6)
W. Fork Quartz Crk.	1999	0	N/A
W. Fork Quartz Crk.	2000	0	N/A
W. Fork Quartz Crk.	2001	11	37.3 (32.8 – 42)
W. Fork Quartz Crk.	2002	12	24.6 (18.3 – 31.5)
W. Fork Quartz Crk.	2003	12	34.1 (31.7 – 36.6)
W. Fork Quartz Crk.	2004	8	36.7 (31.2 – 44.3)
W. Fork Quartz Crk.	2005	8	30.6 (23.3 – 38.4)
W. Fork Quartz Crk.	2006	12	32.3 (27.9 – 36.8)
W. Fork Quartz Crk.	2007	0	N/A
W. Fork Quartz Crk.	2008	12	28.2 (23.9 – 32.8)
W. Fork Quartz Crk.	2009	8	20.7 (16.4 – 25.3)
W. Fork Quartz Crk.	2010	10	24.1 (19.2 – 29.3)
Bear Crk.	1998	0	N/A
Bear Crk.	1999	0	N/A
Bear Crk.	2000	0	N/A

Table A10 (continued). Mean annual fine sediment (<6.35 mm) in eight Montana bull trout spawning tributaries of the Kootenai River. 95% confidence intervals are presented in parenthesis.

Stream	Year	Sample Size	Mean % Fine Sediment
Bear Crk.	2001	0	N/A
Bear Crk.	2002	8	34.5 (30.5 – 38.6)
Bear Crk.	2003	8	28.3 (19.3 – 38.2)
Bear Crk.	2004	12	42.5 (38 – 47.4)
Bear Crk.	2005	12	39 (33.9 – 44.2)
Bear Crk.	2006	8	38.7 (28.7 – 49.2)
Bear Crk.	2007	0	N/A
Bear Crk.	2008	12	15.9(10.7 – 21.9)
Bear Crk.	2009	12	25.8 (22.7 – 29.0)
Bear Crk.	2010	8	24.3 (19.3 – 29.7)
Pipe Crk.	1998	10	47 (41.4 – 52.6)
Pipe Crk.	1999	10	35.3 (26.5 – 44.7)
Pipe Crk.	2000	0	N/A
Pipe Crk.	2001	12	33.3 (25.9 – 41.2)
Pipe Crk.	2002	12	38.5 (33.2 – 45.7)
Pipe Crk.	2003	12	39.8 (31.1 – 43.4)
Pipe Crk.	2004	12	37.1 (31 – 43.4)
Pipe Crk.	2005	12	38.1 (33.6 – 42.6)
Pipe Crk.	2006	12	38 (32.8 – 43.2)
Pipe Crk.	2007	0	N/A
Pipe Crk.	2008	12	23.1 (16.6 – 30.3)
Pipe Crk.	2009	12	29.3 (25.8 – 32.8)
Pipe Crk.	2010	12	34.6 (31.0 – 38.3)
West Fisher Crk.	1998	0	N/A
West Fisher Crk.	1999	0	N/A
West Fisher Crk.	2000	0	N/A
West Fisher Crk.	2001	0	N/A
West Fisher Crk.	2002	0	N/A
West Fisher Crk.	2003	0	N/A
West Fisher Crk.	2004	0	N/A
West Fisher Crk.	2005	0	N/A
West Fisher Crk.	2006	12	32.3 (25.9 – 39.1)
West Fisher Crk.	2007	0	N/A
West Fisher Crk.	2008	12	9.7 (6.4 – 13.7)
West Fisher Crk.	2009	12	30.4 (26.3 – 34.7)
West Fisher Crk.	2010	12	26.0 (21.5 – 30.8)
Grave Crk.	1998	12	28.8 (23.3 – 34.5)
Grave Crk.	1999	0	N/A
Grave Crk.	2000	11	29.8 (19.4 – 41.5)
Grave Crk.	2001	7	32.7 (25.6 – 40.3)
Grave Crk.	2002	10	33.6 (27.1 – 40.6)

Table A10 (continued). Mean annual fine sediment (<6.35 mm) in eight Montana bull trout spawning tributaries of the Kootenai River. 95% confidence intervals are presented in parenthesis.

Stream	**Year**	**Sample Size**	**Mean % Fine Sediment**
Grave Crk.	2003	12	36.4 (33.2 – 39.6)
Grave Crk.	2004	12	36.8 (31.7 – 42)
Grave Crk.	2005	12	30.7 (25.4 – 36.3)
Grave Crk.	2006	12	29.1 (23.9 – 34.6)
Grave Crk.	2007	0	N/A
Grave Crk.	2008	12	30.2 (24.5 – 36.3)
Grave Crk.	2009	12	26.6 (22.1 – 31.4)
Grave Crk.	2009	12	29.2 (25.0 – 33.6)
Wigwam River (MT)	1998	6	34.2 (29 – 39.7)
Wigwam River (MT)	1999	3	36.6 (25 –49)
Wigwam River (MT)	2000	6	32.6 (27 – 38.6)
Wigwam River (MT)	2001	0	N/A
Wigwam River (MT)	2002	0	N/A
Wigwam River (MT)	2003	0	N/A
Wigwam River (MT)	2004	12	38.3 (34.1 – 43.5)
Wigwam River (MT)	2005	8	33.9 (26 – 42.1)
Wigwam River (MT)	2006	12	32 (22.8 – 42.1)
Wigwam River (MT)	2007	12	30.6 (26.9 – 34.3)
Wigwam River (MT)	2008	12	20.5 (17.3 – 23.9)
Wigwam River (MT)	2009	10	25.4 (19.9 – 32.4)
Wigwam River (MT)	2010	7	27.9 (21.3 – 35.0)

Appendix Exhibit A.

Surveyor(s) ____

Survey Date: ____

Page # ______ of ______

Start / End Times:__________/_________

Angler Records									Rainbow Trout				Cutthroat Trout				Bull Trout			Other			Count Data	
Bank Interview Location (**1**=Blackwell, **2** = Alexander, **3** =Dam **4**=Dredge cuts; 5 = Dunn Crk.)	Shore **(S)** / Boat (**B**) Angler	Lincoln County **(Y/N)**	Other Montana **(Y/N)**	Out of State **(Y/N)**	Trip Status (**I**=Incomplete, **C**=Complete)	Start Fishing Time	End Fishing **or** InterviewTime	Gear Type (**L** = Lure, **B**=Bait, **F**=Fly)	# Caught / # Kept				# Caught / # Kept				# Caught			(list spp in notes)		Indicate if scales or fin clips taken	Count of Other Anglers not interviewed	Count of boats observed not interviewed
									< 13"	13-18"	18-24"	> 24"	< 13"	13-18"	18-24"	> 24"	< 13"	13-24"	> 24"	# Caught	# Kept			

Notes: ____

____

____

Appendix Exhibit B

Montana Department of Environmental Quality
Total Dissolved Gas Waiver Letter

Montana Department of
ENVIRONMENTAL QUALITY

Brian Schweitzer, Governor
Richard H. Opper, Director

P.O. Box 200901 • Helena, MT 59620-0901 • (406) 444-2544 • www.deq.mt.gov

24 March 2010

Ken Brunner, Environmental Resources Section
US Army Corps of Engineers
Seattle District
PO Box 4735
Seattle WA 98124

Dear Mr Brunner,

This letter is notice of a temporary waiver of Montana's Total Dissolved Gas ("TDG") standard on the Kootenai River. This waiver is specifically limited to the spill test planned for the spring/summer of 2010 as specified in the stipulated settlement agreement that was filed September 2, 2008, in the Missoula Division of the United States District Court for the District of Montana, Case No. CV 03-29 DWM, Center for Biological Diversity and Wildwest Institute v. US Fish and Wildlife Service (USFWS) and Army Corps of Engineers (ACOE)("the Agreement").

This waiver responds to the USFWS determination that interim operations have been unsuccessful in meeting sturgeon recovery goals under provision 4 of the Agreement. This determination was relayed in a mid-December 2009 letter from Jeff Foss of the USFWS to Olton Swanson of the ACOE.

Per the Agreement, Montana hereby waives its TDG water quality standard on the Kootenai River, currently set at 110%, for the limited purpose of allowing voluntary spill from Libby Dam for the benefit of ESA-listed sturgeon (the "Spill Test").

The waiver of Montana's TDG water quality standard will be subject to the following conditions existing and continuing throughout the term of the Spill Test as specified in provision 5 of the Agreement:

a. This waiver of Montana's TDG water quality limit issued by the Montana Department of Environmental Quality (DEQ) shall be solely for the purpose of allowing the Spill Test described herein to go forward without violating Montana's Water Quality Act (The "Waiver");
b. The Waiver shall not be interpreted as having any application beyond the Agreement, nor shall anyone use, rely upon, cite or repeat the fact of the Waiver as legal or factual precedent for any proposition in this matter or any other, including as support for a future waiver request by any entity or person, or as an indication of the biological, technical or

legal merit of such a waiver request, except as may be necessary to evaluate the efficacy of the Spill Test;
c. Water temperature shall be maintained at or above 8 degrees centigrade, as measured at the USGS gauge at river mile 221.3, downstream of Libby Dam;
d. Tagged sturgeon must be documented at or upstream of Ambush Rock;
e. The Spill Test will be targeted in the minimum amount of 5,000 cfs, potentially to a maximum of 10,000 cfs;
f. Notwithstanding the Waiver, in order to reduce the incidence of gas bubble trauma (GBT) in bull trout and other resident fish, TDG in excess of Montana's water quality standard of 110% caused by the Spill Test shall be limited to seven (7) days during calendar year 2010, excluding any unforeseen flood control measures that do not coincide with sturgeon related spills intended to satisfy the objectives of the Agreement;
g. TDG during the Spill Test shall never exceed a standard of 123%, measured as follows:

1. The specific location of the compliance point will be located at 20% "normalized distance" from left bank (looking downstream) at RM 221.3. The following explanation is provided, to avoid any misunderstand and to unequivocally pinpoint the intent of the Waiver: During interagency planning meetings to prepare for the upcoming Spill Test, a question arose as to the exact location of the TDG compliance point in the river cross-section at RM 221.3, as explained in a 11 December 2009 letter from the State of Montana to Ken Brunner of the ACOE and Jason Flory of the USFWS. In response, the multi-agency TDG Technical Team held a meeting 6 January 2010 in Bonners Ferry, Idaho, and mutually agreed that the specific location of the compliance point be located at 20% "normalized distance" from left bank at RM 221.3. This position was subsequently endorsed by consensus on 19 January 2010 at the Flow Plan Implementation Protocol Policy Team meeting held in Portland Oregon;
2. The TDG measurement instrumentation at the compliance location described in the preceding paragraph shall be placed at or below the compensation point of 7.6 feet below the surface of the water;
3. Exceedance of 123% of Montana's TDG standard shall be determined by calculating the average of the 12 highest hourly readings in any 24 hour period immediately preceding the calculation.

h. If fish mortality from GBT is observed in any Kootenai River trout, the Spill Test shall be reduced to maintain TDG at or below 120%, for any remainder of the seven (7) day period during which TDG in excess of the 110% TDG cap is waived; and
i. Notwithstanding the foregoing, if the Spill Test is demonstrably harming sturgeon or other fish at a population level, significantly impeding the ability to maintain a gradual decline in flow after the spring pulse, or causing the Kootenai River to exceed flood control limits at Bonners Ferry, Idaho, or below Libby Dam, the Spill Test shall immediately cease. Population level impact will be determined as follows:

1. Population level impact is assumed to occur when numbers of dead or distressed fish are observed and are equal to or greater than 2% for bull trout, and

1% for rainbow trout and mountain whitefish, of the Montana Department of Fish Wildlife and Parks's ("MFWP") most recent population estimates;

2. Applying the criteria defining population level impact yields the following fish numbers: bull trout = 4, rainbow trout = 54, and mountain whitefish = 178.

3. The numbers of fish identified in the preceding paragraph may be adjusted as appropriate based on more recent MFWP fish population estimates that may occur prior to the Spill Test. If this adjustment occurs, DEQ will notify the ACOE in writing.

Further explanation of how the above conditions will be determined are found in the "Libby Dam 2010 Spill Test Final Draft Biological and Physical Monitoring Plan" dated 17 March 2010.

Sincerely,

Robert J. Bukantis

Bob Bukantis
Water Quality Standards Section Supervisor

CC: Richard Opper- DEQ
Joe Maurier- MFWP
Bruce Measure- Northwest Power and Conservation Council
Rhonda Whiting- Northwest Power and Conservation Council
David Ponganis- US Army Corps of Engineers
Olton Swanson- US Army Corps of Engineers
Holly Harwood- BPA
Sue Ireland- KTOI
Bruce Rich- MFWP
Dave Risley-MFWP
Rich Torquemada- US FWS
Jeff Foss- US FWS Boise Office
Daniel Spear- Bonneville Power Administration
Kim Johnson-US Army Corps of Engineers