Libby Mitigation Program

Mitigation for the Construction and Operation of Libby Dam

Annual Progress Report

2005

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MITIGATION FOR THE CONSTRUCTION AND OPERATION OF LIBBY DAM

ANNUAL REPORT
2005
(Work Activities July 1, 2005 – June 30, 2006)

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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 2005 to June 2006.

- Bull trout redd counts in Grave Creek and the Wigwam River have significantly increased since 1995. However, bull trout redds in the Wigwam River, an important index tributary located upstream of Libby Dam were lower, only 36.6% of the previous five year average. The large decline in the Wigwam River may have been attributable to a large landslide that blocked upstream passage. Bull trout redd counts in tributaries downstream of Libby Dam including Quartz, Pipe, Bear, and O'Brien creeks, and the West Fisher River have been variable over the past several years, and have not increased in proportion to bull trout redd counts upstream of Libby Dam in recent years.

- MFWP conducted an adult bull trout population estimate below Libby Dam during April 2006. We estimated 176 adult bull trout (95% Confidence Interval = 73-279 fish) were present within this three-mile section of the Kootenai River. This estimate was approximately 20% of similar estimates the previous two years. We recaptured 13 bull trout in April 2006 that were individually marked from 363 – 740 days earlier, which enabled us to calculate growth rates over the period. On average the bull trout grew 113.3 mm (total length) and gained 1,803 g from the time of tagging.

- MFWP monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994. We failed to capture any burbot during the 05/06 trapping season, which represented the lowest catch per effort since we began trapping this site.

The catch of burbot at this location has exhibited a significant exponential decline since 1994.

- We conducted juvenile salmonid population estimates within reference reaches on Therriault, Grave, Young, Libby, and Pipe creeks. Trend analyses related to stream restoration projects are presented for Grave, Young and Libby creeks.

- MFWP has documented the changes in 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. The average fall catch, length and weight of kokanee was lower for the sixth straight year than the 18-year average. The spring gill net catch of bull trout significantly increased since 1990. The catch of Kamloops rainbow trout in fall floating gillnets was significantly and positively correlated with the number of hatchery Kamloops rainbow trout stocked in the reservoir the previous year. 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. Although this adjustment substantially improved the regression model's fit to the data in previous years, it did not improve the fit with the addition of the 2005 and 2006 data. Bull trout redd counts in both the Wigwam River and Grave Creek are both significantly and positively correlated to the spring gill net catch rates for bull trout adjusted for reservoir elevation.

- 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. For the first time since 1997, *Bosmina* replaced Daphnia as the second most abundant genera of zooplankton within the reservoir.

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 past two years, MFWP has implemented several projects to mitigate a portion of the losses attributable to the construction and operation of Libby Dam. This report summarizes the monitoring MFWP conducted in 2005 to evaluate the effectiveness of five stream restoration projects.

- The Grave Creek Phase I Restoration Project was completed in the fall of 2002, and changed the dimension, pattern and profile of this section of Grave Creek, which increased the overall stream length and created a deeper and narrow stream channel with increased pool habitat. We continued to monitor this project to ensure these physical changes were sustained through time. We found no evidence that stream channel dimensions significantly changed within the riffle habitat, with annual changes generally <10% between 2003 and 2005. The total number of pools, mean length and total pool surface area decreased (8.9-19.6%) from 2004 to 2005. However pool mean width, and maximum depth increased slightly (<5%) from 2004 to 2005.

- The Grave Creek Phase II Restoration Project was completed in the fall of 2004. To evaluate project performance, we collected stream channel dimensions prior to construction, shortly after construction (as built) and again after the first spring freshet in the spring of 2005. Within the riffle habitats, this project decreased bankfull width (~40%) and width to depth ratio (56-62%). Mean bankfull width increased in 2004 and 2005 relative to existing conditions. This project also increased the quantity and quality of pool habitat within the project area. Total pool number and volume showed the largest increases relative to existing conditions. Physical changes to stream channel dimensions changed slightly (generally <10%) after the first spring freshet. However, the total number of pools showed the largest relative change decreasing by 28.6%.

- The Libby Creek Upper Cleveland Restoration Project was completed in the fall of 2002, and restored 3,200 feet of stream channel. Previous monitoring 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. We evaluated the effectiveness of these restoration activities by comparing physical habitat parameters over time. The riffle dimensions within this project have not significantly differed from the as-built dimensions in either 2003 or 2005, with relative changes generally less than 10%. Pool mean bankfull depth and width declined from 2003 to 2005. However, maximum bankfull depth and mean length increased from 2003 to 2005. Much of the total pool volume reduction from 2003 to 2005 is attributable to the complete filling of two pools during this period.

- 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 (stream length divided by valley length) from 1.1 to 1.6, and subsequently increased total stream length from approximately 2,700 to 3,200 feet. This project increased the quantity and quality of pool habitat within the project area. Total pool volume exhibited a 4.2 fold increase from 2004 to 2005; total pool area increased by 2.9 fold. Pool mean and maximum depth also increased to lesser extents of 22.3 and 26.2%, respectively. The stream channel that resulted from this restoration project was significantly narrower, decreasing from 69.8 feet to 34.1 feet (51.1% reduction). The stream channel dimensions within the riffle habitats also changed as a result of this project. Mean and maximum riffle depth increased and width and width to depth ratio decreased.

- 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, with an overall increase in cross sectional area and bankfull width, and maximum depth, and a decrease in overall bankfull depth. Pool dimensions and numbers changed little since construction (generally < 10%) within the project area.

ACKNOWLEDGEMENTS

We are thankful to the many people that substantially contributed to this project. Mike Hensler, Neil Benson, and Ryan Sylvester helped with field data collection, data entry and proofing, and lab processing. Joel Tohtz provided thoughtful review of this report. 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 Joe DeHerrera and Cecilia Brown.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1 FIGURES

CHAPTER 2 FIGURES

LIST OF TABLES

CHAPTER 1 TABLES

CHAPTER 2 TABLES

APPENDIX TABLES

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 research be 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.

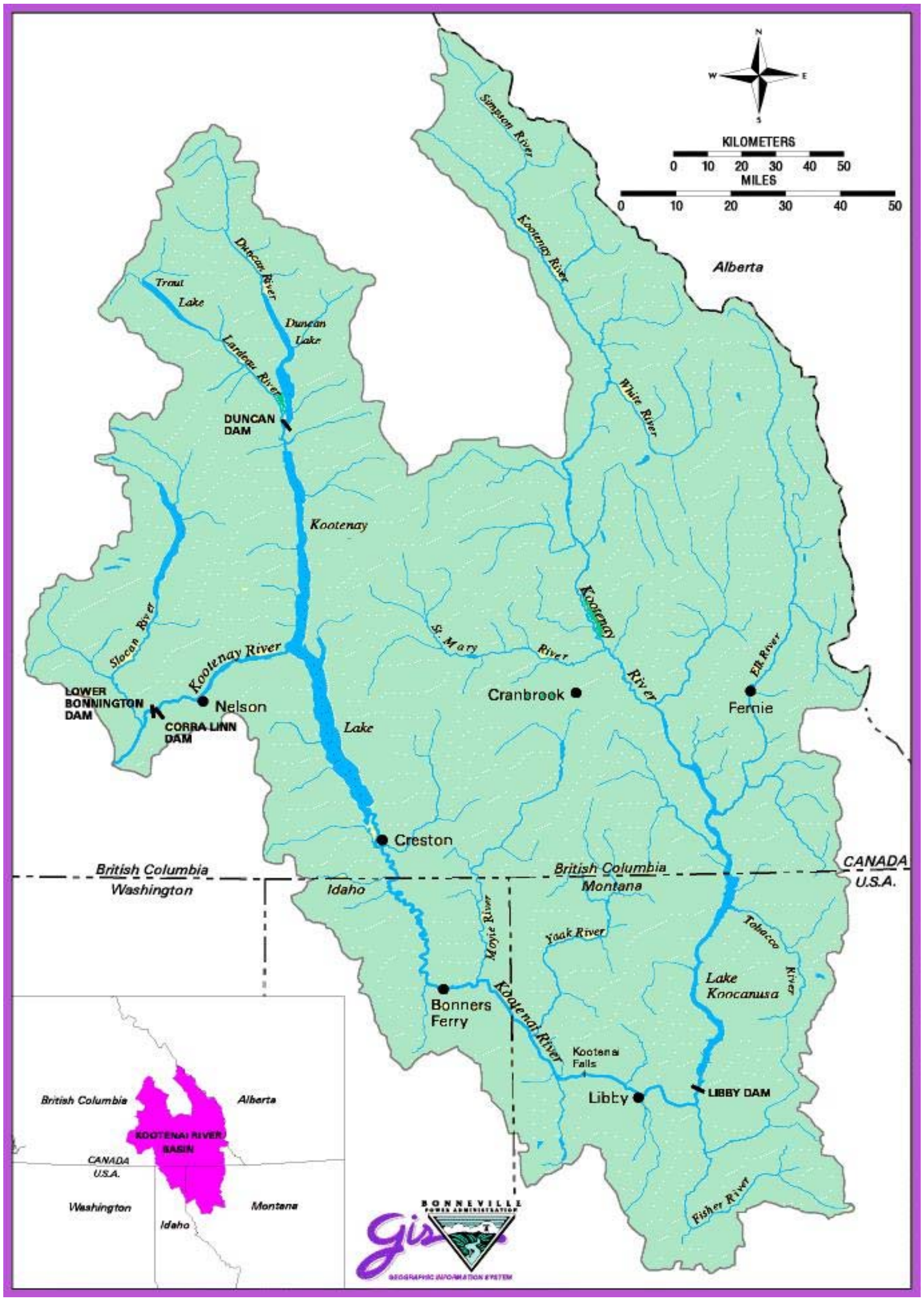

Figure 1. Kootenai River Basin (Montana, Idaho and British Columbia, Canada).

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), 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). 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. 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.

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 restored 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, with natural reproduction currently occurring. 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) to stabilize stream banks, reduce sediment, and improve rearing habitat for salmonids.

ASSOCIATIONS

The primary goals of the Libby Mitigation project are to offset fisheries losses caused by the construction and operation of Libby Dam by improving dam operations and by implementing projects to restore fish species, aquatic habitat and improve fish passage into blocked portions of the Kootenai drainage. Results complement and extend the Kootenai Subbasin Plan (MFWP, CSKT and KTOI 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. Projects in Idaho, British Columbia and Montana 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 was 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) Kootenai Focus Watershed Program (Project 199608720). 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 per day, which equates to approximately 8.14 MAF. Three Canadian rivers, the Kootenay, Elk, and Bull, supply 87 percent of the inflow (Chisholm et al. 1989). The Tobacco River and numerous smaller 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 restore 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. 1988). 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.

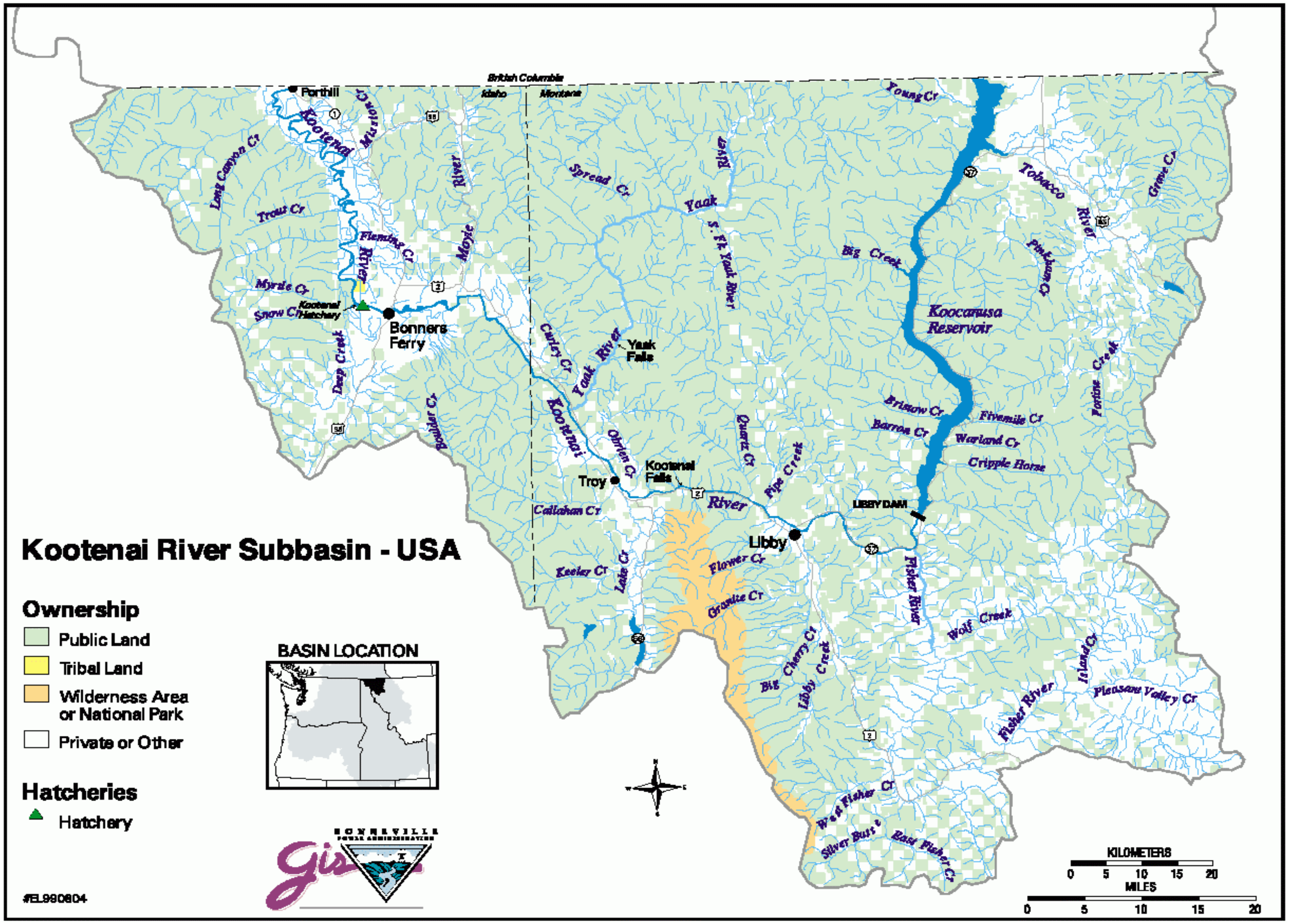

Figure 2. Kootenai River Basin, Montana.

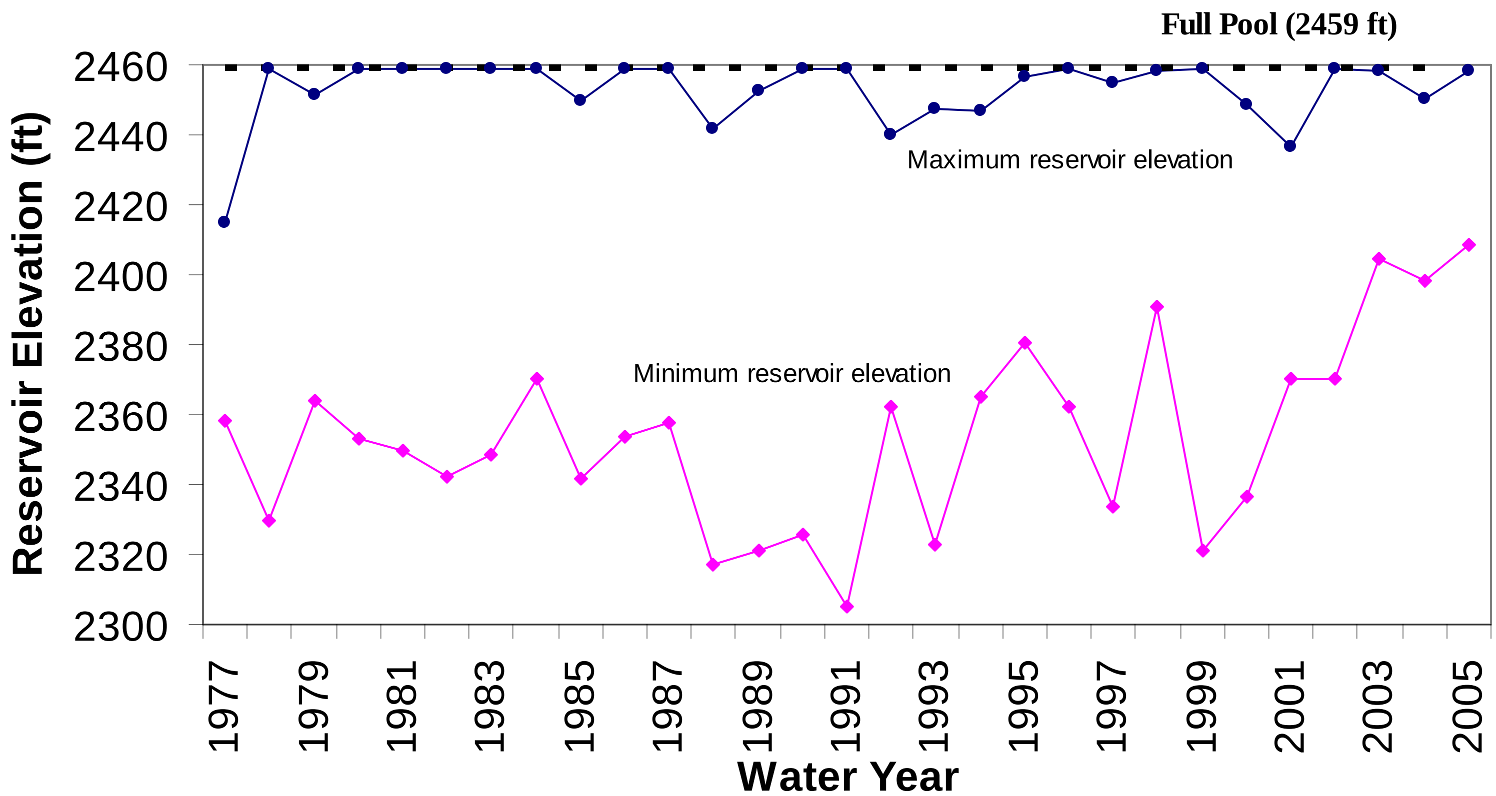

Figure 3. Libby Reservoir elevations (minimum, maximum), water years (October 1 – Sept. 30), 1976 through 2005.

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Chapter 1

Physical and Biological Monitoring in the Montana Portion of the Kootenai River Basin

Abstract

Montana Fish, Wildlife & Parks (MFWP) uses a combination of techniques to collect physical and biological data within the Kootenai River Subbasin. 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.

Bull trout core areas upstream of Libby Dam include Grave and Skookumchuck creeks and the Wigwam and White rivers, with the majority of the spawning occurring in tributaries located in British Columbia. Bull trout redd counts in Grave Creek and the Wigwam River have significantly increased since 1995. However, bull trout redd counts in Grave Creek substantially increased in 2005 relative to the previous year. However, there were a total of 642 bull trout redds within the index portion of the Wigwam River, which represented the lowest number observed since 1997. The decline in the Wigwam River was likely attributable to a large landslide located approximately 3-4 miles upstream of Lodgepole Creek that occurred during the spring of 2005 and represented a substantial migration barrier for most migrating adult bull trout.

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 River. 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. 2005 represented a year of record high and low for five of the six bull core streams located downstream of Libby Dam. Record low bull trout redd counts were observed in both Pipe and Bear creeks, and record high counts were observed in O'Brien Creek and the West Fisher River. Record high bull trout redd counts were also observed in the adjunct Bull Lake population which spawns in Keeler Creek.

MFWP conducted four adult bull trout population estimates below Libby Dam during April 2006, and estimated 176 (95% Confidence Interval = 73 – 279) adult bull trout were present within this 3.5 mile section of the Kootenai River. This estimate was approximately 80% lower than similar estimates conducted during the previous two years. We also recaptured 13 bull trout in April 2006 that were individually marked 363 – 740 days earlier, which enabled us to calculate growth rates for individual fish.

We monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994. The burbot catch in our hoop traps below Libby Dam has declined

precipitously since 1994, exhibiting a significant exponential decline. During the 2005 and 2006 trapping seasons, we did not catch any burbot below Libby Dam, which represents the lowest catch rate during the period of record.

We conducted juvenile salmonid population estimates within reference reaches on Therriault, Grave, Young, Libby, and Pipe creeks. Trend analyses related to stream restoration projects are presented for Therriault, Young, Grave and Libby creeks.

MFWP has documented changes in 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. The average length and weight of kokanee was lower for the fifth straight year than the 18-year average, while the average catch rate was the sixth highest on record. The spring gill net catch of bull trout has significantly increased since 1990. The catch of Kamloops rainbow trout in fall floating gillnets was significantly and positively correlated with the number of hatchery Kamloops rainbow trout stocked in the reservoir the previous year.

MFWP has also 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* and *Bosmina* were the first and second most abundant genera of zooplankton present in the reservoir in 2005. The relative size and abundance of *Daphnia* in Libby Reservoir have remained particularly stable during the past several years.

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), 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. 1988) and Kootenai Subbasin Plan (KTOI and MFWP 2004).

Biological monitoring data were 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 incorporate an alternate flood control strategy called VARQ, which stands for variable discharge (Q) (USACE 2002) and tiered flow augmentation for white sturgeon (USFWS 1999). 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, white sturgeon, 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.

Methods

Bull Trout Redd Counts

Redd surveys were conducted in October after bull trout spawned in the Wigwam and West Fisher Rivers and Grave, Quartz, Bear (a tributary to Libby Creek), Keeler, Pipe, and O'Brien Creeks. MFWP and U.S. Forest Service (USFS) personnel walked streams in the United States and personnel from the British Columbia Ministry of Water, Land, and Air Protection walked 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. However, 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 the amount of suitable habitat and mapped impassible barriers to migrating bull trout when a stream was surveyed for the first time. We used linear regression of redd counts to assess population trends.

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 11 and 12, 2006, and performed recapture sessions on April 18 and 19, 2006. We operated a single jet boat electrofishing crew on April 11 and

12 due to mechanical failures with our second boat, and we used 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. Section 2 was from the Alexander Creek confluence downstream to the Fisher River Confluence, and was 2.3 miles long.

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 (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-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 a computer software program called Mark/Recapture (version 7.0) that uses a log-likelihood estimator to estimate the absolute abundance of adult bull trout within the study reach. We estimated the total population present within the study area after each marking episode, beginning with the second episode.

Burbot Monitoring Below Libby Dam

MFWP has monitored burbot densities directly below 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 below 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 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-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 across 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, Parmenter, Pipe, and Barron creeks in 2001 and 2002, as part of an effort to monitor long-term trends in juvenile salmonid abundance, size distribution and species composition. We conducted estimates on each stream with mobile electrofishing gear using DC current for multiple pass depletions similar to Shepard and Graham (1983). 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 $\geq$ 0.6, 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). A description of reach sampled in 2005 follows for each stream.

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. Section 2 began at the first culvert above highway 93 and extended 120 m downstream. The property is privately owned and the stream channel is highly entrenched with unstable banks and is within the restoration project that was finalized in the spring of 2005. Section 3 extends from the second culvert above highway 93 downstream for 131 m. This section is moderately stable and is 400 m upstream from the highly entrenched reach of Therriault Creek, and is located upstream of the stream restoration project.

Grave Creek

We established a representative sampling reach on Grave Creek to perform population estimates. The shocking section begins at the Vukonich bridge (Latitude 48º 48.569' Longitude 114º 53.997') and extends downstream 1,000 feet to the beginning of the demonstration project area. 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 and 2004. 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. These five sections include the following:

- Section 1: Tooley Lake Section (Sec.23 T37N,R28W).
- Section 2: Meadow Section, near confluence with Spring Creek (Sec.15,T37N,R29W).
- Section 3: Dodge Creek Spur Road #303A (Sec.17 T37N,R28W).
- Section 4: Dodge Creek Road #303, upstream from bridge (Sec. 18 T37N,R28W).
- Section 5: State Lands Section (NE ¼ of Section 16, T37 N, R28W).

We conducted population estimates on Sections 1, 4 and 5 in 2004.

Libby Creek

MFWP personnel collected fish population information in three reference reaches on Libby Creek from 1998 through 2002. We sampled Section 1 using a Coleman Crawdad electrofishing boat with a mobile electrode. The other sections were sampled with a Smith Root backpack electrofisher. The system consisted of a Cofelt model VVP-15 rectifier powered by a 4000 watt generator. The three sections sampled in 2005 include the following:

- Section 1: is a 274 m long reach located approximately 2.4 km below the Highway 2 bridge.
- Section 2: is a 171 m long reach located ~100 m upstream of the Highway 2 bridge.
- Section 3: is a 171 m long reach located on the upper Cleveland property.
- Section 4: is a 201 m long reach located downstream of the lower Cleveland property, and is intended to serve as a control site for the lower Cleveland Stream Restoration Project.
- 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.
- Section 6: is a 172 m long reach near the confluence of Midas Creek located within the lower Cleveland Stream Restoration Project.

The upper and lower Cleveland properties have had a lengthy history of disturbance dating back over a century of mineral exploration (Sato 2000). Stream restoration activities were initiated on Libby Creek at Sections 1 and 3 in 2001 and 2002, respectively (See Chapter 2). Fisheries population work at these two sites was intended to assess fish population response to restoration activities. Monitoring sites 4, 5, and 6 were established and first sampled in 2004, and associated with the lower Cleveland Stream Restoration Project that is planned for implementation during fall 2005.

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 was sampled during the 2004 field season.

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 2002, but the entire database (1975 through 2002) 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). Kamloops (Gerrard and Duncan strain) rainbow trout were distinguished from wild rainbow trout by eroded fins (pectoral, dorsal and caudal); these fish are held in the hatchery until release into the reservoir at age 1+. These fish were also marked (tetracycline or adipose fin clipped) prior to release into the reservoir to facilitate post-mortem age and origin determination.

Species abbreviations used throughout this report are: rainbow trout (RB), Kamloops rainbow trout (KAM), 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°C.

2) Fall (September - October): Drafting of the reservoir began, surface water temperature decreased to 13 - 17°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 Tenmile, 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.

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 33-34 *Daphnia*, *Diaptomus*, *Epischura* and *Diaphanosoma*. We used analysis of variance, and subsequent multiple comparisons to assess whether zooplankton abundance differed by month and sampling area in 2001 and 2002.

Results

Bull Trout Redd Counts

Grave Creek

MFWP counted redds in the Grave Creek Basin (including Blue Sky, Clarence, Williams and Lewis Creeks) for the first time in 1983, as well as in 1984, 1985, and 1993 through 2005. Grave Creek was surveyed from its confluence with the Tobacco River upstream to near the mouth of Lewis Creek (approximately13 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 194 bull trout redds in Grave Creek in 2005, which was 53 more redds than observed the previous year, representing a 38% increase (Table 1). Nevertheless, bull trout have exhibited a significant positive trend in spawning abundance in Grave Creek since 1993 (Figure 2; r^2 = 0.717; p = 0.0005).

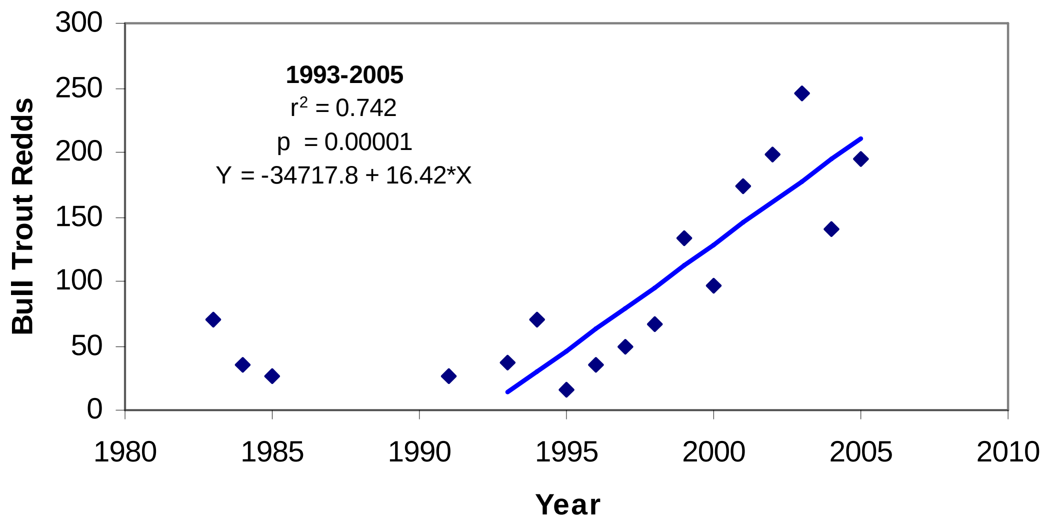

Figure 2. Bull trout redd counts and trend analysis in Grave Creek, 1993 through 2005.

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 2005, a total of 642 bull trout redds were observed in the ten index reaches typically surveyed in the Wigwam Drainage, which was the lowest number since 1997, and only 36.6% of the previous five year average. A large landslide that occurred approximately 3-4 miles upstream of Lodgepole Creek confluence during the spring of 2005 was likely responsible for at least part of the decrease in the number of redds from the previous years. Because this landslide was large and thought to create a partial barrier for migrating bull trout, surveys were conducted between the barrier and the confluence of Lodgepole Creek. An additional 143 redds were observed, for a total of 785 within the Wigwam drainage (Table 1). Even with the additional redds observed within this area, the total number is less than expected (Figure 3).

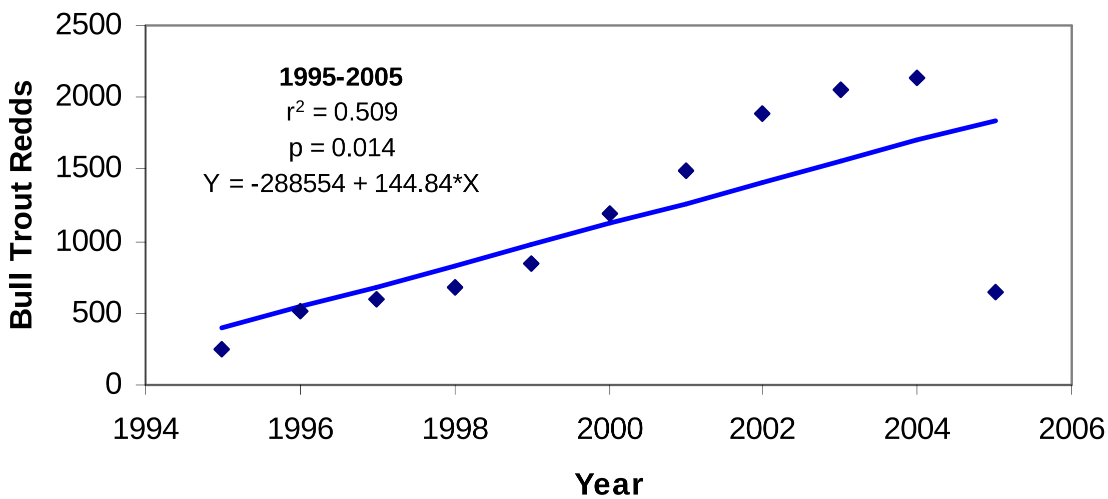

Figure 3. Bull trout redd counts and trend analysis for the Wigwam River (including Bighorn, Desolation, and Lodgepole creeks) 1995-2005.

Table 1. 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
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
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
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
	2002	11	8.0
	2003	10	8.0
	2004	8	8.0
	2005	2	8.0
Bear	1995	6	3.0
	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

Table 1 (Continued). Bull trout redd survey summary for all index tributaries in the Kootenai River Basin.

Stream	Year Surveyed	Number of Redds	Miles Surveyed
Bear (continued)	2003	14	4.25
	2004	6	4.25
	2005	3	4.25
Keeler Includes South and North Forks	1996	74	9.3
	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
West Fisher River	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
Wigwam (B.C and U.S.) Includes Bighorn, Desolation, Lodgepole Creeks	1995	247	22
	1996	512	22
	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
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	
White River (B.C.) Includes Blackfoot Creek in 2002, 2003, and 2005	2001	166	7.8
	2002	261	7.8
	2003	249	
	2004	190	8.1
	2005	243	

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 4; r^2 = 0.025). Although the overall trend is positive, annual variation limits our ability to statistically distinguish this relationship from a stable (zero slope) population (Figure 4; p = 0.557). We observed a total of 71 redds in Quartz and West Fork Quartz creeks in 2005 (Table 1). The average number of redds of the period of record was 74.6 redds. The 2005 observation of 71 redds was very close to the mean over the period of record. A log jam located approximately 0.25 miles upstream of the confluence of West Fork Quartz Creek in 2002 and 2003 may have limited bull trout spawner escapement during these years.

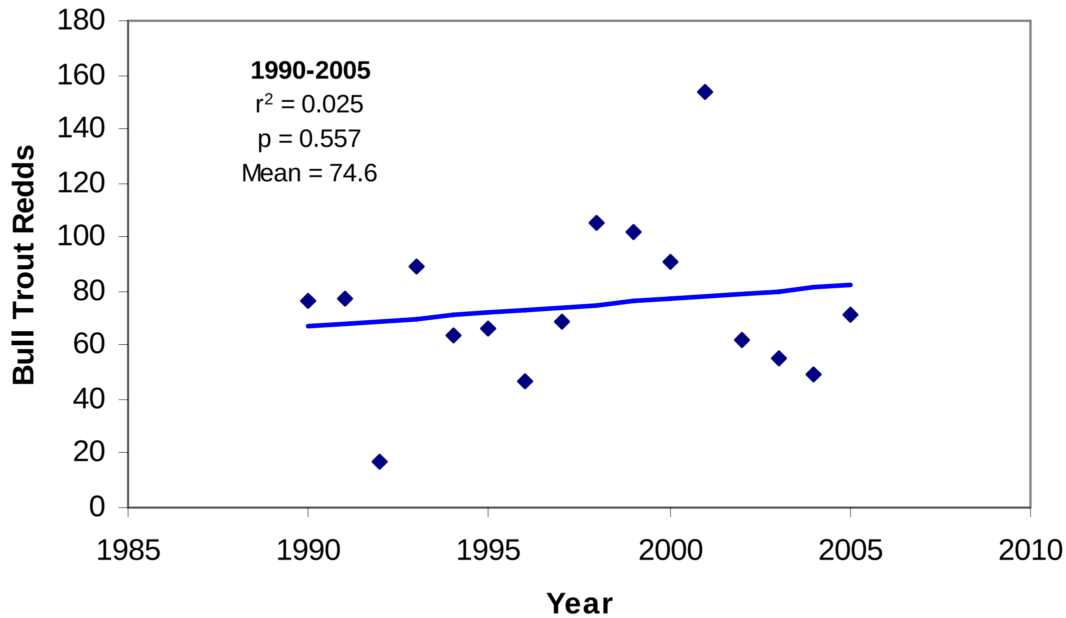

Figure 4. Bull trout redd counts and trend analysis (blue line) for Quartz Creek (including West Fork Quartz) 1990-2005.

Pipe Creek

Bull trout redd counts in Pipe Creek peaked in 1999 with 36 redds, with redd numbers and have decreased since that peak. There is no apparent trend in bull trout redd counts in Pipe Creek during the period of record (1990-2005; Figure 5). The mean number of bull trout redds since 1990 has been 13.75 redds. The 2 redds we observed in Pipe Creek in 2005 was the lowest number observed during the 14 year period of record. Low water conditions during the fall spawning season during the past several years may partially explain the low spawner escapement into Pipe Creek.

Bear Creek

Bear Creek bull trout redd counts have been variable during the period of record (1995-2005; Figure 6; $r^2 = 0.001$). Although the overall trend been a decreasing one since 1995, the relationship is not statistically different than a stable population (Figure 6; $p = 0.534$). We observed a record low number of 3 redds in Bear Creek since surveys first began in 1995, which was 78.9% lower than the mean number of redds (14.0) observed since 1995. Low water conditions in Bear and Libby creeks during the past five years may partially explain the low spawner escapement in Bear Creek.

O'Brien Creek

Bull trout redds in O'Brien Creek have shown an increasing trend since 1991 (Figure 7; $r^2 = 0.692$; $p = 0.0001$). We observed a total of 81 bull trout redds in O'Brien Creek in 2005, which is a record high since we began surveying O'Brien Creek in 1991 (Table 1).

West Fisher River

We were unable to determine a significant trend in bull trout redds in the West Fisher River over the period of record for this stream (1993-2005). From the period 1993-2000, the general trend was one of increasing abundance. However, during the period of 2001-2003, we observed only 1 bull trout redd each year (Table 1). However, we observed 27 bull trout redds in the West Fisher River in 2005, which represented the highest observation during the period of record. The overall trend was nearly significantly different than a stable (zero slope) population ($r^2 = 0.296$; $p = 0.054$). The mean number of redds observed in the West Fisher River since 1993 is 8.4 redds.

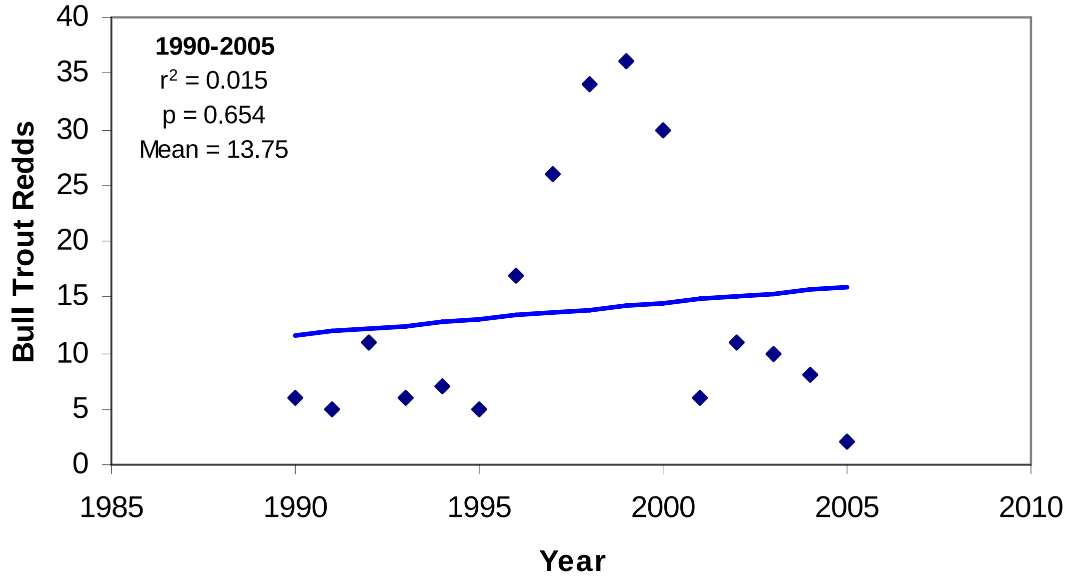

Figure 5. Bull trout redd counts and trend analysis (blue line) for Pipe Creek 1990-2005.

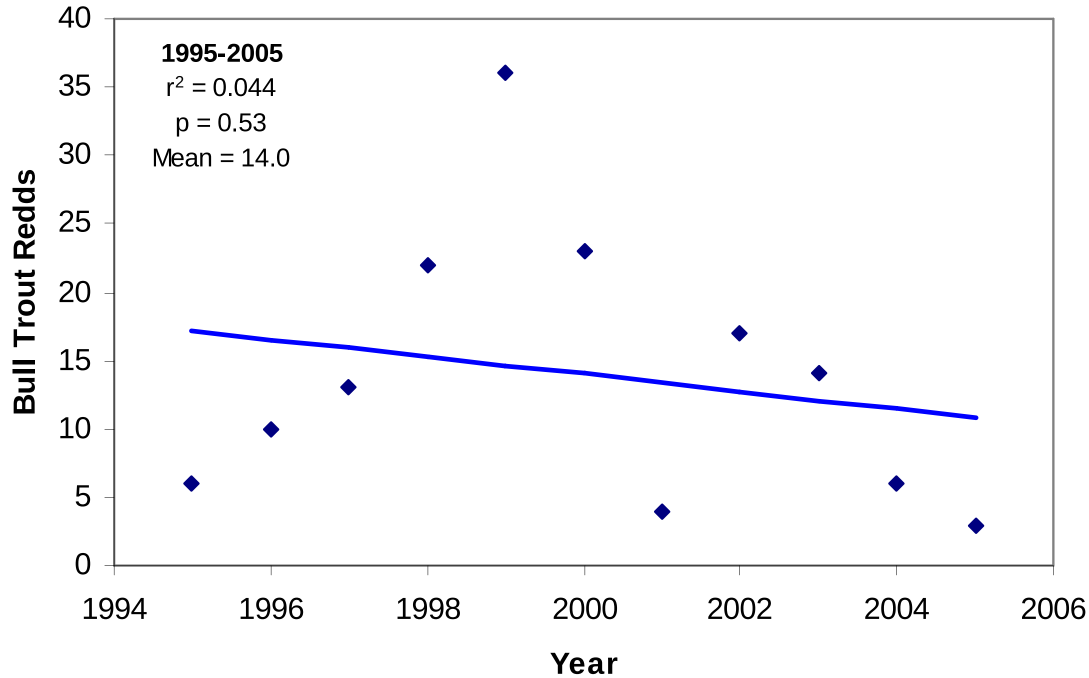

Figure 6. Bull trout redd counts and trend analysis (blue line) in Bear Creek, a tributary to Libby Creek, 1995-2005. The mean number of bull trout redds since 1995 is 14.0.

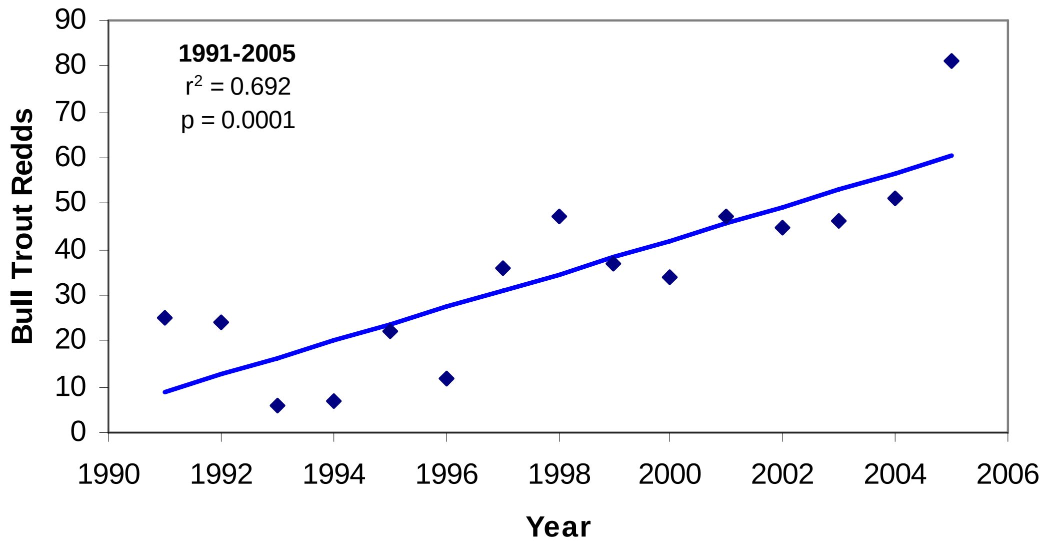

Figure 7. Bull trout redd counts and trend line (blue line) in O'Brien Creek 1991-2005.

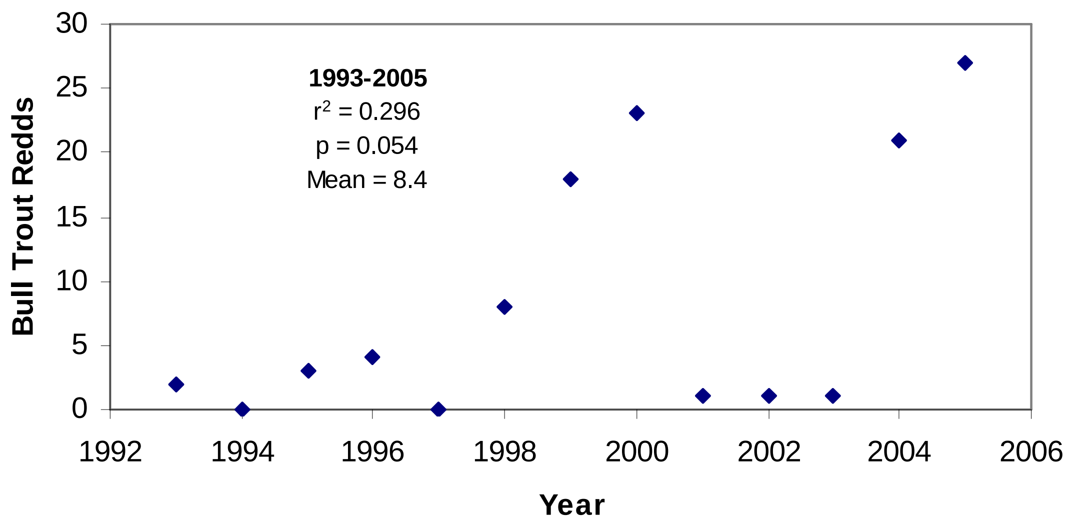

Figure 8. Bull trout redd counts in the West Fisher River, a tributary to the Fisher River, 1993-2005.

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 1996). 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. Keeler Creek may supply some recruitment to the Kootenai River through downstream migration. We observed a total of 186 bull trout redds in Keeler Creek and associated tributaries in 2005 (Table 1), which represented a record high during our period of record for the second straight year. Bull trout redd counts in Keeler Creek have exhibited a nearly significant positive trend since 1996 (Figure 9; p = 0.085). The mean number of redds observed in Keeler Creek is 92.8 redds. The 2005 observation represents a 100% increase relative to the annual mean.

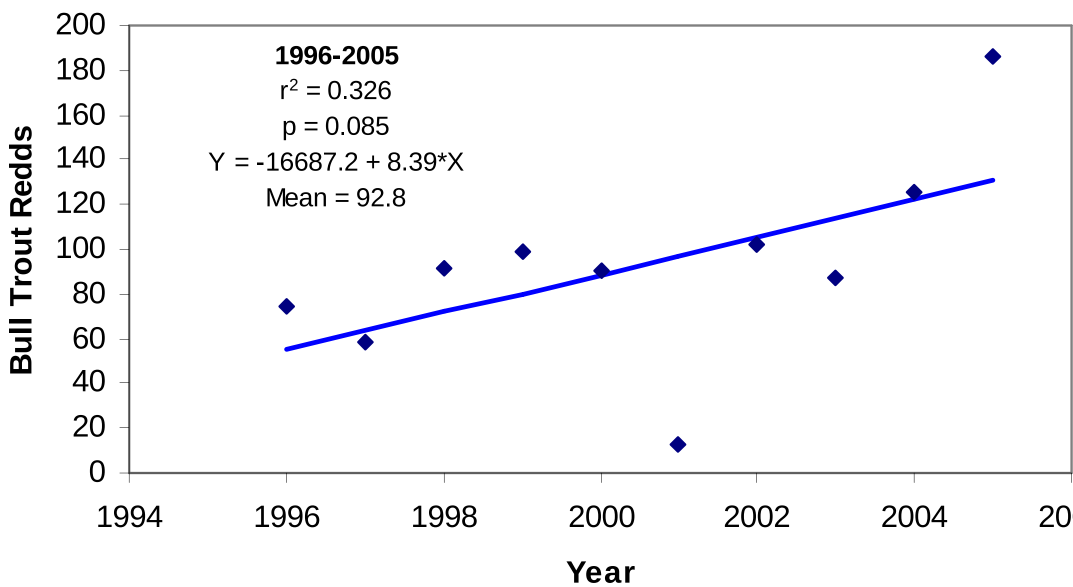

Figure 9. Bull trout redd counts and trend line (blue line) in Keeler Creek, a tributary to Lake Creek, 1996-2005.

Kootenai River Adult Bull Trout Population Estimate

We captured and marked 8 and 11(19 total) bull trout on April 11 and 12, respectively, and during the recapture sampling events on April 18 and 19, we captured 25 and 27 (52 total) bull trout, respectively. A total of 5 fish that were originally marked on April 11 and 12 were recaptured. We estimated that 176 adult bull trout were present below Libby Dam during this period (Table 2). We also standardized each population estimate and 95% confidence interval into fish per mile, with a mean of 50 bull trout per mile (95% confidence interval = 20.7 – 79.7 fish per mile). Our capture efficiency for adult bull trout was 26.3%. The average bull trout total length was 692 mm (range = 450 – 870 mm; Figure 10). We compared the mean length of bull trout captured during our 2006 sampling to the mean length of bull trout captured during similar sampling conducted in 2004 and 2005 (Dunnigan et al. 2005) using ANOVA and subsequent multiple comparison. The mean length of bull trout in 2004 and 2005 captured below Libby Dam was 649 and 677 mm, respectively. Even though bull trout mean length increased each year, the only comparison differed significantly ($p < 0.05$) between years was 2004 and 2006.

We recaptured 13 bull trout during our sampling period April 11-19, 2006 that were previously marked in 2004 and 2005 below Libby Dam ranging between 363 to 740 days prior. The recaptured bull trout grew an average of 113.3 mm (0.16 mm per day; Table 3), and gained an average of 1,802.9 g (2.55 g per day; Table 3).

Table 2. 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.

Dates	**Number Marked**	**Number Recaptured**	**Total Population Estimate (95 % CI)**	**Fish per Mile (95 % CI)**
April 11 and 12, 2006	19	N/A		
April 18 and 19, 2006	52	5	176 (73 – 279)	50 (21 – 80)

Table 3. Recapture summary information for bull trout recaptured below Libby Dam on April 20 and 21, 2005. 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)
4/21/2004	4/11/2006	3D9.1BF1C679B7	500	1274	701	3948	201 (0.28)	2674 (3.71)
4/15/2004	4/12/2006	3D9.1BF1C6FB72	771	4520	805	5867	34 (0.05)	1347 (1.85)
4/21/2004	4/12/2006	3D9.1BF1C67C89	723	4055	820	4795	97 (0.13)	740 (1.02)
4/21/2004	4/18/2006	3D9.1BF1C59DE2	702	3379	758	4642	56 (0.08)	1263 (1.73)
4/20/2005	4/18/2006	3D9.1BF1C68F9B	650	3163	660	2939	10 (0.03)	-224 (-0.62)
8/18/2004	4/18/2006	3D9.1BF1C6FB3B	527	1265	723	3883	196 (0.32)	2618 (4.31)
4/8/2004	4/18/2006	3D9.1BF1C70473	613	2504	765	5412	152 (0.21)	2908 (3.93)
4/22/2004	4/19/2006	3D9.1BF1C68BDD	466	961	651	2865	185 (0.25)	1904 (2.62)
4/22/2004	4/19/2006	3D9.1BF1C67C0A	656	3233	825	7350	169 (0.23)	4117 (5.66)
4/22/2004	4/19/2006	3D9.1BF1C635A4	806	6500	845	7562	39 (0.05)	1062 (1.46)
8/18/2004	4/19/2006	3D9.1BF1C4B282	658	2855	765	4278	107 (0.18)	1423 (2.34)
Mean			642.9	3064.5	756.2	4867.4	113.3 (0.16)	1802.9 (2.55)

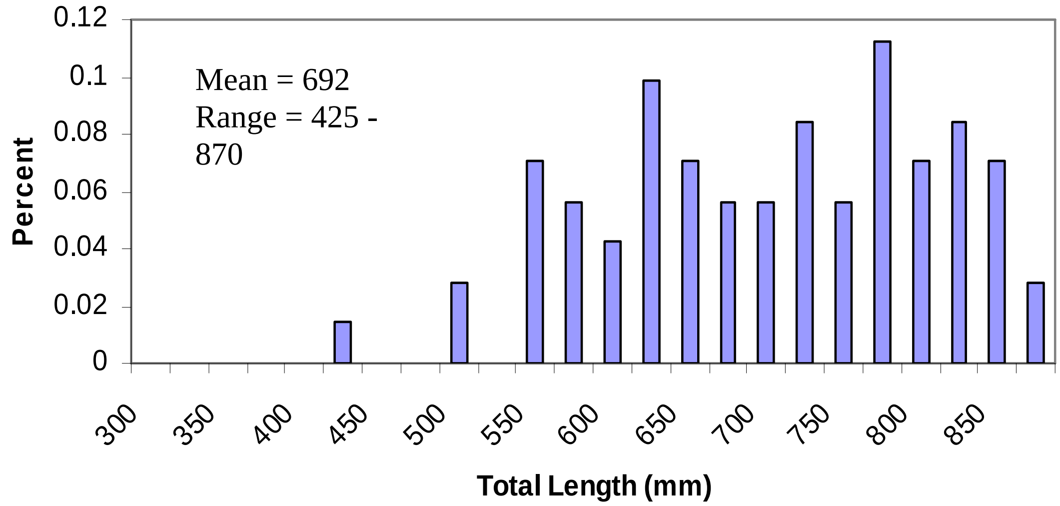

Figure 10. Length frequency distribution of bull trout captured via jet boat electrofishing on April 11 to April 19, 2006 below Libby Dam. Mean length for all fish captured was 692 mm.

Burbot Monitoring Below Libby Dam

The burbot catch in our hoop traps below Libby Dam has declined precipitously since 1996/1997 (Figure 11). During the 2005/2006 trapping season we did not catch any burbot below Libby Dam, this represents the lowest catch rate during the period of record. The most numerous captures occurred in 1995-96 and 1996-97; these years correspond with higher than normal snow-pack, and perhaps greater reservoir drafting. The mean annual catch rate since the 1995/1996 trapping season was 0.597 burbot per trap day. However, the catch rates since then have significantly decreased ($r^2 = 0.703$; $p = 0.002$; Figure 11). This relationship was further improved using an exponential fit ($r^2 = 0.932$; $p < 0.001$; Figure 11).

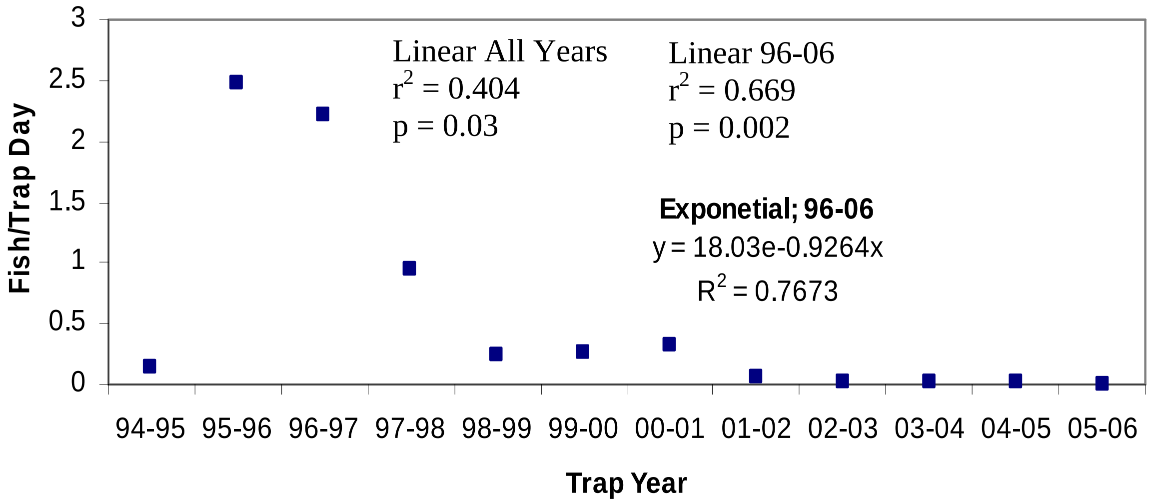

Figure 11. Total catch per effort (burbot per trap day) of baited hoop traps in the stilling basin downstream of Libby Dam 1994/1995 through 2005/2006. The data were fit with linear regression for all years and with an exponential model for 1995/1996 – 2005/2006. The traps were baited with kokanee salmon and fished during December and February.

Juvenile Salmonid Population Estimates

Therriault Creek

Section 1 on Therriault Creek is located downstream of the Therriault Creek Restoration Project Area, and will be used a control site in future years when comparing pre- and post-restoration fish populations. Rainbow trout abundance in Section 1 of Therriault Creek has decreased from 1997-2005, although this trend has not differed significantly from a stable population ($r^2 = 0.161$; $p = 0.431$; Figure 12; Table A1). The mean abundance of rainbow trout during the period of record was 100.7 fish per 1,000 feet, with the observed abundance in 2005 (105.6 fish per 1,000 feet) slightly higher than the mean. This site was not sampled in 2000-2002. The trend in brook trout abundance for this section has also been variable during the past several years, and has not differed significantly from a stable population ($r^2 = 0.002$; $p = 0.927$; Figure 12; Table A1), and has averaged 47.6 brook trout per 1,000 feet, with the observed abundance of brook trout in 2005 slightly higher at 66.01 brook trout per 1,000 feet. Juvenile bull trout were only detected at this site during the past 3 years, with abundance being highest in 2004 (92.1 bull trout per 1,000 feet). Bull trout abundance was substantially lower in 2005 with an estimated 9.9 bull trout per 1,000 feet. Despite the recent increase in bull trout abundance at this site over the past 3 years, the trend does not differ significantly from a stable population ($r^2 = 0.30$; $p = 0.261$; Figure 12). The mean abundance from 1997-2005 was 18.9 bull trout per 1,000 feet.

Section 2 on Therriault Creek lies within the Therriault Creek Restoration Project and was sampled in 1997-1999, 2001, and 2003-2005. The data we collected in 2005 represented the first 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 data were collected (Table A1). We used linear regression to evaluate population trends for each of these three species, but did not detect significant trends (Figure 13; $p > 0.20$ for all species). We compared the abundance of rainbow, brook and bull trout at this site to data collected in 2005 and used site 1 and 3 as control sites. The abundance of rainbow trout we observed at the treatment site (Section 2) in 2005 was 32.3 rainbow trout per 1,000 feet, which was 58.5% lower than the mean abundance prior to project completion (Figure 14; pre-project mean = 78.4 fish per 1,000 feet). The 95% confidence intervals for rainbow trout within the treatment area and those for the two control sections slightly overlap (Figure 14). In contrast, rainbow trout abundance at the two control sites (Section 1 and 3) in 2005 was nearly equivalent compared to pre-project levels (Figure 14). Brook trout abundance at all three sections on Therriault Creek were nearly equal when comparing pre and post-project periods (Figure 15). Brook trout abundance slightly decreased within the project area (Section 2) after project completion decreasing from 69.5 to 66.7 fish per 1,000 feet after the project completion. Although, this slight reduction could not be considered significant given the relatively wide 95% confidence intervals associated with the pre-project period (Figure 15). The variation in bull trout abundance over time was higher than the variation in rainbow or brook trout abundance at all three sections (Figure 16). Bull trout abundance at sections 1 and 2 decreased in 2005 compared to the pre-project levels, but bull trout abundance at Section 3 increased slightly compared to pre-project status. However, given the variability in bull trout abundance through time at all three sites on Therriault

Creek, detecting significant trends for this species between pre- and post-restoration levels is likely to be difficult.

Section 3 on Therriault Creek is located upstream of the Therriault Creek Restoration Project area and was sampled in 1997-1999, and 2003-2005 (Table A1). We observed rainbow and brook trout at this site each year, but bull trout only observed in 2003-2005, with estimated abundances of 9.9, 3.4, and 15.3 bull trout per 1,000 feet, respectively (Figure 17; Table A1). Bull trout abundance at this site did exhibit a significantly positive trend through time ($r^2 = 0.694$; $p = 0.039$). The trends of rainbow and brook trout abundance did not differ significantly from a population with zero slope ($p > 0.35$; Figure 17).

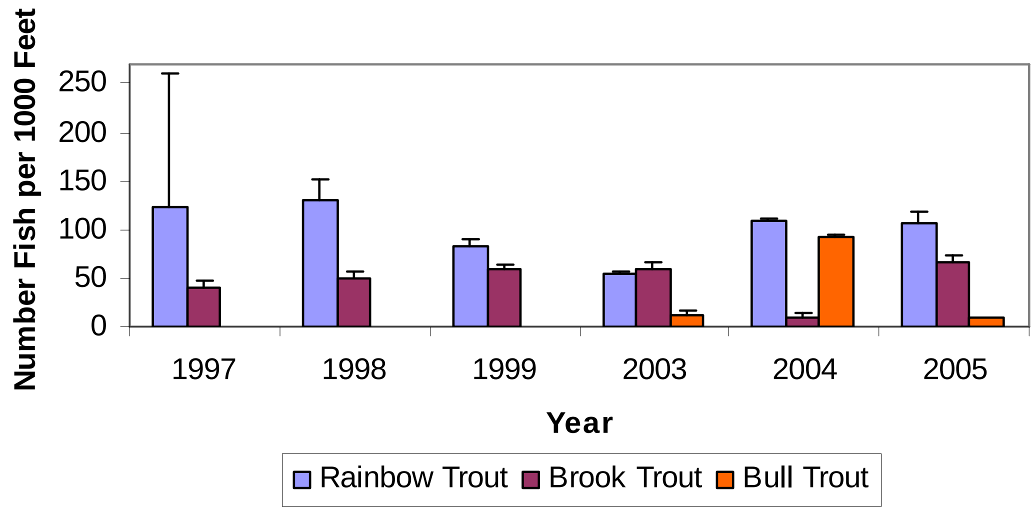

Figure 12. Rainbow trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 1 monitoring site from 1997-1999 and 2003-2005 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

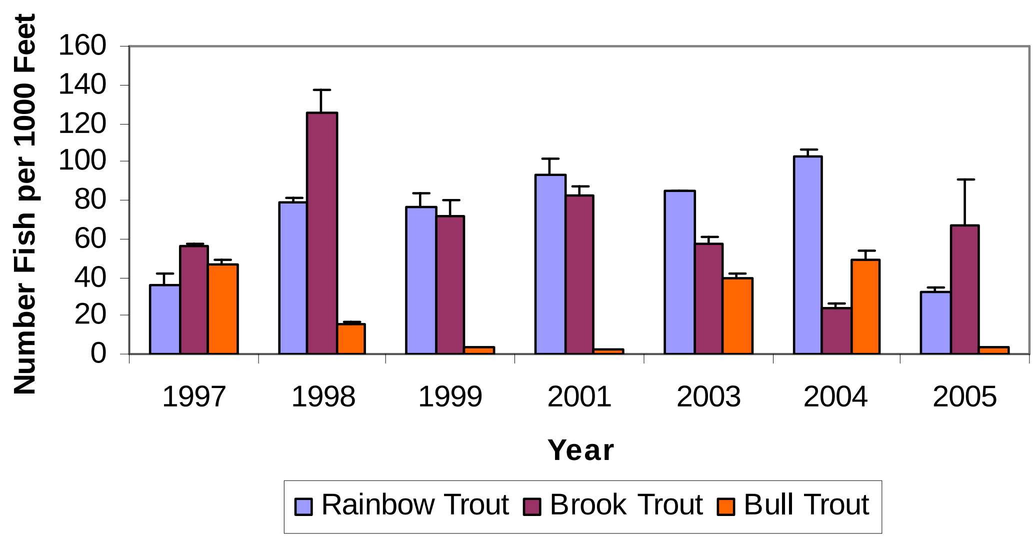

Figure 13. Rainbow trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 2 monitoring site from 1997-1999, 2001 and 2003-2005 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

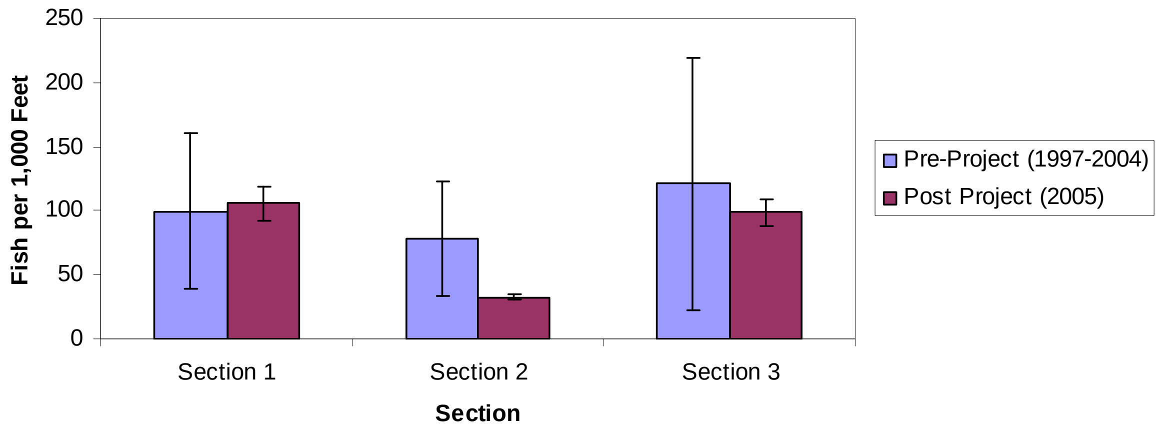

Figure 14. Rainbow trout densities (fish per 1,000 feet) in Therriault Creek. Sections 1 and 3 represent control sites located downstream and upstream, respectively of the treatment section (Section 2). Data collected from 1997-2004 represent pre-project, and data collected in 2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

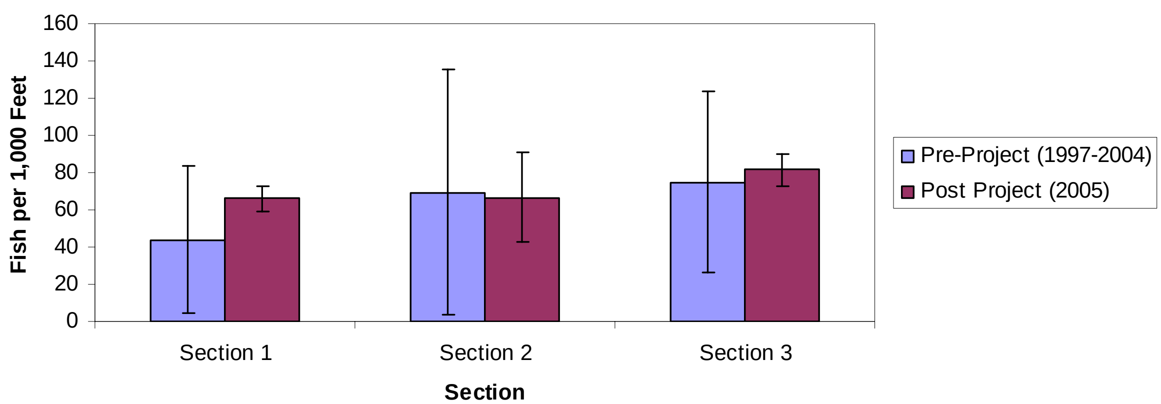

Figure 15. Brook trout densities (fish per 1,000 feet) in Therriault Creek. Sections 1 and 3 represent control sites located downstream and upstream, respectively of the treatment section (Section 2). Data collected from 1997-2004 represent pre-project, and data collected in 2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

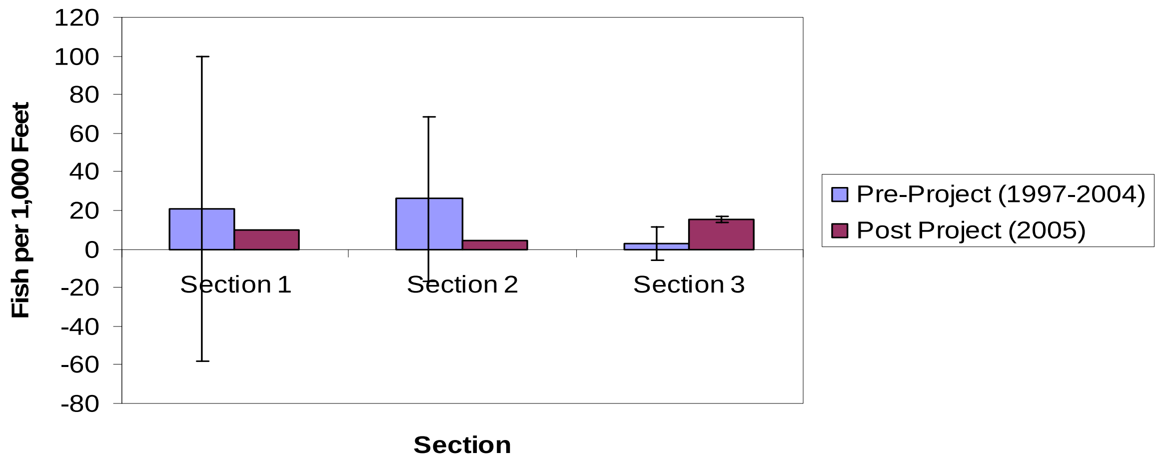

Figure 16. Brook trout densities (fish per 1,000 feet) in Therriault Creek. Sections 1 and 3 represent control sites located downstream and upstream, respectively of the treatment section (Section 2). Data collected from 1997-2004 represent pre-project, and data collected in 2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

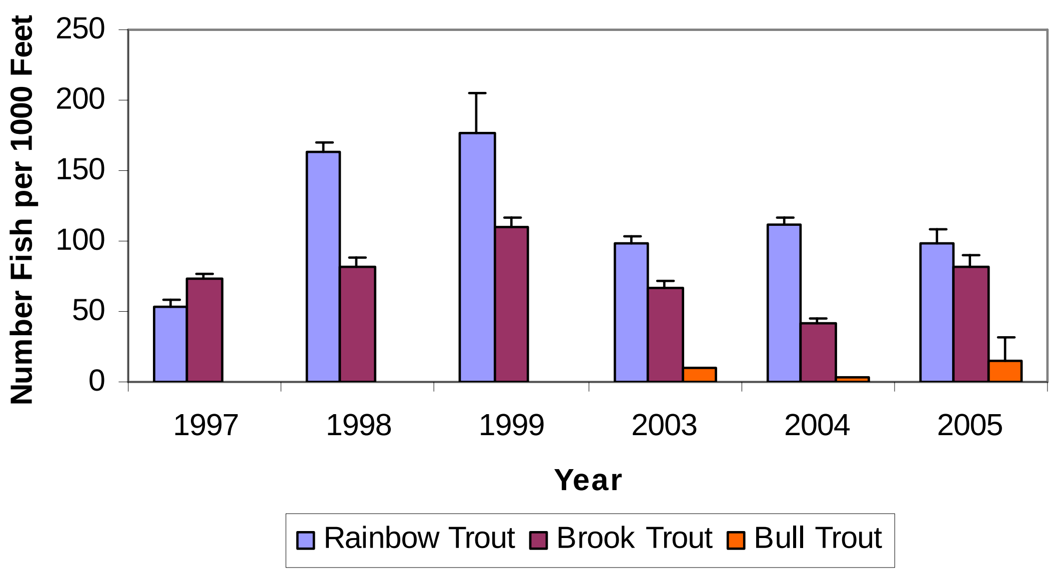

Figure 17. Cutthroat trout, bull trout and brook trout densities (fish per 1,000 feet) in Therriault Creek Section 3 monitoring site from 1997-1999 and 2003-2005 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

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). Cutthroat and Rainbow trout were the two combined most abundant fish species present at this site in all years except 2003 and 2004, when juvenile bull trout were the most abundant species present (Table A2). We compared mean fish abundance (by species) for pre (2000-2001) and post (2002-2005) restoration projects using t-tests (one-tailed tests; Figure 18). However, the variability in pre- and post-project fish abundance estimates is high (Figure 18 and 19), 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 significantly increased from 9.0 to 38.1 rainbow trout per 1,000 feet ($p = 0.057$) after project construction (Figure 18). Bull trout abundance after project completion also increased, but not significantly ($p =0.143$) from 17.0 to 52.1 bull trout after project completion. Brook trout and westslope cutthroat trout abundance were nearly identical before and after project completion, with the differences less than 1.5 fish per 1,000 feet and non-significant ($p > 0.35$; Figure 18). We used linear regression to assess whether there was a temporal trend in abundance for the four fish species at this site (Figure 19). Rainbow trout population trends at this site both exhibited strong significant trends through time ($r^2 = 0.903$; $p = 0.004$). Bull trout abundance at this site also exhibited a positive trend during the period of record (Figure 19), which was close to being significant (r2 = 0.565; $p = 0.085$). There was no apparent trend in westslope cutthroat trout or brook trout abundance over the period 2000-2005 (Figure 19).

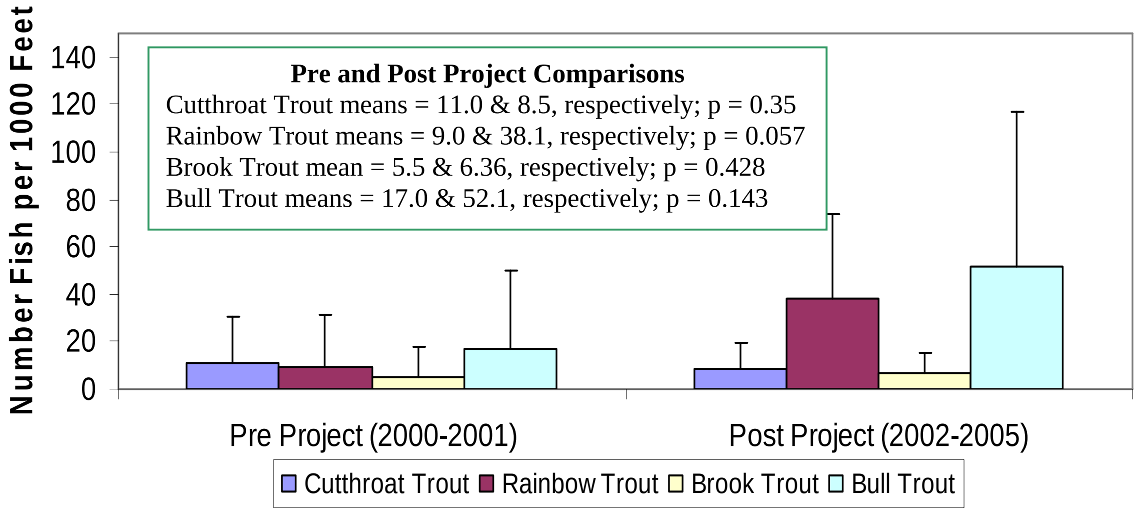

Figure 18. Mean cutthroat, rainbow, brook, and bull trout densities (fish per 1000 feet) within the Grave Creek Demonstration Project area prior to (2002-2001) and after (2002-2005) the completion of the Grave Creek Demonstration Restoration Project. Data collected during 2000 and 2001 represent pre-project 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. Upper 95% confidence intervals are represented by the whisker bars.

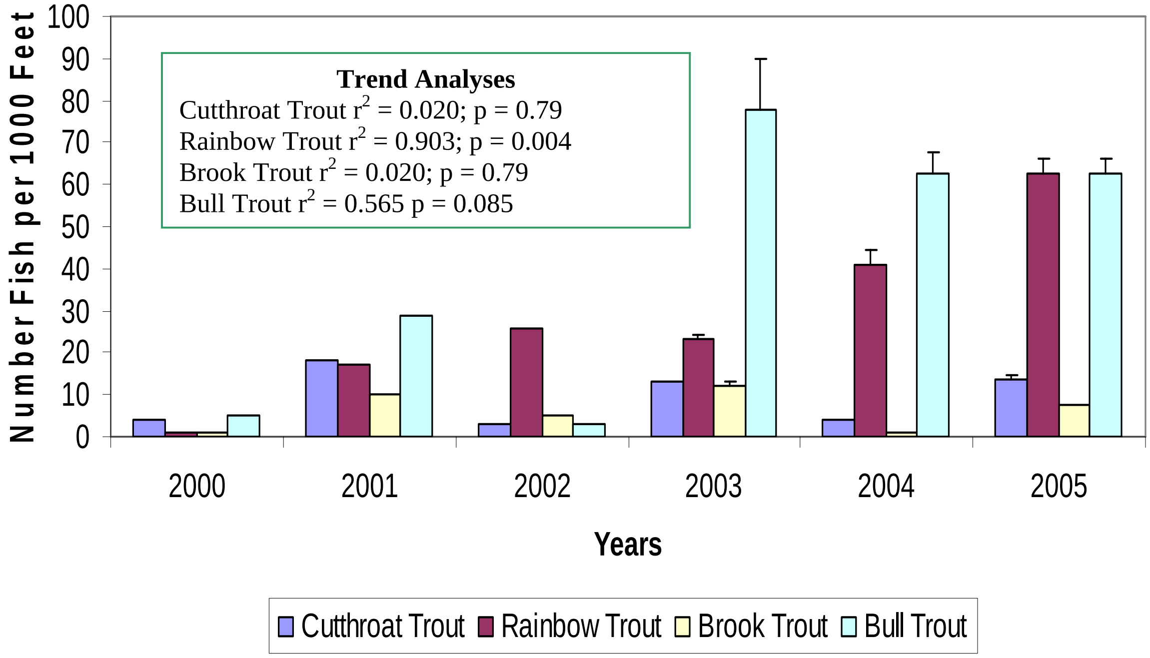

Figure 19. Cutthroat, rainbow, brook, and bull trout abundance estimates (fish per 1,000 feet) and linear regression trend analyses within the Grave Creek Demonstration Project monitoring site from 2000-2005 collected by backpack electrofishing. The 2000 and 2001 data were collected using single pass electrofishing, the data collected in 2002 were collected via snorkel counts, and the 2003- 2005 data were collected using multiple pass electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

Young Creek

The Young Creek Section 1juvenile monitoring site was sampled consecutively from 1997-2005, with the exception of 2000 and 2003 (Table A3). There was no evidence of linear trends in abundance for cutthroat, rainbow or brook trout from 1997-2005 ($p > 0.2$; Figure 20). Brook trout were more abundant than rainbow and cutthroat trout at Section 1 up until 1999. However from 1999 to 2004, cutthroat trout were the most abundant fish species at this site (Figure 20), but in 2005, brook trout were the most abundant species present at this site. For the period 1997-2005, mean cutthroat trout abundance at this section is slightly higher than brook trout abundance, although the difference was not significant ($p = 0.69$ for a two-tailed test; mean densities 65 and 55.9 fish per 1,000 feet, respectively). Bull trout were first observed at Section 1 in 2004, with an estimated abundance of 2 bull trout per 1000 feet, and increased to 10 bull trout per 1,000 feet in 2005.

The Young Creek Section 4 juvenile monitoring site was sampled consecutively from 1996-2005, with the exception of 2000 and 2003 (Table A3). Westslope cutthroat trout dominated the fish community at this sampling location during all years, with cutthroat trout densities averaging approximately 55 fold higher than brook trout densities. Over the period of record for this site, cutthroat trout densities averaged 242.9 fish per 1,000 feet, and brook trout densities averaged 4.5 fish per 1,000 feet. We were unable to distinguish the trend in westslope cutthroat trout abundance from a stable population ($r^2 = 0.027$; $p = 0.70$; Figure 21). However, brook trout abundance has significantly increased at this site over time ($r^2 = 0.901$; $p = 0.0003$; Figure 21). In 2005, we estimated 327.2 and 12.9 fish per 1,000 feet for westslope cutthroat trout and brook trout, respectively. We have never observed a bull trout in this section of Young Creek.

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 represent conditions prior to the restoration project completion. Cutthroat, brook, and bull trout have exhibited relatively stable population trends in Section 5 of Young Creek since 1998, with trends not differing significantly from a stable population ($p > 0.2$; Figure 22). Mean annual mean abundance estimates for cutthroat, brook and bull trout have averaged 182.7, 55.1 and 0.9 fish per 1,000 feet for each species respectively (Table A3). We compared mean fish abundance (by species) for pre (1998-2003) and post (2004-2005) restoration projects using t-tests (one-tailed tests; Figure 23). Abundance estimates for cutthroat trout prior to project completion averaged 199.5 fish per 1,000 feet, and decreased to 132.6 fish per 1,000 feet in 2004 and 2005 (Figure 32), but the difference was not significant ($p = 0.173$, for a 2-tailed test). Brook trout abundance significantly increased after the restoration project was completed from a mean of 39.8 fish per 1,000 feet before the project to 101.1 fish per 1,000 feet after the project ($p = 0.04$, for a 2-tailed test; Figure 23). Bull trout abundance also significantly increased after the project, from a mean of 0.3 to 2.5 bull trout per 1,000 feet after the project ($p = 0.03$, for a 2-tailed test; Figure 23). We also present comparisons of pre- and post-project abundance estimates between Sections 1, 4 and 5 for cutthroat, brook and bull trout in Figures 24-26.

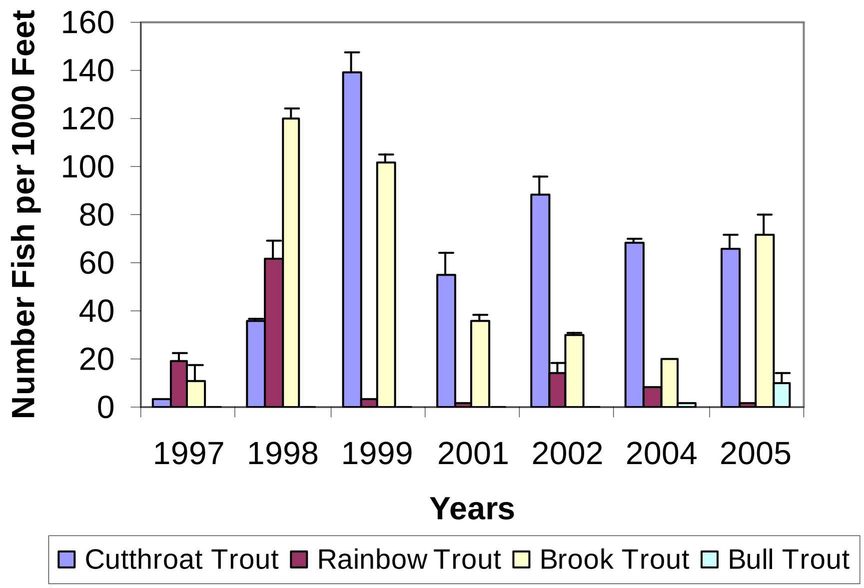

Figure 20. Cutthroat, rainbow, brook and bull trout densities (fish per 1,000 feet) within the Young Creek Section 1 monitoring site from 1997-2005, with the exception of 2003. Data were collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

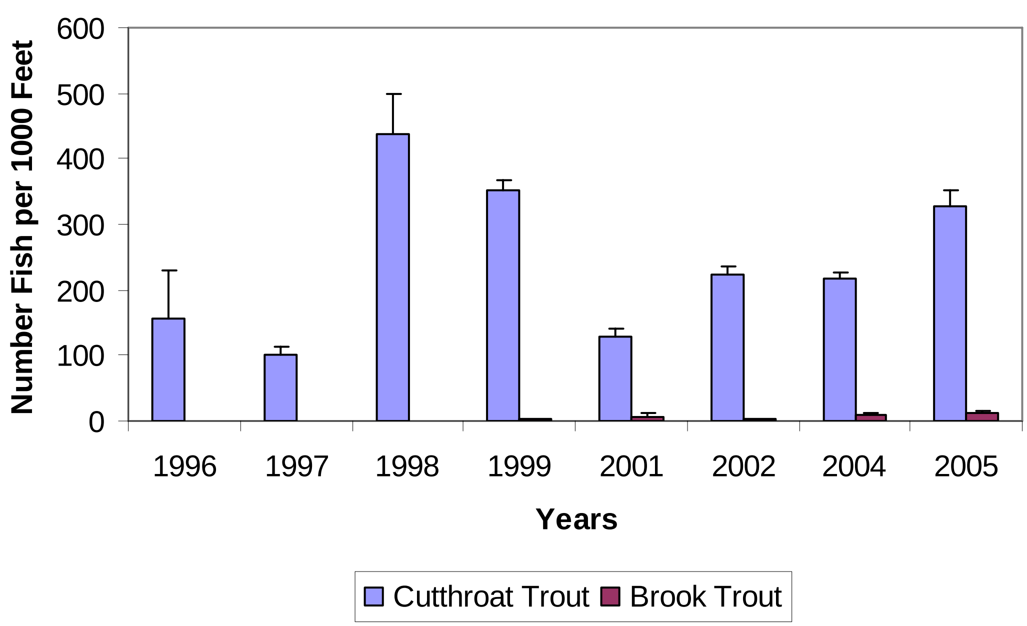

Figure 21. Cutthroat trout and brook trout densities (fish per 1,000 feet) within the Young Creek Section 4 monitoring site from 1996-2005, with the exception of 2000 and 2003. Data were collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

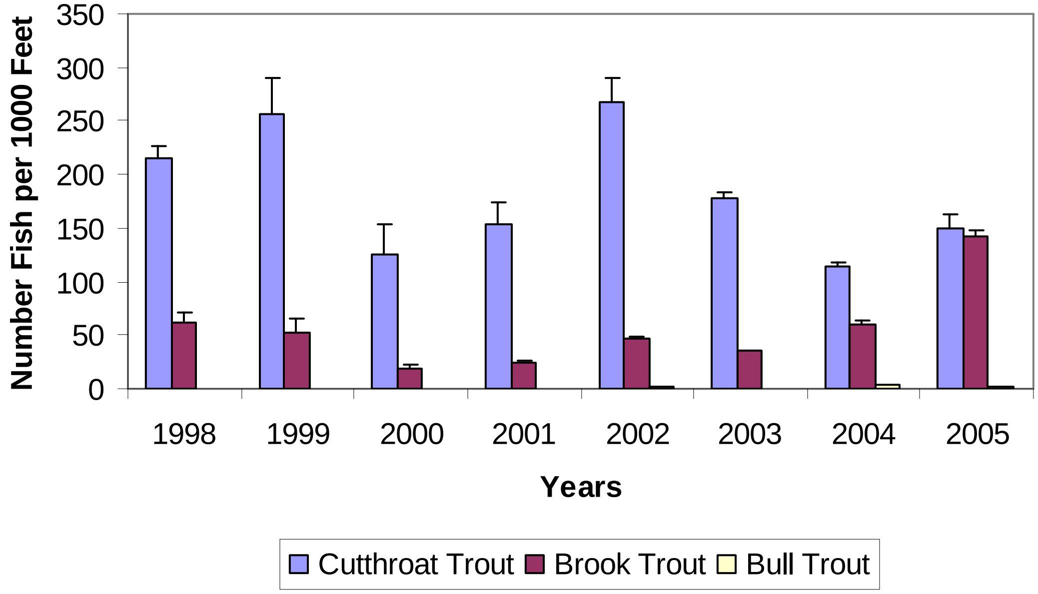

Figure 22. Cutthroat, brook and bull trout densities (fish per 1,000 feet) within the Young Creek Section 5 monitoring site from 1997-2005 collected by backpack electrofishing. The data presented for 2004 and 2005 represent post restoration data. Upper 95% confidence intervals are represented by the whisker bars.

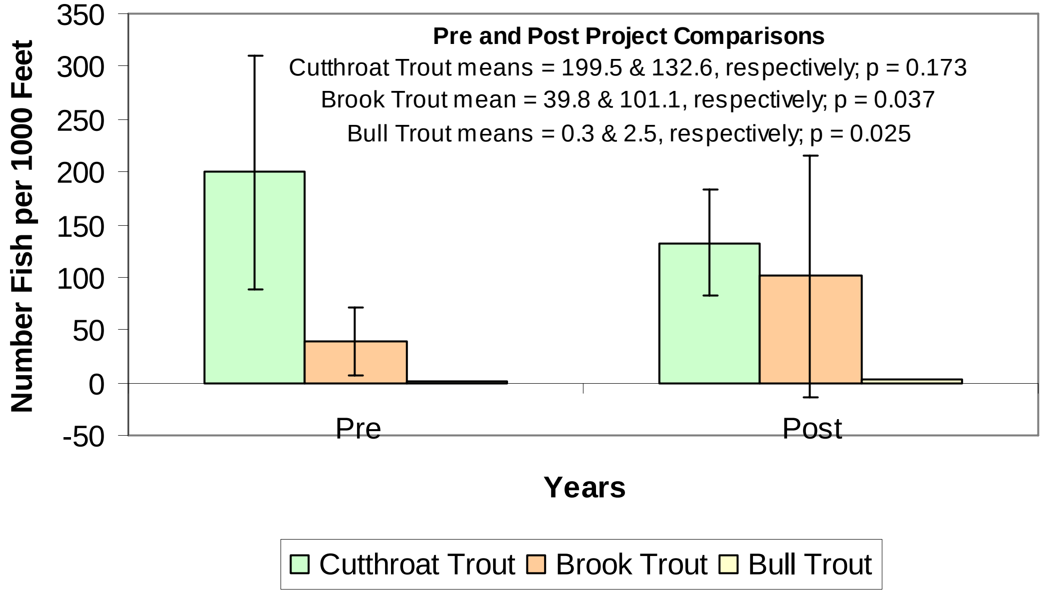

Figure 23. Cutthroat, brook and bull trout densities (fish per 1000 feet) within the Young Creek Section 5 (State Lands Restoration Project Area), comparing annual mean pre-project (1998-2003) data and post-project (2004-2005) using mobile electrofishing gear. Comparisons were made using a 2-tailed t-test. Upper and lower 95% confidence intervals are represented by the whisker bars.

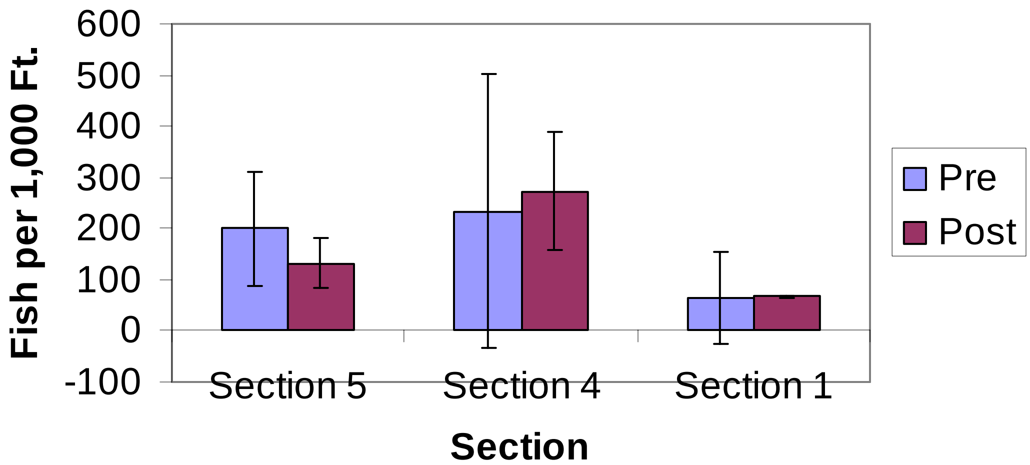

Figure 24. Cutthroat trout densities (fish per 1,000 feet) for 3 sections within Young Creek. Sections 1 and 4 represent control sites located downstream and upstream, respectively of the treatment section (Section 5). Data collected from 1996-2003 represent pre-project, and data collected in 2004-2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

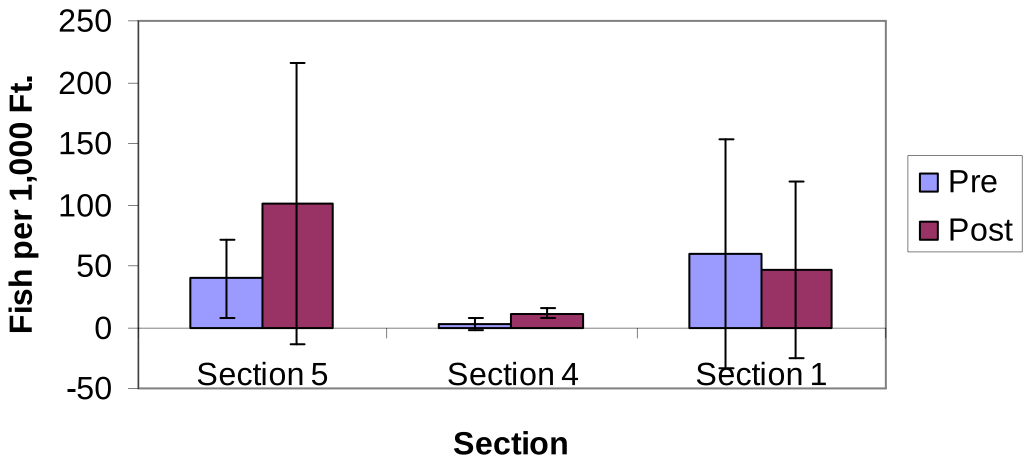

Figure 25. Brook trout densities (fish per 1,000 feet) for 3 sections within Young Creek. Sections 1 and 4 represent control sites located downstream and upstream, respectively of the treatment section (Section 5). Data collected from 1996-2003 represent pre-project, and data collected in 2004-2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

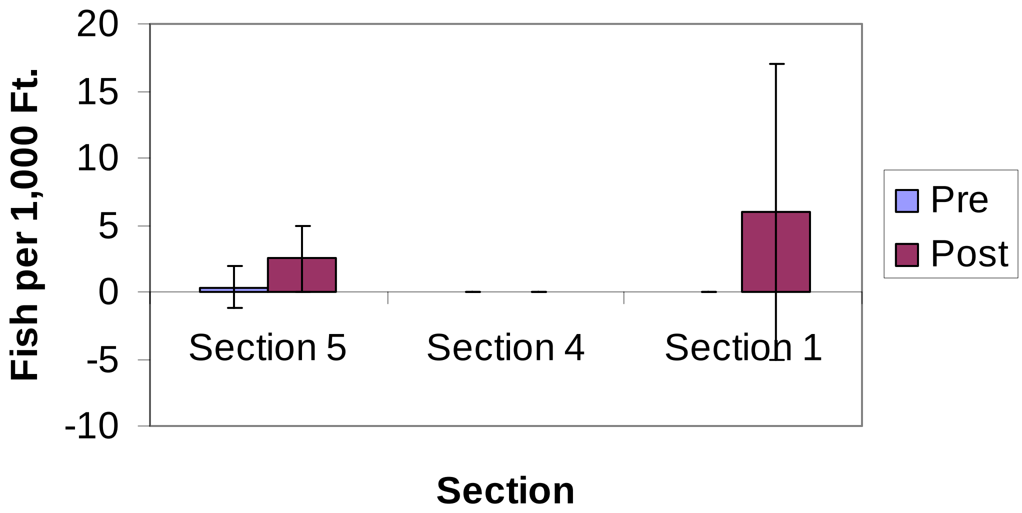

Figure 26. Bull trout densities (fish per 1,000 feet) for 3 sections within Young Creek. Sections 1 and 4 represent control sites located downstream and upstream, respectively of the treatment section (Section 5). Data collected from 1996-2003 represent pre-project, and data collected in 2004-2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

Libby Creek

Section 1 of Libby Creek has been sampled each consecutive year since 1998, and the Libby Creek Demonstration Restoration Project was completed in the fall of 2001. 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. Mean rainbow trout densities at this site were higher for the three years following the restoration project implementation (104.5 fish per 1,000 feet) compared to the four years prior to implementation (69.5 fish per 1,000 feet), the difference was nearly significant ($p = 0.118$; two tailed test). Similarly, mean brook trout abundance at this site before and after project completion were higher after project completion (8.8 and 25.6 fish per 1,000 feet, respectively; Figure 27), the difference also nearly significant ($p = 0.191$; two tailed test). 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. The estimated bull trout abundance prior to project implementation was 0, and the abundance after project implementation was higher (0.89 bull trout per 1,000 feet), but the difference was not significant ($p = 0.221$; two tailed test). Rainbow, brook and bull trout all exhibited positive trends in abundance at this site from 1998 to 2005, but none of the relationships differed significantly from a stable population. However, the trends for rainbow trout ($r^2 = 0.40$; $p = 0.091$) and brook trout ($r^2 = 0.38$ $p = 0.14$) abundance were nearly significant. Bull trout abundance has been low and variable, with no bull trout being observed in 6 of the previous 8 years (Figure 28; Table A4). 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 2003-2005 (Table A4). Rainbow trout were substantially more abundant at this section than brook trout and bull trout during all years (Figure 29; Table A4). We estimated 203, 148, 100 and 120 rainbow trout per 1000 feet in 1998 through 2004, respectively. There was a significant negative trend in rainbow trout abundance through time at this site ($r^2 = 0.923$; $p = 0.009$). Rainbow trout abundance significantly decreased when compared over the pre (1998 and 2001) and post (2003-2005) implementation period for the Libby Creek Demonstration Project (Figure 30). Brook trout abundance at Section 2 exhibited a positive trend over the period of record. However, this trend did not differ significantly from a stable population ($r^2 = 0.41$; $p = 0.25$; Figure 29). Brook trout abundance increased when compared over the pre and post implementation period for the Libby Creek Demonstration Project (Figure 31). Bull trout were only observed in this section in 1998, 2003, and 2005 (Figure 29; Table A4), and have exhibited a negative trend through the period of record, although the relationship was not significant ($r^2 = 0.379$; $p = 0.26$). Bull trout abundance decreased when compared over the pre- and post-implementation period for the Libby Creek Demonstration Project, although the difference was not significant ($p = 0.608$; Figure 32).

Our estimates of rainbow trout abundance in Section 3 of Libby Creek were similar between 2000 and 2002 (Figure 33; Table A4), with no evidence that the population differed from a stable population ($p = 0.469$; $r^2 = 0.548$) during this period. These data represent conditions prior to completion of the upper Cleveland's Stream Restoration Project. During 2003 - 2005, however, our rainbow trout estimate was significantly lower than previous years (mean abundance 88.1 and 168.3 fish per 1,000 feet, respectively; $p = 0.005$; Figure 34). Rainbow trout abundance through the period of record has exhibited a significant negative trend (r^2 = 0.912; p = 0.003; Figure 33). No brook trout were observed at this site during the past five years. We estimated 1.9 juvenile bull trout per 1,000 feet in this section in 2005 (Figure 32). Estimates of juvenile bull trout abundance before and after project implementation were similar (means = 6.0 and 4.9 fish per 1000 feet, respectively), and did not differ significantly (p = 0.75; Figure 34). Similarly, we found no evidence of a trend in bull trout abundance through time at this site for the period of record ((r^2 = 0.08; p = 0.58; Figure 33).

We established juvenile monitoring sites 4, 5, and 6 on upper Libby Creek in 2004 to monitor the fish community response to the upper Cleveland Stream Restoration Project planned for implementation in the fall of 2006. Sites 4 and 5 serve as control sites and are located downstream and upstream of the proposed restoration project area, respectively. Site 6 is located within the proposed restoration project area. Fish population data collected in 2004 and 2005 will provide baseline data for comparison after project implementation. Rainbow trout (presumed to be redband trout) dominated the fish community at all three sampling locations (Figure 35; Table A4). Rainbow trout abundance was highest within Section 4 (downstream of lower Cleveland Property), where we estimated 272.9 rainbow trout per 1,000 feet. Rainbow trout abundance at sections 5 and 6 were 173.0 and 221.3 per 1,000 feet, respectively. Bull trout were encountered at low abundance at sections 4 and 5, but absent at Section 5. We estimated 1.7 and 3.5 bull trout per 1,000 feet at sections 4 and 6, respectively. Brook trout were also relatively scarce, being only encountered at Section 4, with an estimated abundance of 1.7 fish per 1,000 feet.

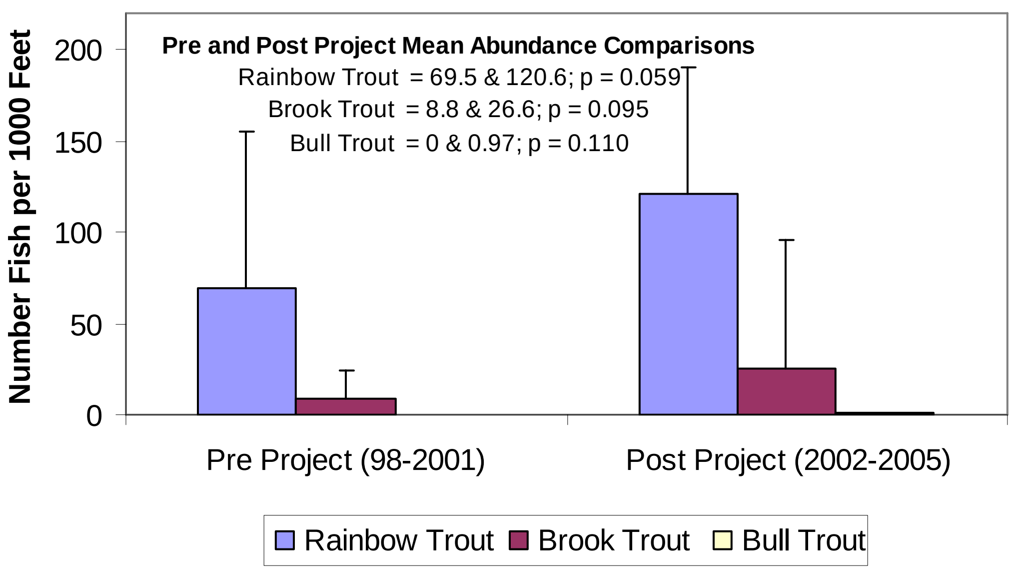

Figure 27. Rainbow trout and brook trout densities (fish per 1,000 feet) within the Libby Creek Demonstration Project area, comparing annual mean pre-project (1998-2001) data and post-project (2002-2005) using mobile electrofishing gear. Upper 95% confidence intervals are represented by the whisker bars.

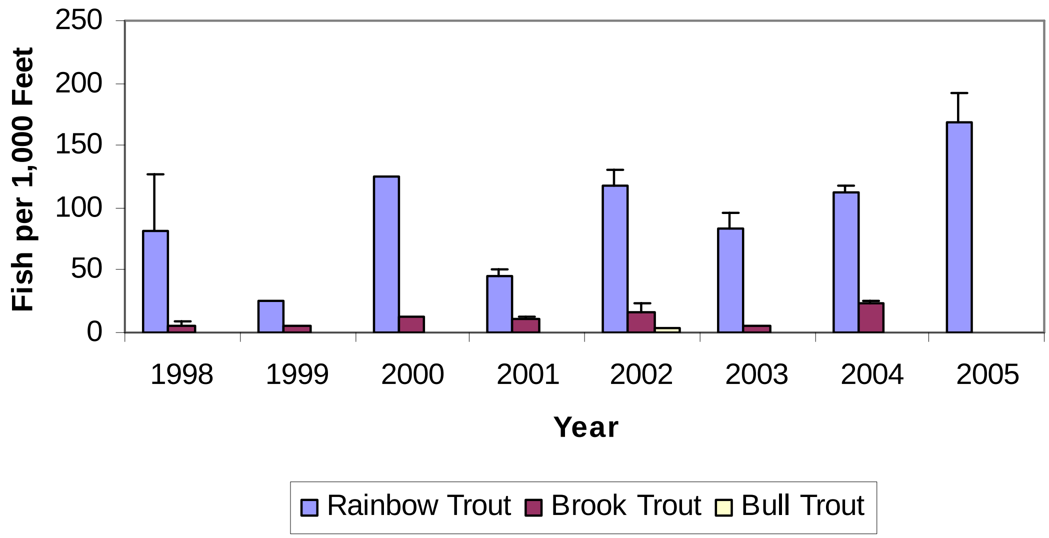

Figure 28. Rainbow trout, brook trout, and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 1 monitoring site 1998 through 2005 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. The site was sampled using single pass electrofishing in 1999 and 2000.

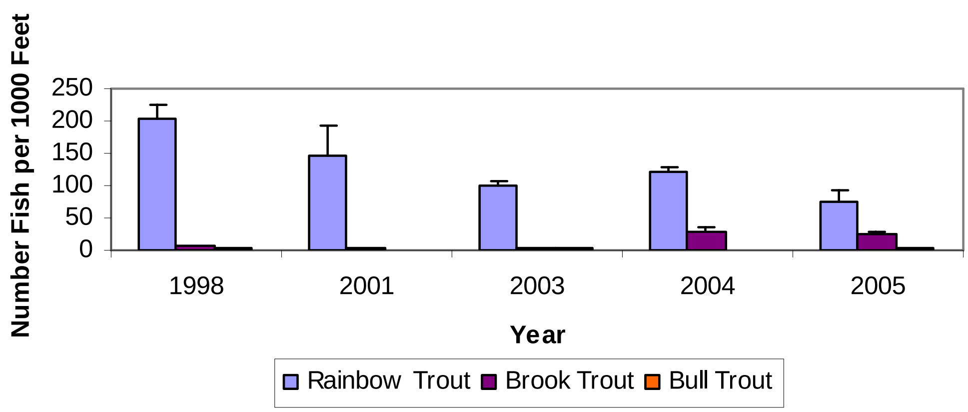

Figure 29. Rainbow trout, brook trout, and bull trout densities (fish per 1000 feet) within the Libby Creek Section 2 monitoring site sampled in 1998, 2001, 2003-2005 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars.

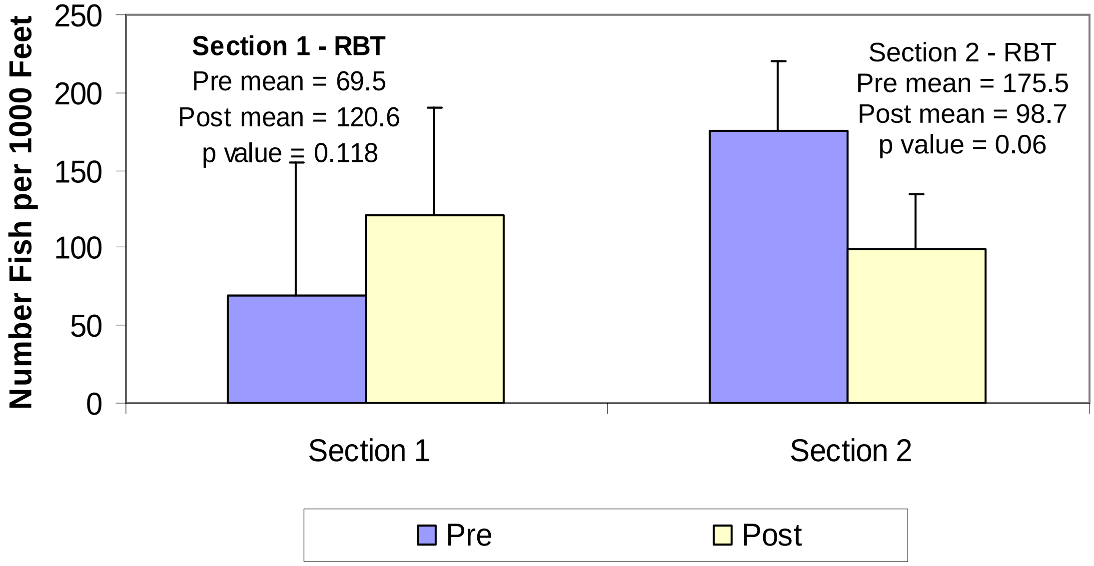

Figure 30. Rainbow trout densities (fish per 1,000 feet) for Sections 1 (Demonstration Project) and Section 2 (Control) on lower Libby Creek. Data collected from 1998-2001 represent pre-project, and data collected in 2002-2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. P-values were estimated from a two sided t-test. Upper 95% confidence intervals are represented by the whisker bars.

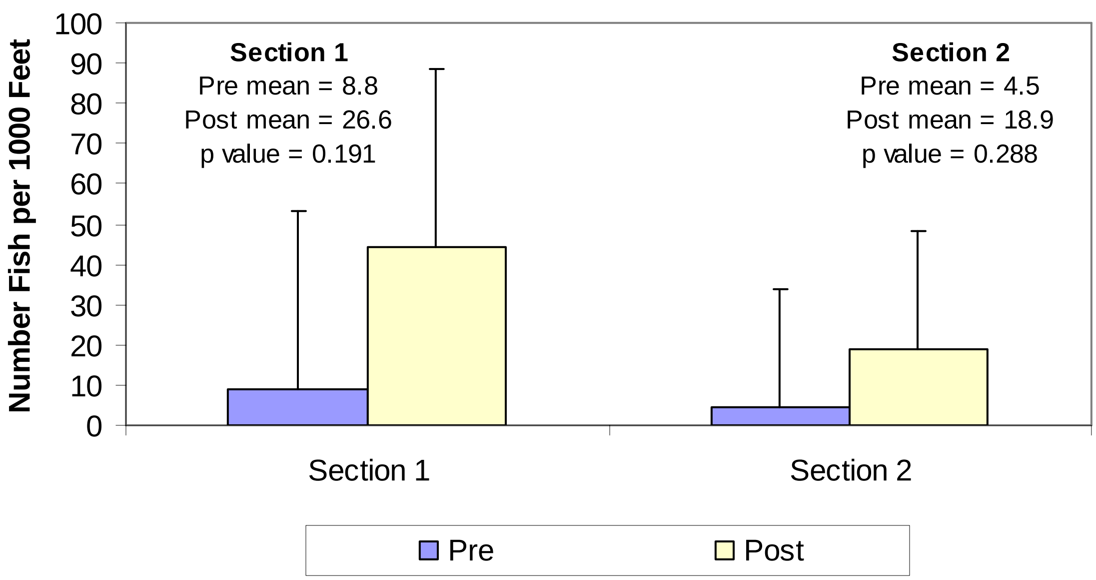

Figure 31. Brook trout densities (fish per 1,000 feet) for Sections 1 (Demonstration Project) and Section 2 (Control) on lower Libby Creek. Data collected from 1998-2001 represent pre-project, and data collected in 2002-2005 represent post-project results. Depletion

estimates were calculated from backpack electrofishing. P-values were estimated from a two sided t-test. Upper 95% confidence intervals are represented by the whisker bars.

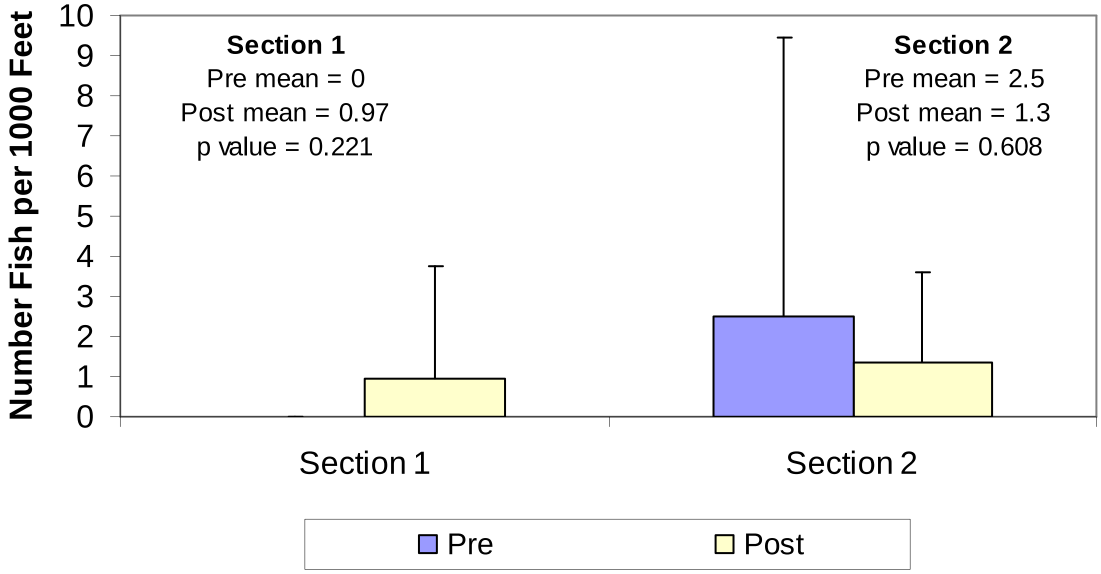

Figure 32. Bull trout densities (fish per 1,000 feet) for Sections 1 (Demonstration Project) and Section 2 (Control) on lower Libby Creek. Data collected from 1998-2001 represent pre-project, and data collected in 2002-2005 represent post-project results. Depletion estimates were calculated from backpack electrofishing. P-values were estimated from a two sided t-test. Upper 95% confidence intervals are represented by the whisker bars.

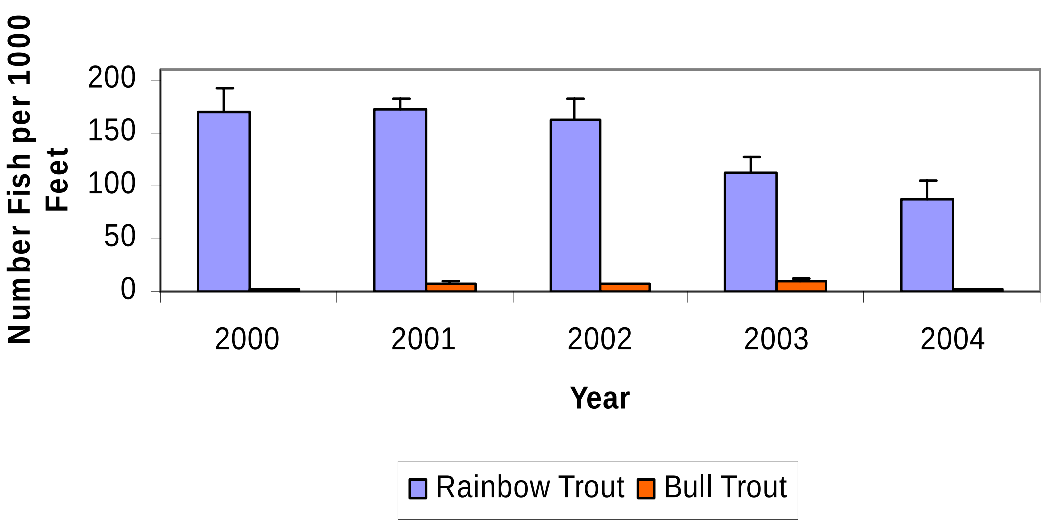

Figure 33. Rainbow trout and bull trout densities (fish per 1,000 feet) within the Libby Creek Section 3 monitoring site in 2000-2005 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. This site is located within the upper Libby Creek restoration project area. The data from 2000-2002 represent pre-project trends of fish abundance, and the 2003-2005 data represent conditions after project completion.

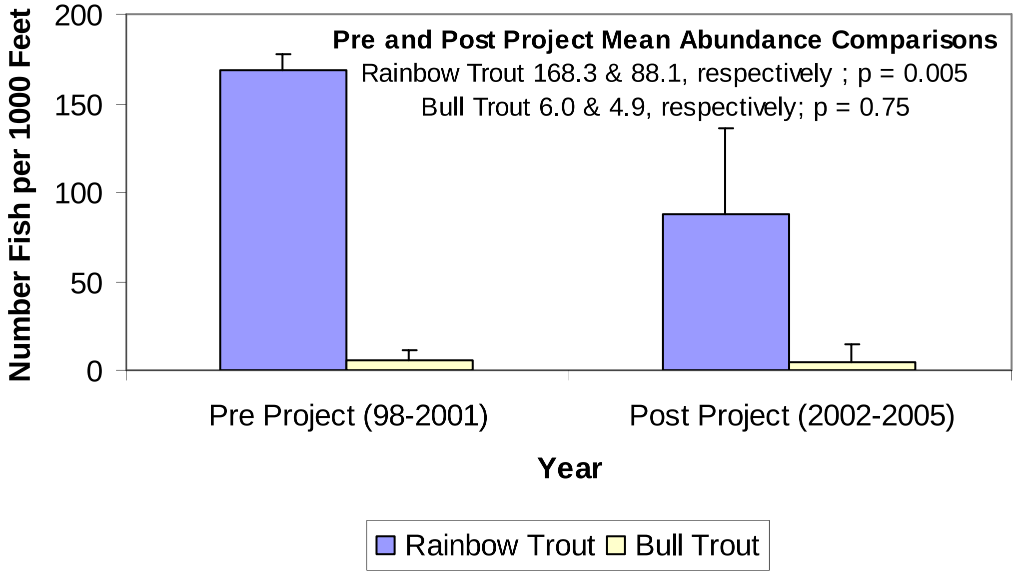

Figure 34. Rainbow trout and bull trout densities (fish per 1,000 feet) within the Libby Creek Upper Cleveland's Stream Restoration Project area (Section 3), comparing annual mean pre-project (2000-2002) data and post-project (2003-2005) using mobile electrofishing gear. Upper 95% confidence intervals are represented by the whisker bars.

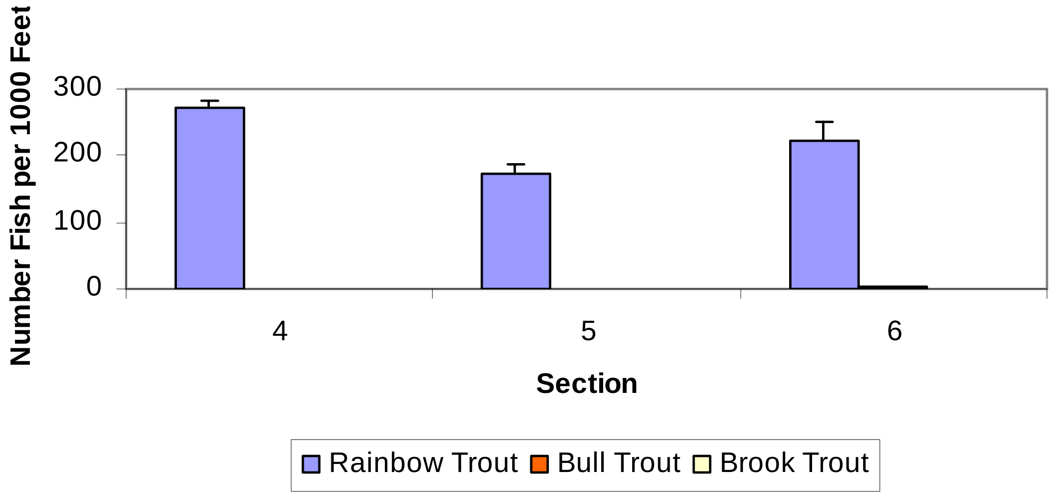

Figure 35. Rainbow, bull and brook trout densities (fish per 1,000 feet) within the Libby Creek Sections 4-6 monitoring sites in 2005. These sites were sampled using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. These monitoring sites are located below, above and within the lower Cleveland Stream Restoration Project Area on upper Libby Creek.

Pipe Creek

Juvenile rainbow trout were the most abundant fish species at the lower Pipe Creek Section during all years sampled. (Table A5), with estimates ranging from a high of 73 fish per 1,000 feet in 2002 to our lowest estimate of 20.8 fish per 1,000 feet in 2005 (Figure 36; mean for all years = 40.0 fish per 1,000 feet). The juvenile rainbow trout trend in abundance has been slightly declining through time, but the trend did not differ significantly from a stable population ($r^2 = 0.484$; $p = 0.192$). Brook trout abundance increased slightly through time, but were generally about an order of magnitude less abundant at this site than rainbow trout, with estimates ranging from a high of 6.5 brook trout per 1,000 feet in 2003 to a low of 0 brook trout in 2001 (mean for all years = 4.0 fish per 1,000 feet). Although the overall general trend for brook trout increased through time, the trend nearly differed significantly from a stable population, based on the limited time interval we have sampled ($r^2 = 0.657$; $p = 0.096$). We estimated 6.3 brook trout per 1,000 feet were present at the Pipe Creek site in 2005.

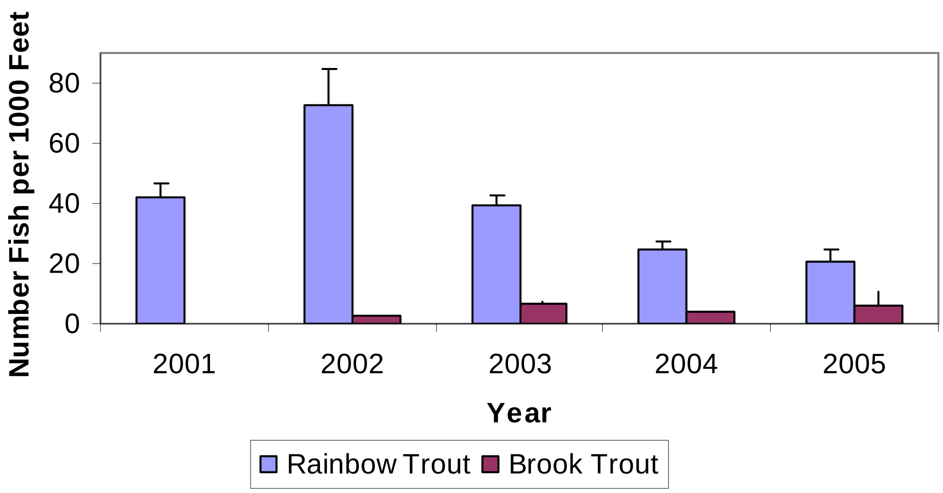

Figure 36. Rainbow trout and brook trout densities (fish per 1,000 feet) within the Pipe Creek monitoring site from 2001-2005. Fish were collected using a backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

Libby Reservoir Gillnet Monitoring

We documented changes in the assemblage of fish species sampled in Libby Reservoir since impoundment. 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, westslope cutthroat trout and redside shiner were common in the Kootenai River before impoundment, but have decreased in abundance since impoundment.

Kokanee

Since the accidental introduction of 250,000 fry from the Kootenay Trout Hatchery in British Columbia into Libby Reservoir in 1980, kokanee have become the second most abundant fish captured during fall gillnetting. Fluctuations in catch have corresponded to the strength of various year classes (Hoffman et al. 2002), and have varied by year, with no apparent continuous trend in abundance (Figure 37). However, kokanee catch in the fall net series follows a general trend of decreasing abundance from 1988-1995 and an increasing trend in abundance from 1996-2005 (Figure 37). Average length of kokanee has varied among years. Average length and weight between 1988 and 2005 was 285.4 mm and 224.4 g respectively (Table 4). The maximum average size occurred in 1992 (350 mm, 411 g) when numbers were low and the minimum mean length was observed in 2002 when numbers were high (Table 4). This is likely attributable to density dependant growth exhibited by this species.

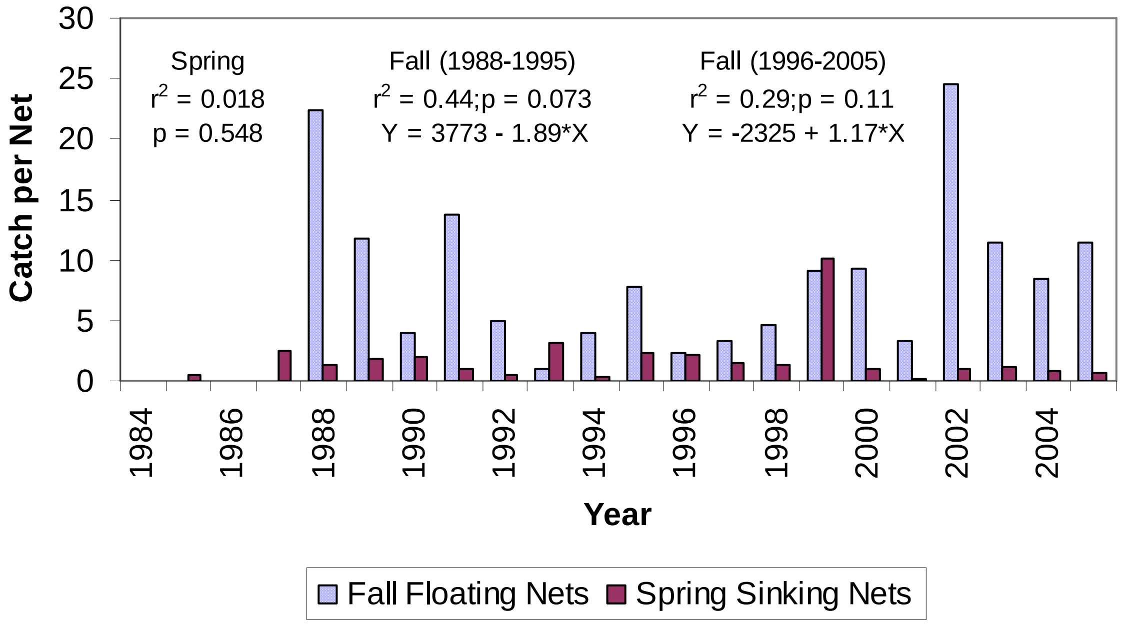

Figure 37. Average catch per net of kokanee for fall floating (1988-2005) and spring sinking (1984-2005) gill nets in Libby Reservoir.

Table 4. Average length and weight of kokanee salmon captured in fall floating gillnets (Rexford and Canada Sites) in Libby Reservoir, 1988 through 2005.

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Sample size (n)	2150	1259	517	624	250	111	291	380	132	88
Length (mm)	315.5	275	257.3	315.8	350	262.7	270.2	300.2	293.7	329.6
Weight (gm)	289.1	137.2	158.4	327.3	411.3	162.3	191.7	261.6	234.5	363.2

Table 4. Continued

YEAR	1998	1999	2000	2001	2002	2003	2004	2005	AVG.
Sample size (n)	76	200	342	120	357	263	194	320	426.3
Length (mm)	333.9	291.6	271.3	261.6	251.3	264.9	261.0	285.4	288.4
Weight (gm)	322.0	229.6	185.6	161.6	152.2	175.5	159.2	224.4	230.4

Mountain Whitefish

Mountain whitefish are one of three native species that have declined in abundance since impoundment of the Kootenai River (Huston et al. 1984, Figure 38). A natural logarithm transformation provided the best fit to the sinking gillnet catch data (Figure 38; $r^2 = 0.463$, $p < 0.05$). The trend in catch data for mountain whitefish during the first 13 years after reservoir impoundment (1975-1988; mean catch = 3.5 fish per net) decreased annually, until it reached a significantly lower ($p < 0.0001$) equilibrium since 1989 with mountain whitefish catch rates averaging 0.76 fish per net ($r^2 = 0.012$; $p = 0.66$). Catch rates since 1988 remained low; with mountain whitefish comprising an average of 0.8% of the spring catch during 1988 through 2006. 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.

Rainbow and Westslope Cutthroat Trout

Rainbow trout and westslope cutthroat trout catch have both significantly declined since the impoundment of Libby Reservoir (Figure 38). Similarly to mountain whitefish gillnet catch data, rainbow and westslope cutthroat trout gillnet catch data was best fit with linear regression using a natural logarithm transformation (Figure 38). Although both species exhibit similar declining trends in catch since 1975, rainbow trout catch per net since 1975 has declined more precipitously than cutthroat trout catch per net. Rainbow trout have exhibited two general trends since impoundment. The first trend showed a significant decline in abundance from 1975 to 1988 (Figure 38), followed by a period of relative stability from 1989 to 2005, where the average catch per net during this period (mean fish per net = 0.346) was not significantly different than a stable population (zero slope; Figure 38). Gillnet 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 38), where mean catch rates averaged 1.37 fish per net. 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 2005, characterized by a significantly lower level of abundance (0.149 fish per net; $p < 0.001$), at a somewhat stable level ($r^2 = 0.117$; $p = 0.275$). 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. During the period 1989 – 1994 an average of 43,274 cutthroat trout were stocked in the reservoir annually (Table 5). Hatchery cutthroat trout were last stocked in the reservoir in 1994.

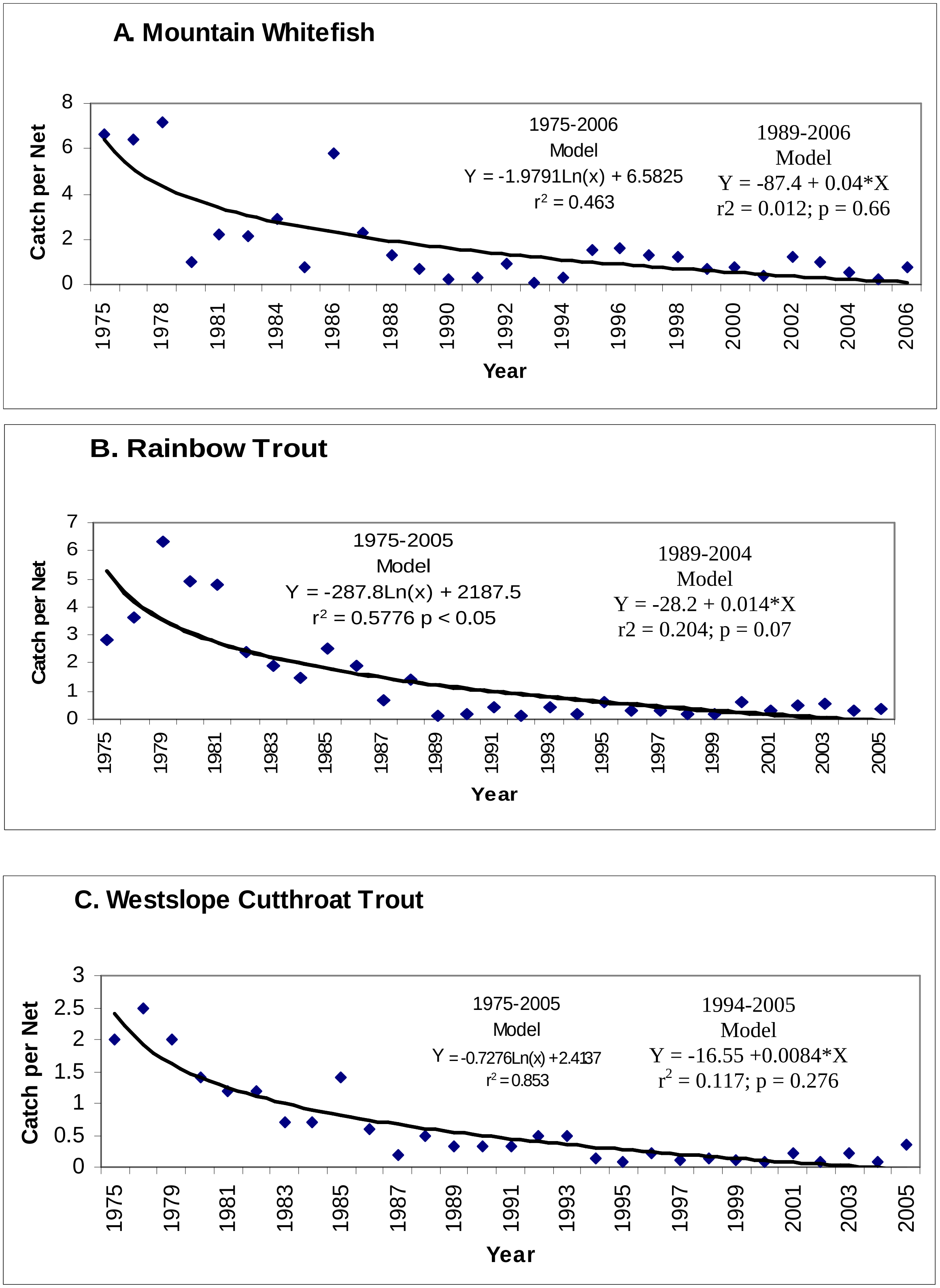

Figure 38. Mean catch rates (fish per net) of three native species (mountain whitefish (a) in spring sinking gillnets in the Rexford area, rainbow (b) and westslope cutthroat trout (c) in

floating gillnets from Tenmile and Rexford areas in Libby Reservoir, 1975 through 2005. The Tenmile area was not sampled during the fall from 2001-2005.

Table 5. 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 2005. The Tenmile location was not sampled in 2000-2005.

	1988	1989	1990	1991	1992	1993	1994	1995	1996
Catch Rate	0.50	0.32	0.32	0.32	0.50	0.50	0.14	0.07	0.21
Avg. Length (mm)	295	264	238	261	275	260	251	314	252
Avg. Weight (gm)	249	196	146	191	211	191	156	316	161
No. Stocked	none	5,779	40,376	67,387	72,376	72,367	1,360	none	none
Length (mm)	n/a		33	104	216	190	287	n/a	n/a

	1997	1998	1999	2000	2001	2002	2003	2004	2005
Catch Rate	0.11	0.14	0.11	0.07	0.21	0.07	0.21	0.07	0.36
Avg. Length (mm)	225	267	305	302	259	305	270	196	215
Avg. Weight (gm)	128	228	296	271	175	256	206	76	132
No. Stocked	none	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	n/a

Kamloops Rainbow Trout (Duncan Strain)

Kamloops rainbow trout were first introduced to Libby Reservoir in 1985 by BCMOE. The BCMOE continued stocking approximately 5,000 fingerling Kamloops (Gerrard strain) annually into Kikomun Creek (a tributary to the Kootenai River) from 1988-1998 (L. Siemens, BCMOE, personal communication). MFWP has stocked approximately 11,000 to 73,000 Duncan strain Kamloops rainbow trout since 1988 directly into the reservoir (Table 6). The catch of Kamloops rainbow trout in fall floating gillnets (fish per net) was significantly and positively correlated with the number of hatchery Kamloops rainbow trout stocked in the reservoir the previous year ($p = 0.049$; $r^2 = 0.23$; Table 6) for 1989 through 2005. However, the catch rate of Kamloops rainbow trout in fall floating gillnets shows no significant trend (Figure 39; $r^2 = 0.155$; $p = 0.11$). Catch rates for Kamloops rainbow trout in fall gillnets has been low since 1996, averaging only 0.06 fish per gillnet.

Table 6. Kamloops rainbow trout captured in fall floating gillnets in the Rexford and Tenmile areas of Libby Reservoir, 1988 through 2002. The Tenmile site was not sampled in 2001 or 2002.

	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
No. Stocked	20,546	73,386	36,983	15,004	12,918	10,831	16,364	15,844
Length (mm)	208-327	175-198	175-215	180-190	198-208	165-183	168-185	165-178
	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
No. Stocked	12,561	22,610	16,368	13,123	none	none	29,546	44,769
Length (mm)	170.5	152-178	127-152	255-280	N/A	N/A	80.3	81-206
	2004	2005						
No. Caught	0	0						
Avg. Length (mm)	N/A	N/A						
Avg. Weight (gm)	N/A	N/A						
No. Stocked	63,099	53,198						
Length (mm)	76 - 178	106-190						

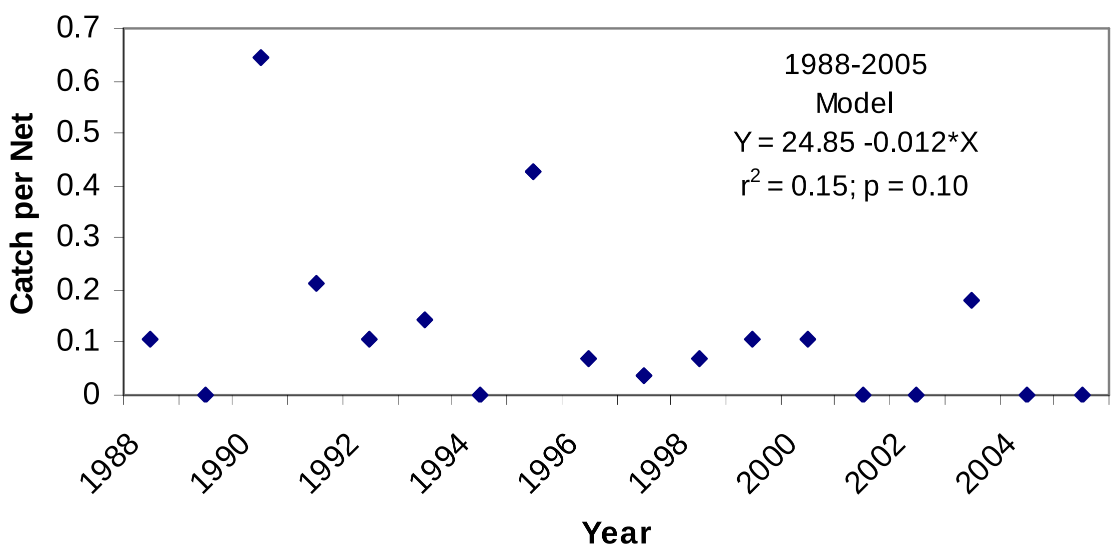

Figure 39. Average catch (fish per net) of Kamloops rainbow trout (Duncan strain) in fall floating gill nets in Libby Reservoir at the Rexford and Tenmile sites 1988-2005. The Tenmile site was not sampled in 2001-2005.

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 ($r^2 = 0.011$; $p = 0.751$). However, beginning in approximately 1990, bull trout catch per net in Libby Reservoir began significantly increasing through 2006 (Figure 40; $r^2 = 0.744$; $p = 8.4*10^{-7}$). The mean catch rate we observed in 2006 was 4.36 bull trout per net, which represented a 26% reduction from the previous year (2005 mean catch rate = 5.93 bull trout per net). Bull trout catch rates peaked in 2000 at 6.71 bull trout per 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 to the data in previous years (Dunnigan et al. 2004), but did not improve the fit with the addition of the 2005 and 2006 data (Figure 41; $r^2 = 0.611$; $p = 9.06*10^{-7}$). However, this adjustment did slightly improve the fit of the data over the time period 1990-2006 (Figures 40 and 41, respectively). Bull trout redd counts (see above) in both the Wigwam River and Grave Creek are both significantly and positively correlated to the spring gill net catch rates for bull trout (Figure 42; $r^2 = 0.557$; $p = 0.005$).

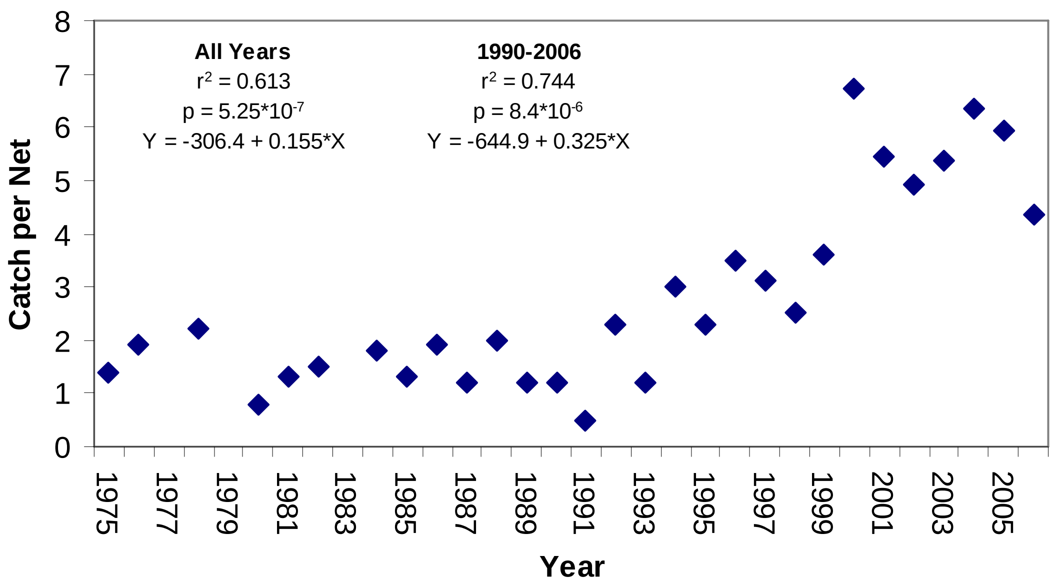

Figure 40. Average catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir 1975-2006.

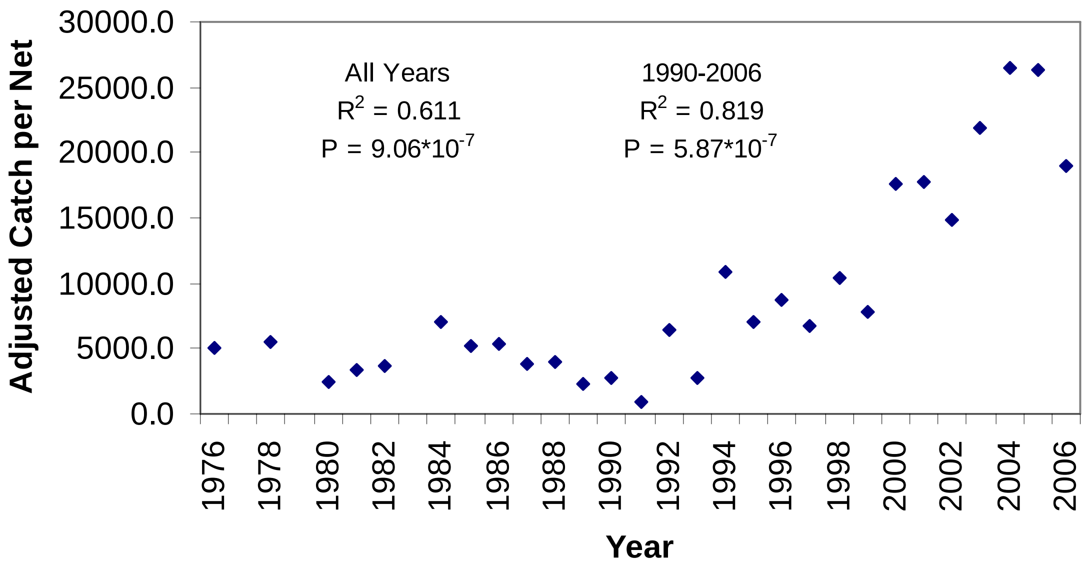

Figure 41. Average adjusted catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir. Average annual bull trout catch per net was adjusted by multiplying catch by reservoir volume at the time of gillnetting.

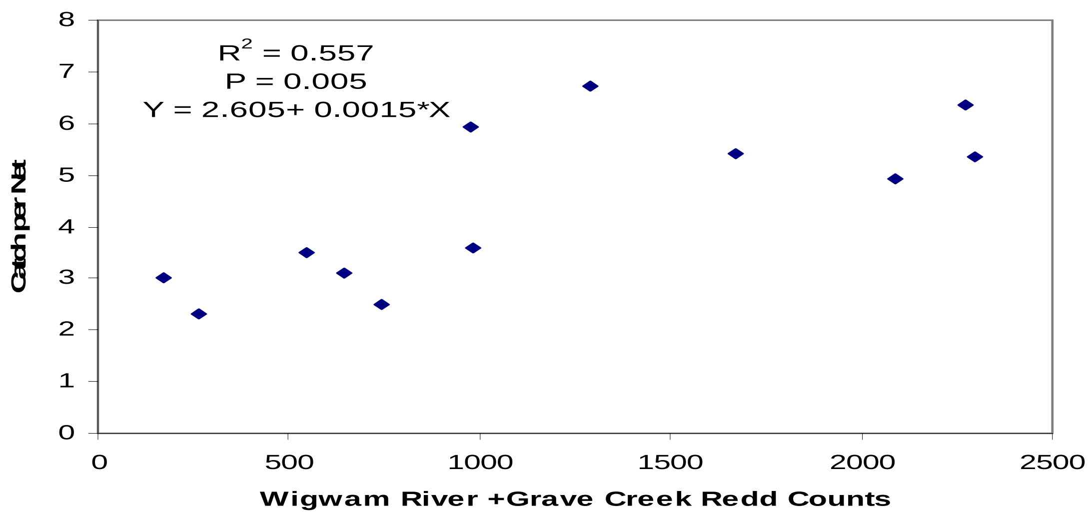

Figure 42. Average catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir related to total annual bull trout redd counts for the Wigwam River and Grave Creek during the period 1994-2005.

Burbot

Burbot catch rates in spring sinking gillnets since 1990 show no clear trend in abundance (Figure 43; $r^2 = 0.144$; $p = 0.13$). Burbot catch per net for spring sinking nets has averaged 0.27 fish per net, and ranged from 0.07 to 0.5 fish per net. Burbot are not readily captured in floating gill nets. Burbot catch rates in spring gillnets is however significantly and positively correlated ($r^2 = 0.493$; $P = 0.016$; Figure 44) 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.

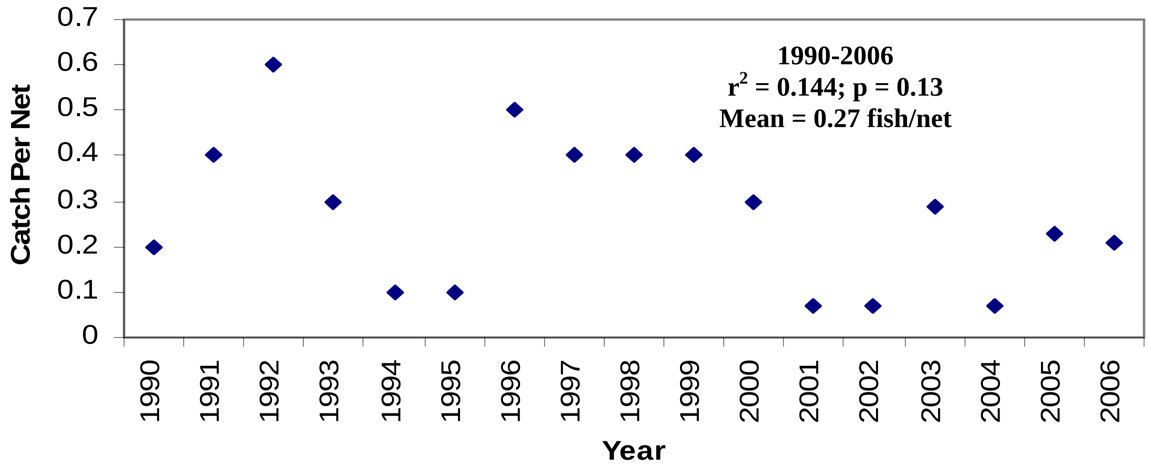

Figure 43. Mean catch per net of burbot in sinking gillnets during spring gillnetting at the Rexford site on Libby Reservoir, 1990-2006. The mean catch per net during the period was 0.27 fish per net.

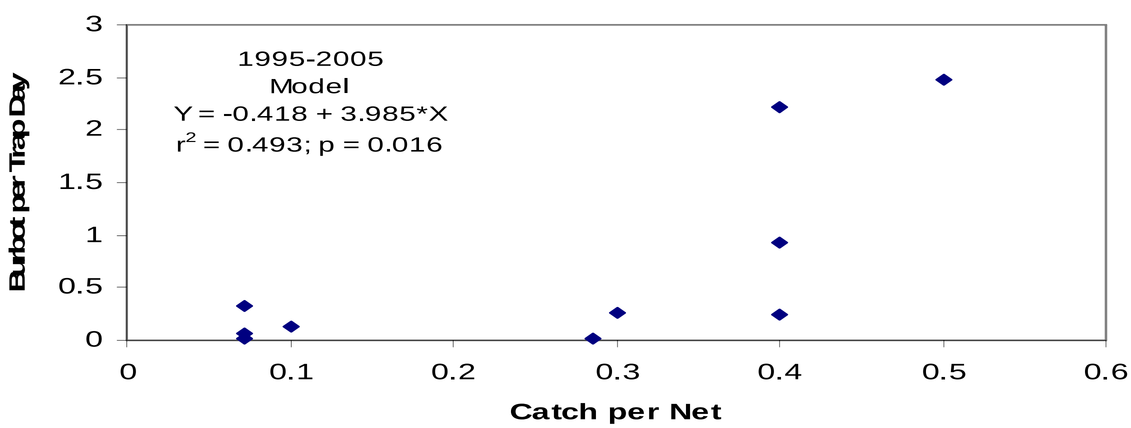

Figure 44. The relationship between mean burbot catch per net for spring sinking gillnets on Libby Reservoir and burbot catch rates (fish/trap day) of baited hoop traps in the stilling basin below Libby Dam 1995-2005.

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 45; $r^2 = 0.056$; $p = 0.225$; Table 7), and is indicative of an increase in the biomass of species that prefer reservoir habitats: Columbia River chub, suckers, northern pikeminnow, etc. However, there is no significant trend in total catch (fish per net) for fall gillnets (Figure 45; $r^2 < 0.0001$; $p = 0.96$; Table 8). Species composition for the catch of fall and spring gillnets has remained relatively stable since 1988 (Table 9).

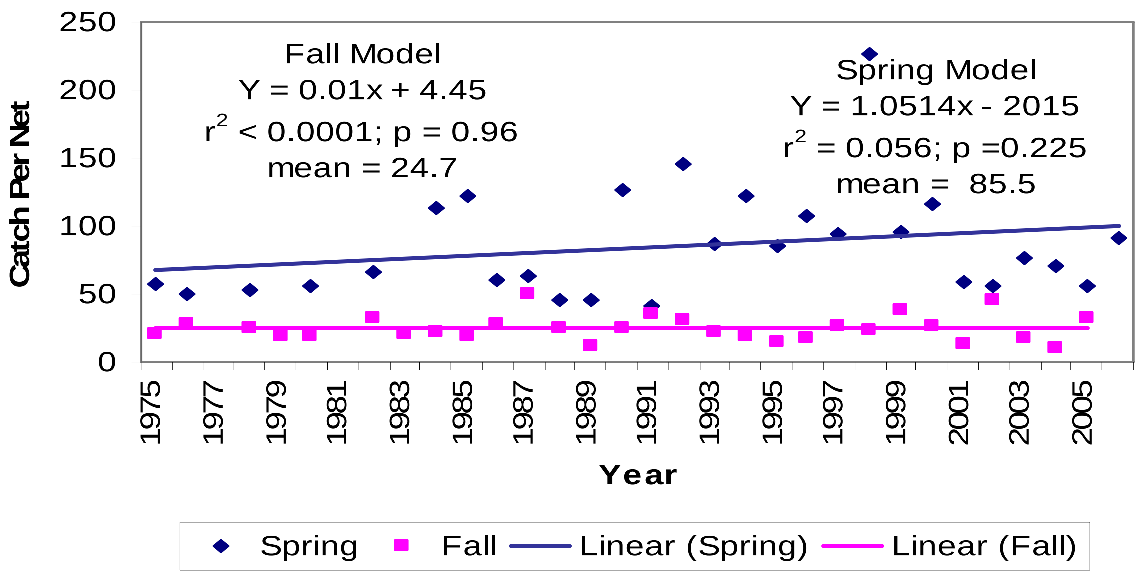

Figure 45. Catch per net (all species combined) in fall floating and spring sinking gillnets and associated trend lines in Libby Reservoir, 1975 through 2005.

Table 7. 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, 1990 through 2005.

	YEAR															
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Date	9/25	10/2	9/25	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
Number Nets	54	28	28	28	28	28	28	28	28	28	28	14	14	14	14	14
Res. Elevation	2456	2448	2421	2441	2446	2454	2450	2448	2439	2453	2434	2433	2441	2435	2445	2437
	Average number of fish caught per net for individual fish species															
RBT	0.2	0.4	0.1	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
WCT	0.2	0.4	0.5	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
RB X WCT∠	0.3	0.2	0.2	0	0	0	0	0	<0.1	0	0	0	0	<0.1	0	0
SUB-TOTAL	0.7	1	0.8	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
MWF	0.2	0.5	0.2	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
CRC	18.2	18.4	23.3	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
NPM	1.8	2.1	1.8	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
RSS	0	0.1	0	0	0.3	0.2	0.1	1.0	0.3	0.3	<0.1	0	0.3	<0.1	0	0.1
BT	0	0	0.1	0.3	0	1.2	<0.1	0	<0.1	<0.1	0.2	0	0.1	0	0.21	0.04
CSU	0.1	0.1	0	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
KOK	3.9	13.7	5	1	4	7.9	2.3	3.1	2.7	7.3	8.0	2.1	14.2	7.4	3.5	11.4
TOTAL	24.9	35.9	31.2	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

*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 8. Average catch per net for 12 different fish species* captured in sinking gillnets set during spring in the Rexford area of Libby Reservoir, 1990 through 2005.

	YEAR																
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Date	5/10	5/16	5/5	5/17	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
Number of Sinking Nets	27	28	28	28	28	28	28	28	27	28	14	14	14	14	14	14	14
Reservoir Elevation	2358	2330	2333	2352	2405	2386	2365	2350	2417	2352	2371	2392	2384	2417	2419	2425	2424
	Average number of fish caught per net for individual fish species																
RBT	0.1	0.1	0.1	0.3	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
WCT	<0.1	0.0	0.1	0.0	<0.1	0.1	0.1	0.2	0.0	0.3	0.1	0	0	0.2	0.2	0.1	0
RB x WCT	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0	0.2	0.0	0	0	0
SUB-TOTAL	0.1	0.2	0.2	0.3	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
MWF	0.2	0.3	0.9	0.1	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
CRC	104.8	31	119	63.3	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
NPM	6.0	2.0	4.2	3.8	7.6	8.0	10.0	13.1	15.1	14	12.6	11	9.9	13.0	11.9	9.7	10.9
RSS	<0.1	0.0	0.5	0.0	0.0	0.0	0.0	0.1	1.0	0.1	0.4	0	0	0.1	0	0	0
BT	1.2	0.5	2.3	1.2	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
LING	0.2	0.4	0.6	0.3	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
CSU	5.8	2.4	12.9	9.8	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
FSU	1.8	1.1	2.9	4.1	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
YP	4.7	2.1	1.8	1.1	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
KOK	2.0	1.0	0.4	3.5	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
TOTAL	120.7	40.0	145.3	84.3	121.9	86.3	107.1	93.25	226.2	95.9	115.1	59.2	55.2	76.8	70.9	53.4	90.1

*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 9. Percent composition of major fish species* caught in fall floating and spring sinking gillnets in Libby Reservoir, 1989 through 2005. Blank entries in table indicate either no fish were captured or that they occurred in very small proportions.

	1989		1990		1991		1992		1993		1994		1995		1996		1997	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RB	0.1		0.7		1.0		0.3		1.8		0.9		4.4		1.4		Fall	Spr.
WCT	0.3		0.7		1.0		1.7		3.8		0.7		0.8		1.2		1.7	0.2
HB	0.3		1.1		0.5		0.7		0.2		0.0		0.3		0.2		0.6	0.4
ONC	0.7	0.4	2.4	0.1	2.4	0.4	2.7	0.1	5.8	0.3	1.7	0.2	5.5	0.4	2.8	1.0	0	0
MWF	0.2	0.8	0.9	0.2	1.4	0.7	0.7	0.6	1.4	0.2	2.2	0.3	2.1	1.7	1.4	1.5	2.3	0
CRC	70.5	66.0	71.4	82.6	50.0	76.5	72.6	81.7	72.8	73.9	54.3	77.0	8.6	62.9	66.5	56.9	2.4	1.9
NPM	4.1	7.4	7.2	4.8	5.8	5.0	5.6	2.9	9.3	5.0	17.5	6.2	19.6	9.3	10.2	8.7	56.0	33.8
RSS	0.2	0.1	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0	1.5	0.0	1.3	0.0	0.6	0.0	18.0	20.0
FSU	0.0	1.6	0.0	1.5	0.0	2.6	0.1	2.0	0.0	5.2	0.0	5.3	0.0	3.5	0.0	4.4	3.5	0.2
CSU	0.2	10.3	0.2	4.5	0.3	5.9	0.0	8.8	0.6	9.7	0.6	7.3	0.0	13.9	2.4	18.6	0	7.2
KOK	23.4	2.1	15.5	1.5	37.3	1.6	15.7	0.3	4.4	3.4	20.6	0.2%	57.4	2.4	13.2	1.8	3.38	20.8
YP		9.4		3.7		5.2		1.2		1.1		0.9		2.9		3.4	14.4	2.2
BT		1.4		1.0		1.1		1.7		1.1		2.5		2.8		3.3	0	7.4

	1998		1999		2000		2001		2002		2003		2004		2005		Average	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RB	1.5	0.1	0.6	0.9	1.1	0.2	1.4	0.4	0.4	0.4	2.8	0.9	3.7	0.8	1.2	0.8	1.2	0.3
WCT	0.5	0.1	0.3	0.2	0.8	0.1	1.7	0	0.1	0	0.8	0.3	0.7	0.3	1.1	0.1	0.9	0.1
HB	2.3	0	0	0	0	0	0	0	0	0	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
ONC	4.2	0.4	0.9	1.3	1.9	0.3	3.1	0.4	0.5	0.4	4.0	1.2	4.5	1.1	2.3	0.9	2.4	0.4
MWF	1.2	2.5	0.6	1.1	0.5	0.7	2.5	0.6	0.3	1.5	2.0	1.6	6.0	0.7	0.5	0.4	1.1	1.0
CRC	50.2	33.0	44.6	38.3	46.4	66.0	49.3	42.2	41.5	62.4	27.7	54.9	16.4	62.6	35.2	41.1	46.7	50.3
NPM	21.1	17.6	22.5	20.8	18.1	10.8	22.5	18.6	14.4	11.8	18.6	16.9	34.3	16.8	22.8	17.2	11.7	9.7
RSS	0.8	1.4	0.7	0.1	0.1	0.4	1.4	0	0.9	0	0.4	0.1	0.0	0.0	0.5	0.0	0.7	0.2
FSU	0.3	12.1	0.1	8.7	0.1	4.0	0	1.9	0	3.4	0.4	3.0	0.0	0.4	0.0	1.9	0.0	3.7
CSU	4.6	24.1	3.3	13.7	4.0	9.1	3.4	24.0	0.6	12.3	1.2	13.3	2.2	7.4	0.7	20.9	1.4	11.8
KOK	17.3	1.8	27.1	8.1	28.6	0.9	17.5	0.4	41.6	1.2	41.1	1.6	36.6	1.2	36.0	6.1	22.5	1.7
YP	0	3.2	0.1	2.8	0.3	1.1	0	2.7	0.1	0.8	5.1	0.1	0.0	0.7	1.8	0.6	0.1	3.1
BT	0.3	3.3	0.1	2.6	0	5.8	0.3	9.2	0	5.9	0	7.0	2.2	9.0	0.1	10.5	0.1	3.1

*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 several years (Appendix Tables A6-A9). During the period 1997 through 2004, *Cyclops* and *Daphnia* have been the first and second most abundant genera of zooplankton present in the reservoir (Figure 46). However, in 2005 Cyclops remained the most abundant, but *Bosmina* was more abundant than *Daphnia*. Other lesser abundant genera in decreasing order of abundance include *Diaptomus, Diaphanosoma, Epichura and Leptodora* (Figure 46). Zooplankton abundance within the reservoir varies by month (Table 10; Figure 47). The results from 7 analysis of variance procedures that tested for differences in monthly zooplankton abundance (by genera) indicated that at least one month was significantly different from other months in 2005 for 6 of the 7 genera of zooplankton. Leptadora was the exception to this trend (Table 10). We did not perform multiple comparisons required to determine pairwise comparisons. Although zooplankton abundance varies within a season, seasonal peaks in abundance over the past seven years (Figure 47) have remained relatively consistent across years. For example, *Daphnia* abundance has peaked during July each year except 2003 (June peak) since 1997, *Diaphanosoma* abundance has peaked in September during 7 of the last 9 years, *Diaptomus* has peaked during October during 5 of the last 9 years, and Cyclops has peaked in June during 4 of the last 9 years. In most cases when the 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 found only weak evidence that zooplankton abundance differed between the three sampling areas (Tenmile, Rexford, and Canada) in 2005 (Table 10). For the 7 most abundant genera of zooplankton in the reservoir at the three sites, *Leptodora*, *Bosmina* and *Daphnia* were the only three genera that were close to being significantly different between sites (P = 0.028, 0.071 and 0.110, respectively; Table 10). *Leptodora* and *Daphnia* densities differed on a longitudinal gradient, with the highest abundances observed in the lower two strata within the reservoir. Multiple comparisons indicated that *Leptodora* and *Bosmina*, densities were significantly higher at the Rexford and Tenmile starta, than the Canada strata, and that the Rexford and Tenmile strata were not significantly different from each other. However, *Daphnia* abundance exhibited the opposite trend, with the highest abundances observed in the upper third of the reservoir within the Canada stratum. Multiple comparisons indicated that *Daphnia* densities were significantly higher at the Canada stratum than the Rexford and Tenmile starta, and that the Rexford and Tenmile strata were not significantly different. The month and area interaction term was significant for *Bosmina, Cyclops*, and *Epischura* in 2005 (Table 10).

The trends in Daphnia abundance (Figure 45) and size (Figures 48 and 49) in Libby Reservoir have remained particularly stable during the past several years. Mean annual *Daphnia* densities in Libby Reservoir from 1997 through 2004 have averaged 2.13 *Daphnia* /liter (standard deviation = 0.59/liter; Figure 48). Mean *Daphnia* length has also varied relatively little since 1991, averaging 0.90 mm (standard deviation = 0.05; Figure 49). 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 = 0.61, standard deviation =

0.052; Figure 48), with the majority of the remainder in the size class 1.0 – 1.499 (mean annual proportion = 0.334, and standard deviation = 0.032). *Daphnia* larger than 1.5 mm have on average comprised less than 5% of the total since 1993 (Figure 48).

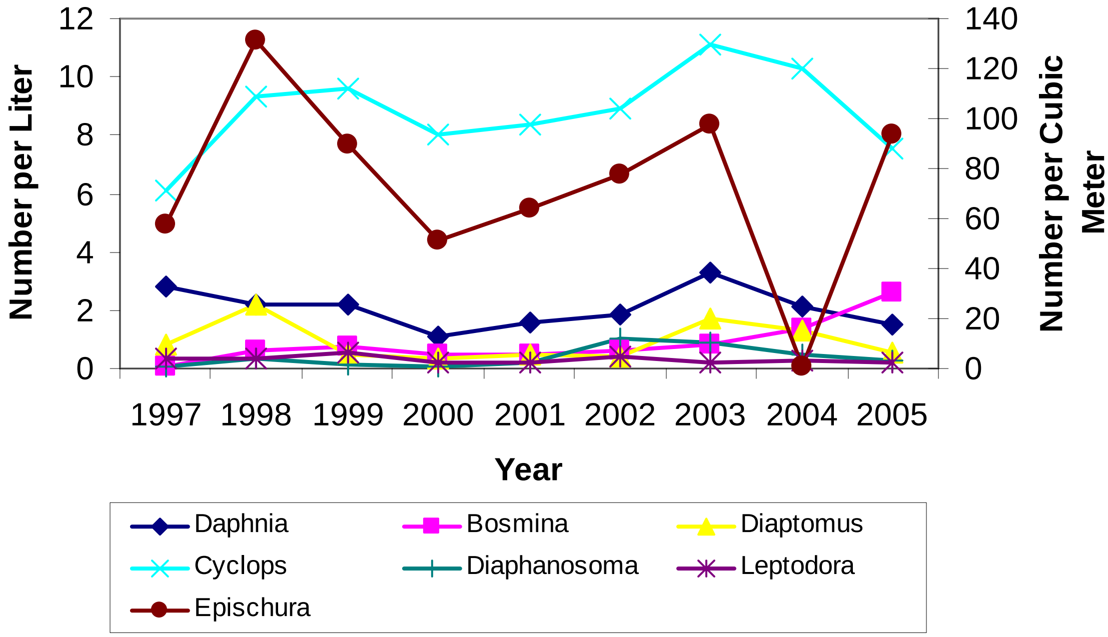

Figure 46. Annual zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2005. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter. The data utilized for this figure are presented in Appendix Table A9.

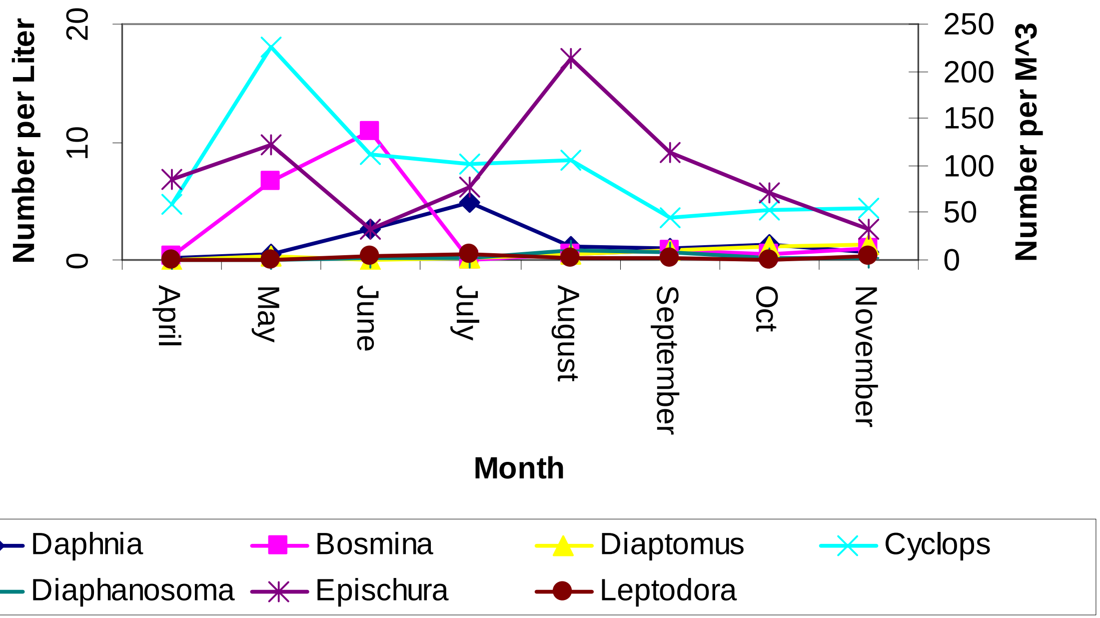

Figure 47. Mean monthly zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2005. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter.

Table 10. 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 2005.

Genus	**Month**	**Area**	**Month X Area Interaction**
Daphnia	$2.87*10^{-8}$	0.1101	0.1820
Bosmina	$1.01*10^{-5}$	0.0711	0.0241
Diaptomas	0.0018	0.9906	0.972
Cyclops	0.0062	0.2487	0.0732
Leptodora	0.1131	0.0284	0.5607
Epischura	0.0141	0.2525	0.0172
Diaphanosoma	$7.78*10^{-10}$	0.3334	0.8603

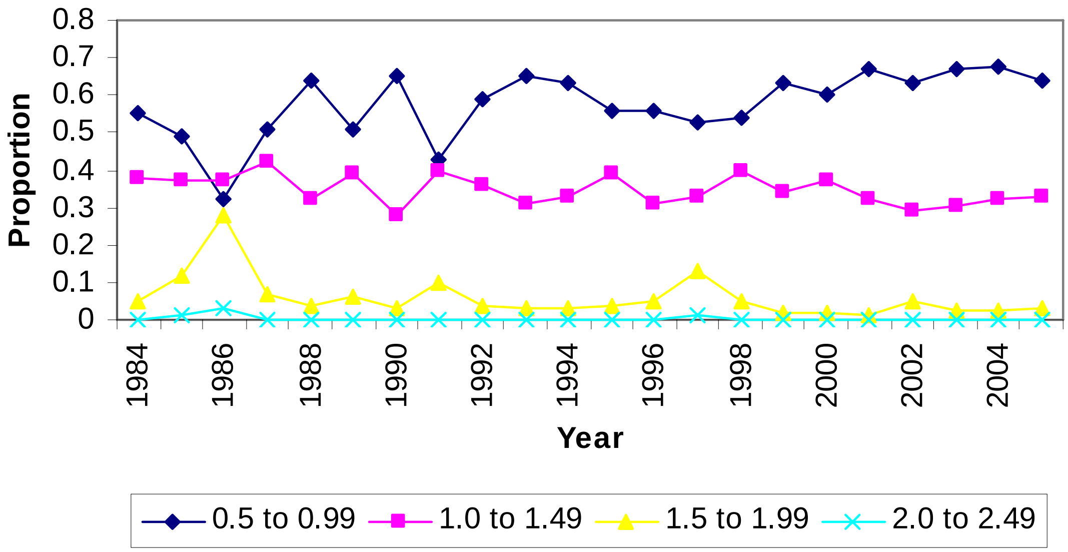

Figure 48. *Daphnia* species size composition in Libby Reservoir, 1984 through 2005.

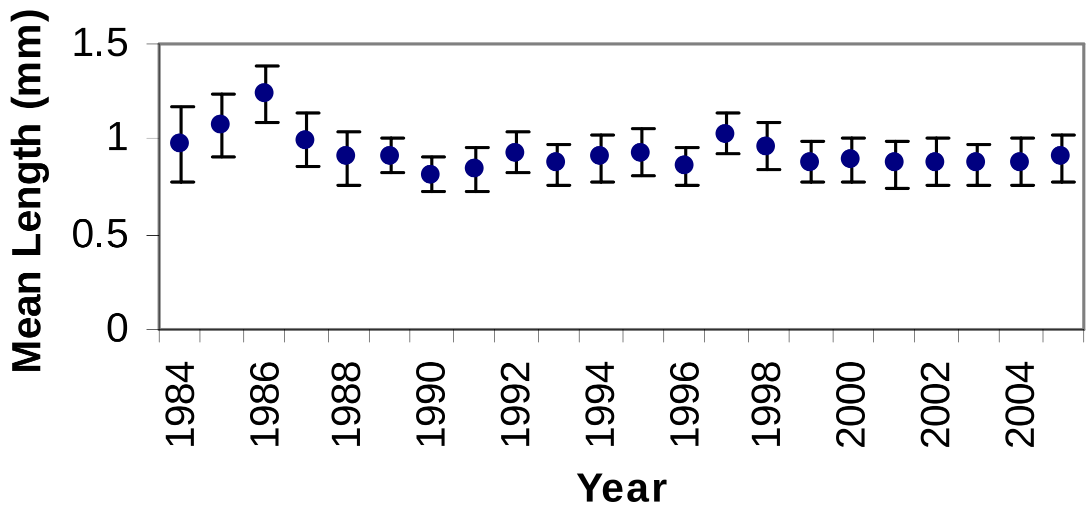

Figure 49. Mean length of *Daphnia* species in Libby Reservoir, 1984 through 2005, with whisker bars representing plus and minus one standard deviation from the mean.

Discussion

Long-term monitoring of bull trout redd numbers can be an important tool to assess bull trout population trends (Rieman & McIntyre 1993). Bull trout redd counts in the tributaries below Libby Dam occurred at either record high or low levels for all but one stream in 2005. We counted record high numbers of bull trout redds in Keeler, O'Brien, and West Fisher creeks, since the period of record. However, record low numbers of bull trout redds were also recorded for Bear and Pipe creeks. The total number of bull trout redds we observed in Quartz Creek in 2005 were about average for the period of record. Given the fact that 3 of the 5 bull trout populations below Libby Dam produced average or record high escapement numbers in 2005, it seems likely that the major limiting factors for the Bear and Pipe creek populations may not be related to the mainstem Kootenai River. We suspect that tributary conditions may be limiting adult escapement in these two tributaries.

The adult bull trout estimate in the Kootenai River below Libby Dam in early 2006 was dramatically lower than the previous two years. We estimated 176 adult bull trout were present in the three mile section below Libby Dam in 2006, which was a reduction of approximately 82% over the previous two years (Dunnigan et al. 2005). Estimates over the previous three years have had relatively tight 95% confidence intervals (~ 40% of the estimate). Therefore, we believe the reduction observed in 2006 relative to the previous two years was real. However, it is not known if the fish that occupied this section of the Kootenai River the previous two years moved out of this reach of the river, or if mortality was responsible for the reduction. We did recapture 13 individual bull trout that were originally tagged in this section in either 2004 or 2005. The mean total length of the bull trout captured at this site increased annually from 2004 to 2006, with the differences between 2004 and 2006 being significant. This suggests that these fish may be senescing. Monitoring the population of bull trout in the Kootenai River below Libby Dam will remain a high priority for the Libby Mitigation Project.

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. The fishery allowed limited harvest of bull trout within the United States portion of Libby Reservoir from June 1to February 28. Anglers were required to obtain a permit and catch card from the regional FWP Headquarters in Kalispell, which allowed us to obtain contact information for a creel survey of anglers. The creel surveys conducted on the 2004 and 2005 angling seasons estimated total harvest of 650 and 371 bull trout from Libby Reservoir (Hensler and Benson 2005 and 2006) during the 2004 and 2005 seasons, respectively. The angler harvest estimates for the 2004 and 2005 angling seasons were conducted prior to the 2005 and 2006 (respectively), gillnetting activities conducted on Libby Reservoir. Therefore, based on the spring gillnetting information for 2005 (Dunnigan et al. 2005), we were not able to detect a reduction in bull trout abundance within Libby Reservoir attributable to the 2004 fishery. However, there was a substantial reduction of the total number of redds observed in the Wigwam River in 2005, but most of this reduction may have been attributable to a large landslide on the Wigwam River (see above). Bull trout redd counts also decreased on Skookumchuck Creek from 2004 to 2005 by 20% (see above). Conversely, bull trout redds increased in the White River and Grave Creek in 2005 by 28 and 24%, respectively. The catch of bull trout in the sinking nets during the spring on Libby Reservoir in 2006 (4.36 bull trout per net) was the lowest catch rate since 1999. The spring gill net catch rates have been highly correlated to total annual redd counts in the Wigwam River and Grave Creek. It is unknown if the observed reduction in catch rates in the spring of 2006 reflects a real decrease in bull trout abundance in Libby Reservoir, or if it represents variation in sampling. Bull trout redd counts conducted during the fall of 2006 will provide valuable information used to evaluate the trends in bull trout abundance in the Kootenai River system above Libby Dam, and the overall impact of the recreational bull trout fishery on Libby Reservoir.

Our results indicate that secondary and tertiary production in Libby Reservoir has stabilized during the previous 12-16 years. Total fish abundance, as indexed by trends in gill net catch rates, has stabilized since 1988. Fish and zooplankton species composition and abundance have also experienced similar trends. Mountain whitefish, rainbow trout and westslope cutthroat trout abundance all exhibited dramatic decreases in abundance (Figure 29) following the first ten years after reservoir filling, but have stabilized at much lower abundances than the pre-dam period. Fish species composition also shifted during the first 10 years after reservoir construction, but has also stabilized. Zooplankton abundance, species composition, and size distribution have also all been similar during the second half of the reservoir's history. 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 16 years.

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Chapter 2

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

Abstract

A cooperative mitigation and implementation plan developed by Montana Fish, Wildlife & Parks, the Kootenai Tribe of Idaho and the Confederated Salish and Kootenai Tribes documents the 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 Columbia Basin Fish and Wildlife Program (MFWP et al. 1998). The actions and projects MFWP prioritizes and implements are also identified in the Kootenai Subbasin Plan (KTOI and MFWP 2004). A mix of mitigation techniques is necessary to offset losses caused by dam construction and operation. This report describes five stream restoration projects and associated physical monitoring one to three years after project construction. MFWP collaborated on two restoration projects on lower Grave Creek, near Eureka. The Grave Creek Phase I Restoration Project was completed in the fall of 2002, and the Phase II Restoration Project was completed during fall 2004. MFWP also collaborated with a local landowner on upper Libby Creek to complete two restoration projects, the upper and lower (Phase I) Cleveland Restoration Projects completed in 2002 and 2004, respectively. Finally, MFWP completed the Young Creek State Lands Restoration Project in the fall of 2003. The physical monitoring efforts for each restoration project focuses on describing the initial physical changes that occurred to the stream as a result of project construction, and an evaluation of whether physical changes are sustained through time. All five restoration projects changed the dimension, pattern and profile of the stream within the project reaches relative to preexisting conditions. We observed an overall increase of stream length and the creation of a deeper and narrower stream channel with increased pool habitat. We generally found no evidence that stream channel dimensions significantly changed within the riffle habitat, with annual changes generally <10% for each project from one to three years after completion. Each restoration project substantially increased the frequency, and depth of pool-type habitat within the project areas, with total pool number and volume showing the largest increases relative to existing conditions. However, changes in pool habitat within the project after construction have been more variable and generally less sustained through time when compared to riffle dimensions. When pool characteristics changed over time after construction, it was generally a slight decrease in pool mean bankfull depth and total number of pools. Nevertheless, the quantity and quality of pool habitat within each project area still exceeded preexisting conditions by a factor of several fold.

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.

Operation of Libby Dam causes 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).

Large gravel deltas have formed at the mouths of several tributaries of the Kootenai River (Quartz, O'Brien and Pipe Creeks) due to the loss of high spring flows. These deltas have reached proportions that are potential barriers to migrating fish such as bull trout, westslope cutthroat trout, burbot, and mountain whitefish at low river levels below Libby Dam (Graham 1979; MFWP et al. 1988).

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 that do not require modification of dam operation to be successful. These include aquatic habitat improvement, fish passage improvements, off-site mitigation, fisheries easements, and conservation aquaculture and hatchery products.

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 poor fish habitat that likely reduced the productivity and carrying capacity for resident salmonids within Libby Creek. Currently 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).

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 (MFWP, CSKT and KTOI 2004).

Stream restoration efforts when applied appropriately can be successful at restoring streams to an equilibrium state. 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 discuss the results of the restoration activities and monitoring results.

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 longitudinal profile (Figure 1). The existing stream channel prior to implementing this project contained long riffle sections and relatively low sinuosity. 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). We continued to monitor the physical stream dimensions, pattern and profile during 2005 to determine if the reconstructed stream channel was maintaining the dimensions through time. We re-photographed the 25 photo points that were originally established shortly after project construction. We currently have photo documentation for the post construction from 2002 through 2005. Although we did not present any of those photographs within this document, they have been digitally archived within our project files. In 2005, we re-surveyed the same six permanent cross sections that were surveyed annually in 1999 (pre project) and after project construction from 2002-2005. However, it should be noted that since these transects were established in 1999 (prior to the restoration work), the stream habitat types (i.e. riffle, pool, run, etc) may have differed at any particular transect before and after the restoration work. We measured mean bankfull width, depth, cross sectional area, maximum depth, and width to depth ratio at each transect. We compared each parameter using analysis of variance and subsequent multiple comparisons (Fisher's Least Significant Difference; Zar 1996) to test for significant differences between years (alpha = 0.05; Table 1). We found no evidence that the stream channel dimensions changed significantly since the project was completed in 2002 at the six permanently located transects (Table 1). However, the mean pre-restoration (1999) values for mean width, maximum depth, mean depth, and width to depth ratio all significantly differed when compared each year since the project was constructed in 2002 (Table 1). No other significant differences were detected between years after restoration.

The Grave Creek Phase I Restoration Project also 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 in 2003, 2004 and 2005. There were a total of 27 pools in 2003 and 2004, but the total number of pools decreased to 23 in 2005. 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. Each of the five parameters we measured decreased from 2003 to 2004 (Table 2). However, mean bankfull width and maximum depth increased from 2004 to 2005, although increases were relatively small (<5%; Table 2). Mean length, total length and total surface area decreased from 2004 to 2005. Total pool area had the highest relative change between years, decreasing by 34.1% between 2003 and 2005 and decreasing by another 19.6% from 2004 to 2005 (Table 2). The loss of four pools within the project area exacerbated decreases in total pool length and area in 2005.

In addition to a complete census of all pools within the project area, we also surveyed 7 riffles in 2003 and 2004 and 10 riffles in 2005 within the project area to evaluate changes in riffle dimensions through time. 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. Our cross sectional surveys indicated that riffle dimensions changed little between years, relative to pool dimensions. Changes in mean bankfull width, depth, cross sectional area, width to depth ratio and maximum depth were generally small (<10%) between years, with annual means for each riffle dimension not significantly different (Table 3). Riffle slope varied the most between years, with the largest differences between years occurring between 2003/2004 and 2003/2005, with changes of -18.3% and -16.6%, respectively (Table 3). However annual mean riffle slopes did not differ significantly between the three years. After a decrease in riffle slope from 1.06% in 2003 to 0.86% in 2004, riffle slope changed only 2.0% from 2004 to 2005.

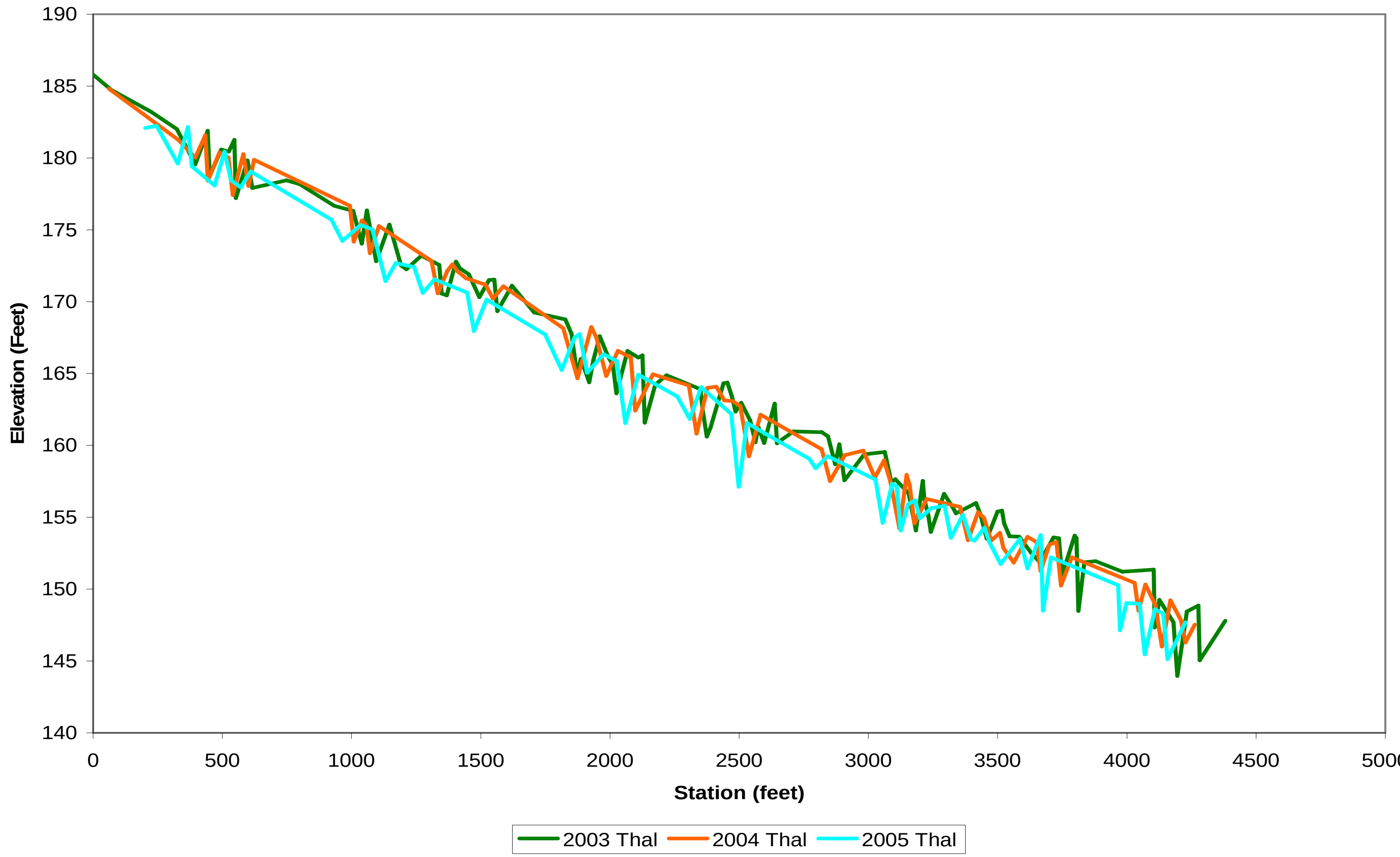


Figure 1. The longitudinal profile survey for the Grave Creek Phase I Restoration Project. The survey was completed after the spring freshet in 2003, 2004, and 2005. The station (longitudinal location measured at the channel thalweg) begins at the upstream boundary of the project.

Table 1. Mean bankfull width, depth, width to depth ratio, cross sectional area, and maximum depth for 6 permanent cross sectional surveys in 1999 (pre-restoration) and 2002-2005 located in the Grave Creek Phase I Project. Variance estimates for annual mean values are presented in parentheses. An analysis of variance was preformed for each parameter, and the P-value and results of the multiple comparisons is presented.					
	Mean Bankfull Width (ft)	**Mean Bankfull Depth (ft)**	**Width to Depth Ratio**	**Cross Sectional Area (Square ft.)**	**Maximum Bankfull Depth (ft)**
1999	110.7 (1135.1)	1.26 (0.08)	96.1 (2461.2)	136.0 (1322)	2.85 (0.78)
2002	53.7 (51.47)	2.06 (0.20)	27.0 (39.8)	114.7 (885.5)	4.67 (2.45)
2003	51.8 (21.0)	2.32 (0.05)	22.5 (8.3)	125 (342.4)	4.73 (1.7)
2004	53.9 (12.84)	2.39 (0.04)	22.7 (5.4)	128.2 (219.0)	4.58 (1.0)
2005	53.7 (72.92)	2.35 (0.07)	23.3 (37.2)	125.2 (175.8)	4.30 (0.73)
ANOVA and Multiple Comparison Results	$P = 1.89*10^{-6}$ 1999/All others Significant	$P = 2.06*10^{-6}$ 1999/All others Significant	$P = 1.14*10^{-5}$ 1999/All others Significant	P = 0.668 None Significant	0.048 1999/All others Significant

Table 2. Mean bankfull width, maximum bankfull depth, and mean length, total length and surface area measured from 27 pools in 2003 and 2004 located in the Grave Creek Phase I Project. The total number of pools decreased to 23 in 2005. 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.						
	Number of Pools	**Mean Bankfull Width (ft)**	**Maximum Bankfull Depth (ft)**	**Mean Length (ft.)**	**Total Length (ft.)**	**Total Area (ft^2)**
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
Percent Change **2003/2004** **2003/2005** **2004/2005**	0% 0% -14.8%	-8.3% -5.4% 3.2%	-12.5% -8.9% 4.1%	-10.6% -18.2% -8.5%	-10.5% -27.6% -19.1%	-18.0% -34.1% -19.6%

Table 3. 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 2003 - 2005. Variance estimates for annual mean values are presented in parentheses. An analysis of variance was preformed for each parameter, and the P value is presented.

	Sample Size	Mean Bankfull Width (ft)	Maximum Bankfull Depth (ft)	Mean Bankfull Depth (ft.)	Cross Sectional Area (sq. ft.)	Width to Depth Ratio	Riffle Slope (%)
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 ($1.42*10^{-5}$)
P-value		0.694	0.587	0.910	0.467	0.760	0.610
Percent Change							
2003/2004		4.6%	6.5%	3.0%	8.2%	0.7%	-18.3%
2003/2005		5.7%	5.8%	1.1%	5.2%	8.9%	-16.6%
2004/2005		1.0%	-0.7%	-1.8%	-2.8%	8.1%	2.0%

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 landowner furthest downstream in 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).

Stream restoration work began in September 2004 and proceeded through November. During this period River Design Group excavated approximately 3,050 feet of new channel including an average design bankfull width and depth of 50-76 and 2-2.8 feet, respectively (Table 4). 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.

The stream channel profile prior to project construction contained was over widened, often braided and contained only three pools (Figures 2 and 3). The designed channel profile required excavation at numerous depositional areas throughout the project reach (Figure 3) and resulted in an increased quantity of pool habitat within the project area. Prior to project construction, the mean pool-to-pool distance was 930 feet. We resurveyed the project area shortly after construction in the fall of 2005, and estimated the mean pool spacing was 218 feet, which resulted in a 76.5% reduction from the existing conditions. Pool spacing measurements during both years represented a complete sampling of all pools present.

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 surveyed every riffle within the newly completed project area (as built). We surveyed every riffle again in the summer of 2005, after the project had experienced the first spring freshet. 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 (Fisher's Least Significant Difference; Zar 1996) to test for significant differences between existing (pre-restoration conditions) and as built (immediately after construction in 2002) and all subsequent years including 2005 conditions (alpha = 0.10; Table 5). Statistical comparisons between the as built and 2005 riffle dimensions were unnecessary since these measurements were performed on all riffle habitats within the project area (i.e. complete census). Mean bankfull width, depth, and width to depth ratio were significantly reduced from existing conditions when compared to the as built and 2005 conditions (Table 5). The Grave Creek Phase II Restoration Project created a significantly deeper and narrower stream channel. This section of Grave Creek changed little after the first spring freshet that occurred after project construction. Riffle dimensions changed slightly, with changes generally less than 6% (Table 5). The general trend was that mean width and width to depth ratio increased, and maximum depth and mean depth and cross sectional area within riffle type habitats decreased. The profile within the riffle type habitats also changed slightly after the spring runoff. Riffle slope decreased from 1.08% as built to 0.90% in 2005, which represented a 17% decrease in riffle slope (Table 5). The upper end of the riffles slightly degraded and the lower end of the riffles slightly aggraded, resulting in an overall decrease in riffle slope.

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 project 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 the mean 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 in the fall of 2004 (as built) and again in the spring of 2005 after the spring freshet. 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. We observed substantial change in the mean values of the measured parameters after project construction (Table 6). Pools that resulted from this construction project were slightly shorter and narrower than existing pools prior to the project. However increases in the total number of pools and pool depth resulted in an overwhelming increase in total pool area and volume after project construction. Total existing pool area increased by 153.6% and 139.2% compared to the as built and 2005 conditions, respectively (Table 6). Total pool volume expressed a similar trend, increasing by 275.6 and 190.1%, respectively (Table 6). Our monitoring efforts associated with restoration project demonstrate that the quantity of salmonid rearing habitat was increased over existing conditions. This project increased the total number of pools within this reach of Grave Creek from 3 to 14 pools (366.7% increase). The channel shaping flows that occurred during the 2005 spring freshet reduced the total number of pools from 14 (as built) to 10, which represented a 28.6% reduction in the number of pools, and even though four pools (28.6%) were lost as a result of the 2005 spring freshet, this still represented a 233.3% increase over existing conditions. Mean maximum bankfull depth decreased from 2004 (as built) to 2005 by 14.2 and 8.1%, respectively. However, pool mean width and length increased slightly from 2004 (as built) to 2005 by 5.6 and 24.2%, respectively (Table 6). 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.

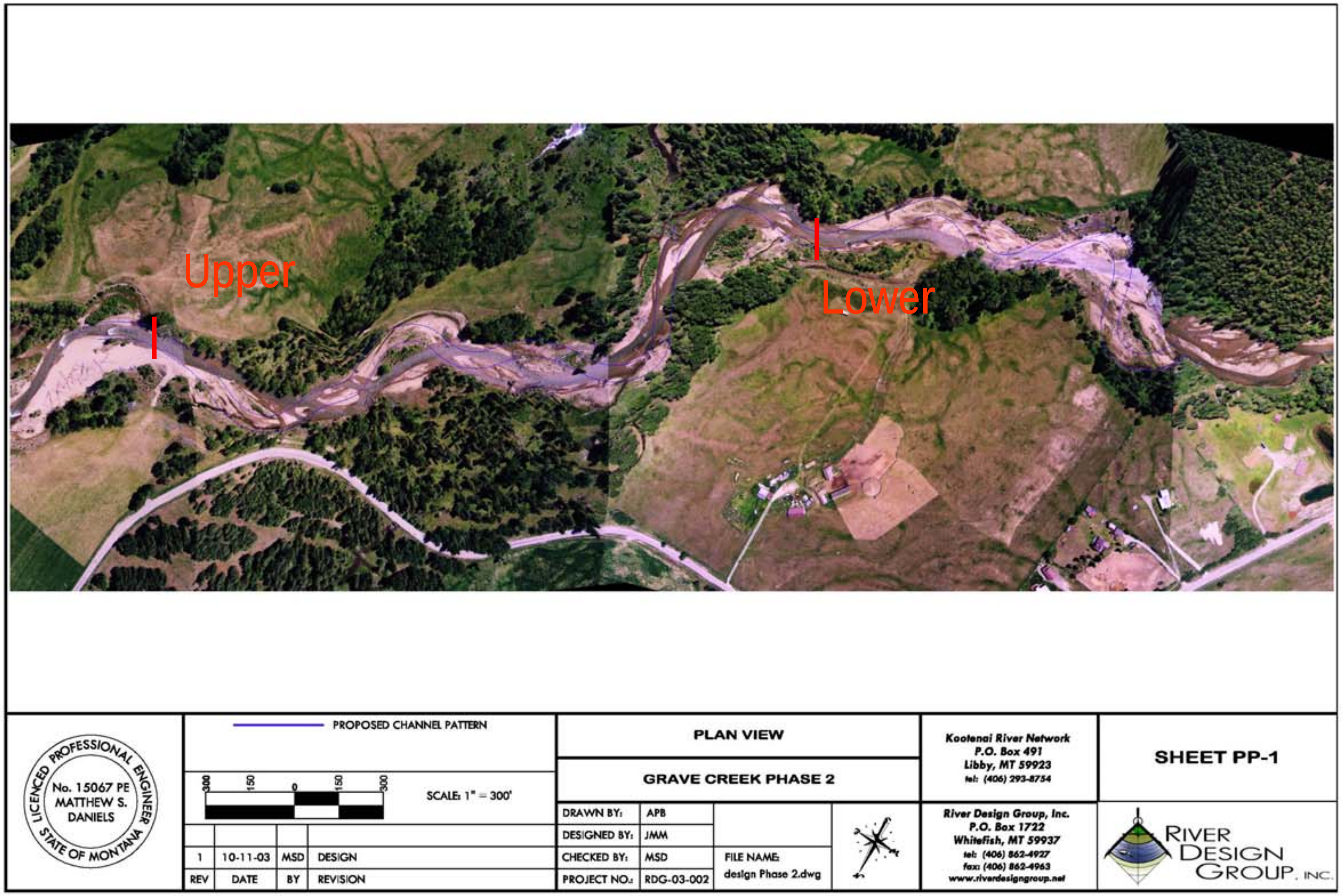


Figure 2. Aerial photograph of the Grave Creek Phase II Restoration Project area. The upper and lower boundaries of the project area are indicated in red on the photo. Photograph provided by River Design Group.

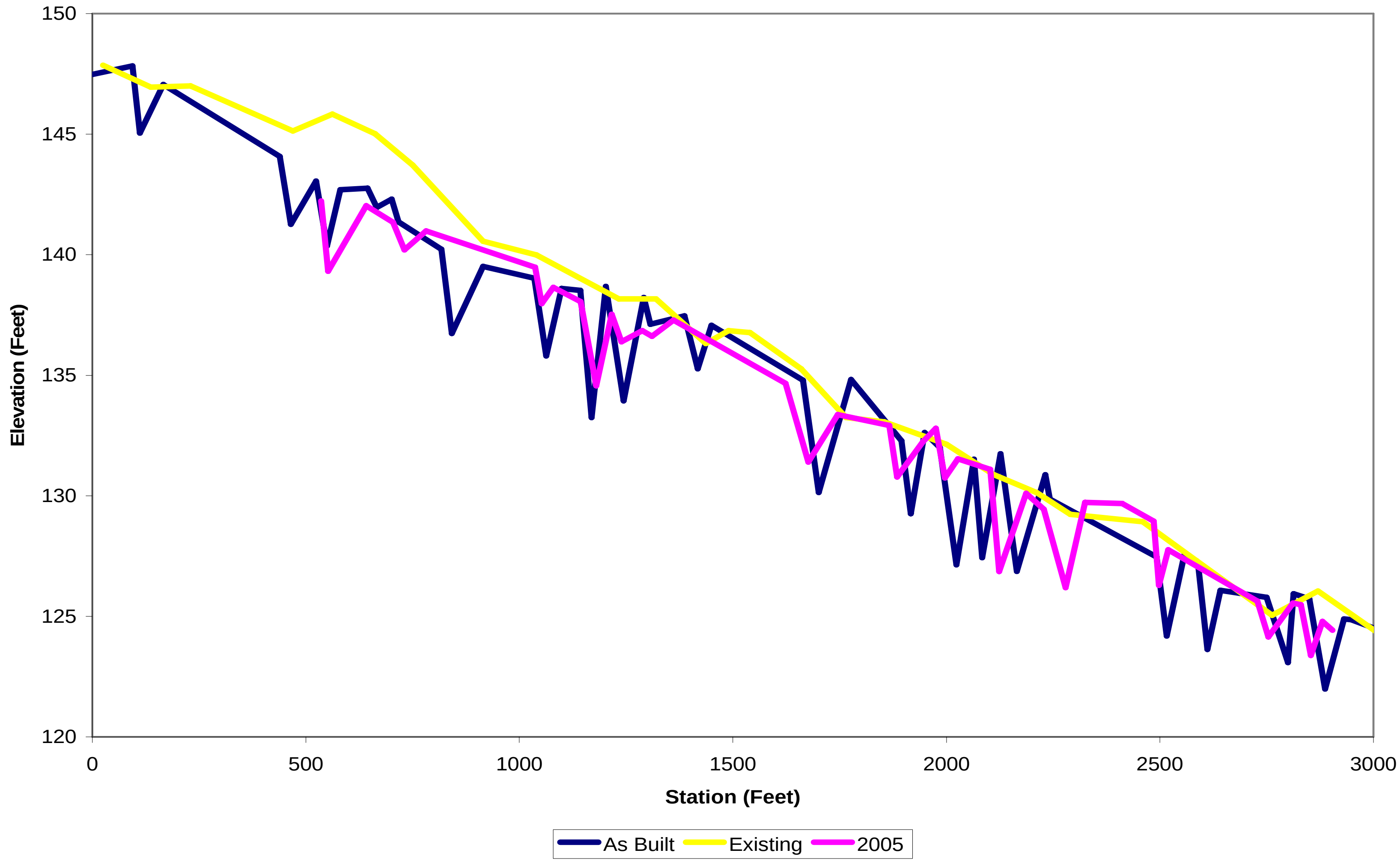


Figure 3. The longitudinal profile survey for the Grave Creek Phase II Restoration Project. The survey was completed prior to project implementation (Existing), shortly after project construction (As Built) and after the spring freshet in 2005. The station (longitudinal location measured at the channel thalweg) begins at the upstream boundary of the project.

Table 4. Stream channel design dimensions for the Grave Creek Phase II Restoration Project.				
	Habitat Type			
Parameter/Feature	**Pool**	**Riffle**	**Run**	**Glide**
Discharge (CFS)	660	660	660	660
Width (feet)	68	56	50	76
Mean Depth (feet)	n/a	2.3	2.8	2.5
Max. Depth (feet)	5.8	3.1	4.2	2.9
Scour Depth (feet)	8.1	3.5	4.7	3.0
Cross Sectional Area (sq. feet)	163	129	137	197
Width to Depth Ratio	N/A	24	18	30

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. Variance estimates for annual mean values are presented in parentheses. An analysis of variance was preformed for each parameter, and the P value is presented. Multiple comparisons were performed using Fisher's Least Significant Difference. Significant comparisons are indicated via * (alpha < 0.10).							
	Sample Size	**Mean Bankfull Width (ft)**	**Maximum Bankfull Depth (ft)**	**Mean Bankfull Depth (ft.)**	**Cross Sectional Area (sq. ft.)**	**Width to Depth Ratio**	**Riffle Slope (%)**
2003 (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 ($2.08*10^{-5}$)
P-value		0.004	0.626	0.098	0.229	0.015	N/A
Percent Change							
2003/2004		-41.8% *	11.9%	40.9% *	-12.6%	-61.8% *	
2003/2005		-39.7% *	6.3%	32.5% *	-16.5%	-56.1% *	
2004/2005		3.6%	5.0%	-6.0%	-4.5%	14.8%	-17.0%

Table 6. 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 after the spring freshet. 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.							
	Number of Pools	**Mean Bankfull Width (ft)**	**Mean Bankfull Width (ft)**	**Maximum Bankfull Depth (ft)**	**Mean Length (ft.)**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2003 (Existing)	3	77.0 (48.0)	2.0 (0.1)	4.4 (1.7)	78.7 (646.3)	18,236 (4,175,446)	37,570 (33,430,608)
2004 (As Built)	14	59.0 (344.0)	2.9 (0.7)	5.6 (1.5)	57.1 (421.9)	46,252 (2,238,911)	141,092 (41,147,540)
2005	10	62.3 (72.6)	2.5 (0.1)	5.2 (1.1)	70.9 (452.3)	43,629 (1,633,776)	108,993 (14,759,161)
Percent Change							
2003/2004	366.7%	-23.4%	43.9%	28.6%	-27.5%	153.6%	275.6%
2003/2005	233.3%	-19.1%	23.5%	18.2%	-9.9%	139.2%	190.1%
2004/2005	-28.6%	5.6%	-14.2%	-8.1%	24.2%	-5.7%	-22.8%

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) 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. The monitoring results presented in this document evaluate whether these physical changes were maintained through time by comparisons of the physical habitat to evaluate changes as a result of these restoration activities.

The stream channel profile prior remained similar between 2003 and 2005 within the project area (Figure 4). The designed channel profile required excavation at numerous depositional areas throughout the project reach and resulted in an increased quantity of pool habitat within the project area (Dunnigan et al. 2004). Prior to project construction, the mean pool-to-pool distance was 325.4 feet. Dunnigan et al. (2004) demonstrated that this restoration project deceased pool spacing to an average of 172.8 feet (S.D. = 86.0), which represented a 46.9% reduction in the distance between pools when compared to pre-restoration conditions. We measured distance between pools again in 2005 to evaluate if pool frequency was self sustaining and found that pool spacing had increased slightly (10.5%) to a mean distance of 191 feet (S.D = 82.5). Pool spacing measurements in 2003 and 2005 represented a complete sampling of pools.

In 1999, prior to project construction, we measured stream channel morphology at 5 cross sectional survey locations in riffle habitat within the project area. After project construction in 2002 we sampled 9 out of 15 total transects in riffle habitats. We resurveyed the same riffles during the summer of 2003, after the project had experienced the first spring freshet. In 2005, we sampled all 15 riffles. 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 2002-2005. We used analysis of variance (ANOVA) and a subsequent multiple comparison test (Fisher's Least Significant Difference; Zar 1996) to test for significant differences between years (alpha = 0.05; Table 7). Mean bankfull width, depth, and width to depth ratio were significantly reduced from 1999 in all subsequent years after the restoration project (Table 7). However, the riffle dimensions did not significantly differ from the as built dimensions in either 2003 or 2005, with relative changes generally less than 10% (Table 7). We were unable to show any significant changes in cross sectional area between years ($p = 0.328$). Riffle slope decreased from the as built conditions in 2003 and 2005, to 1.28 and 1.46%, respectively. Riffle slopes were not measured prior to construction of this project. We attribute the overall flattening of the riffles within this project to two factors. Further examination of our survey information revealed that the top end of our riffles generally incised within the channel (degraded) due in part to the scour achieved below many of the gradient control cobble structures installed at the tailout area of many of the pool structures. The lower portion of many of these same riffles aggraded with bed materials, which had the overall result of reducing the overall riffle slope. However, the greatest overall flattening occurred after the first spring freshet following construction (2003), and then the riffle slopes increased closer to the design dimensions.

Due to the importance of pool habitat to rearing redband and bull trout within the project area, we devoted a substantial effort to monitor pool habitat after project construction to evaluate whether the pools maintained depth, width and length through time. We measured mean bankfull depth, width, length and maximum bankfull depth of the 20 pools constructed in the project area in 2002 (as-built) and 2003. However in 2005, we only measured 18 pools within the project area because two of the pools had filled with bed material, and were no longer classified as pool habitat. 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. We observed a decrease in the mean values of each of the four parameters from 2002 to 2003 (Table 8). Mean bankfull depth and width also declined from 2003 to 2005, with mean width exhibiting the sharpest decline (Table 8). However, maximum bankfull depth and mean length increased from 2003 to 2005 by 2.63 and 22.02%, respectively (Table 8). Total pool volume within the project reach has decreased each year since project construction. Total pool volume decreased by 38.8% from 2002 to 2003, and continued to decrease by an additional 19.3% from 2003 to 2005, for an overall reduction of 50.6% from 2002 to 2005; Table 8). Much of the total pool volume reduction from 2003 to 2005 is attributable to the complete filling of two pools during this period.

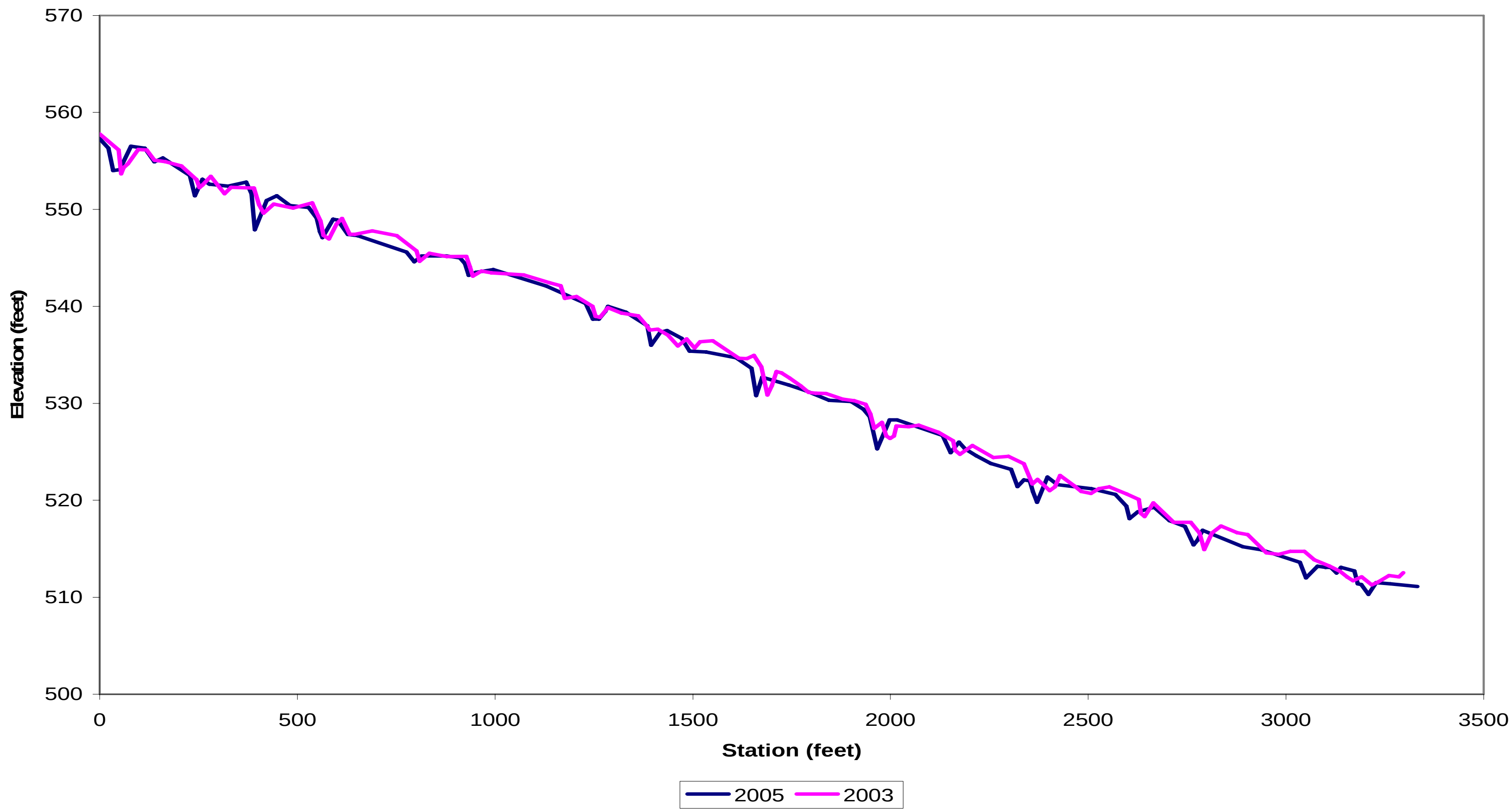


Figure 4. The longitudinal profile of the constructed stream channel thalweg for the Libby Creek Upper Cleveland Restoration Project in 2003 and 2005. The survey begins at the upper project boundary (station 0) and proceeds downstream to the lower project boundary (approximate station 3,200 feet).

Table 7. Mean bankfull width, depth, maximum bankfull 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 the P value is presented. Multiple comparisons were performed using Fisher's Least Significant Difference. Significant comparisons are indicated via * (alpha < 0.05). The riffle slope was measured for every riffle (n=15) in the project area in 2002-2005.

	Sample Size	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Width to Depth Ratio**	**Cross Sectional Area (Square ft.)**	**Slope**
1999 (Pre Restoration)	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)	0.0191 ($7.499*10^{-5}$)
2003	9	31.5 (18.5)	1.48 (0.04)	21.8 (25.4)	47.9 (62.5)	0.0128 ($1.941*10^{-5}$)
2005	15	31.9 (32.8)	1.36 (0.05)	24.3 (65.0)	43.0 (26.7)	1.46 ($2.548*10^{-5}$)
P-Value		0.009	0.003	0.0001	0.328	N/A
Percent Change						
1999/2002		-17.4%*	42.5%*	-44.0%*	16.0%	
1999/2003		-24.1%*	57.9%*	-54.2%*	20.9%	
1999/2005		-23.1%*	45.0%*	-48.9%*	8.5%	
2002/2003		-8.1%	10.8%	-18.3%	4.3%	-33.0%
2002/2005		-7.0%	1.8%	-8.8%	-6.5%	-23.2%
2003/2005		1.2%	-8.2%	11.7%	-10.3%	14.5%

Table 8. Pool dimensions within the Libby Creek Upper Cleveland Restoration Project including mean bankfull width, depth, maximum bankfull depth, length and total volume in 2002, 2003, and 2005. 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 area and volume.						
	Mean Bankfull Width (ft)	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Length (ft.)**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2002 (As Built)	37.95 (23.75)	2.64 (0.763)	4.32 (1.148)	36.7 (205.2)	3676.9	73,538
2003	34.5 (16.07)	2.16 (0.30)	3.80 (0.684)	30.2 (130.8)	2250.5	45,010
2005	28.8 (31.68)	1.9 (0.19)	3.9 (0.87)	36.9 (75.69)	2019.2	36,345
Percent Change						
2002/2003	-9.16% (-32.3%)	-18.01% (60.7%)	-12.03% (-40.4%)	-17.67% (-36.2%)	-38.8%	-38.8%
2003/2005	-16.46% (97.13%)	-12.14% (-35.20%)	2.63% (27.30%)	22.02% (-42.13%)	-10.3%	-19.3%
2002/2005	-24.11% (33.38%)	-27.96% (-74.52%)	-9.3% (-24.14%)	0.46% (-63.11%)	-45.1%	-50.6%

__Libby Creek Lower Cleveland Phase I Project__

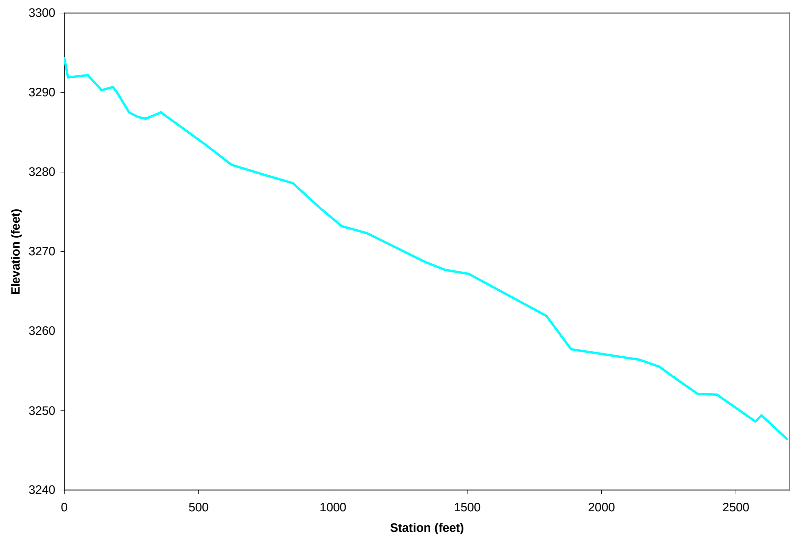
The lower Cleveland property on Libby Creek is located approximately 1 mile downstream of the upper Cleveland Property, and has been identified by MFWP as a high priority site for stream restoration. Past land management activities including logging, mining, riparian road construction, and stream channel 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 present length of Libby Creek through the entire lower Cleveland property is approximately 9,100 feet. MFWP proposes to implement the restoration of this large site in 3 phases. The Libby Creek Lower Cleveland Phase I Project (approximate river mile 21-20), restored approximately 2,950 feet of stream channel to the proper dimension, pattern and profile, and was completed in the fall of 2005.

Stream restoration work began in September 2005 and proceeded through October 2005. During this period MFWP 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. We designed the channel pattern to utilize existing riparian vegetation in project reach wherever possible, in an attempt to maximize channel stability, and promote recovery of the riparian area. The resulting stream pattern design increased sinuosity (stream length divided by valley length) from 1.1 to 1.6, and subsequently increased total stream length from approximately 2,700 to 3,200 feet. During construction phase of this project, numerous structures were installed including 11 Cobble grade control structures for grade control and bank protection in pool tail-outs created by outside bends and rootwad complexes, 19 rootwad complexes for bank stabilization on outside bends of the newly constructed stream channel, 3 rock vanes to provide gradient control and pool habitat. Substantial effort was also expended to restore a healthy riparian vegetative community. These efforts included transplanting approximately 100 shrubs and tree clumps during construction, and creating floodplain roughness to promote riparian community regeneration.

The stream channel profile prior to project construction contained few pools (Figure 5), and due to the limited geographical overlap with the newly designed channel thalweg could not accurately be displayed on the same figure as the new channel profile surveyed after construction in 2005 (Figure 5). The designed channel profile required excavation at numerous depositional areas throughout the project reach, and resulted in an increased quantity of pool habitat within the project area. Prior to project construction, the mean pool-to-pool distance was 811 feet. We resurveyed the project area shortly after construction in the fall of 2005, and estimated the mean pool spacing was 152 feet, which resulted in an 81.3% reduction from the existing conditions. Pool spacing measurements during both years represented a complete sampling of all pools present.

Due to the importance of pool habitat to rearing redband and bull trout within the project area, we devoted a substantial effort to monitor pool habitat after project construction to evaluate whether the restoration project increased the quantity and quality of pool habitat within the project area. Prior to the initiation of this project in 2004, we measured the mean bankfull depth, width, length, maximum bankfull depth, total area and total volume of the 4 pools within the project area. We repeated these measurements on the 18 newly constructed pools in the fall of 2005 to represent the as built pool dimensions. 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. We observed substantial change in the mean values of the measured parameters after project construction (Table 9). Total pool volume exhibited a 4.2 fold increase from 2004 to 2005, followed by total pool area, increased by 2.9 fold (Table 9). Pool mean and maximum depth also increased to lesser extents of 22.3 and 26.2%, respectively. However, mean pool width and length decreased as a result of project construction, although the decrease was modest (< 10%; Table 9). The overall increase in total pool area and volume within the project reach was overwhelmingly attributed to the increase in the overall number of pools within this section of Libby Creek. Nonetheless, depth and cover within these newly constructed pools also exceeded the existing conditions which increase the quality of pools within the project reach.

In addition to a complete census of all pools within the project area, we also surveyed 13 riffles within the project area to evaluate changes in riffle dimensions as a result of the project. In 2004 and 2005 (as built) we measured mean bankfull width, depth, width to depth ratio, and cross sectional area at each cross section transect. We used student's t-test (Zar 1996) to test for significant differences between years (alpha = 0.05; Table 10). The stream channel that resulted from this restoration project was significantly narrower, decreasing from 69.8 feet to 34.1 feet (51.1% reduction). The stream channel within the riffle habitats was also deeper, increasing from 1.94 to 2.21 feet mean depth and 3.16 and 3.39 feet mean maximum depth in 2004 to 2005, respectively. However, the increase in mean depth was not significant ($P > 0.10$; Table 10). The reduction in width and the increase in depth resulted in a significant reduction in the width to depth ratio within the riffle habitats of this project. Mean width to depth ratio decreased by 61.1% from an average of 41.2 in 2004 to 15.9 in 2005 (Table 10).



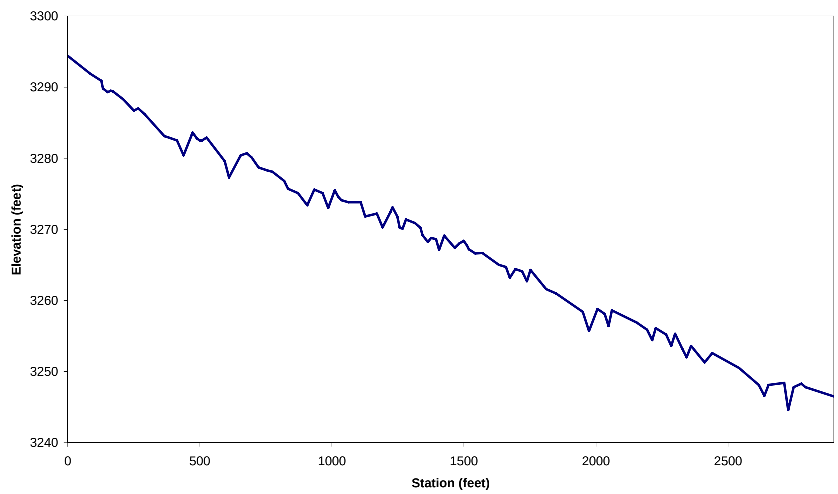


Figure 5. The top figure is the longitudinal profile of the existing stream channel prior to the implementation of the Libby Creek Lower Cleveland Phase I Restoration Project. The survey was conducted beginning at station 0 (upper project boundary) to approximately 2,700. Note the lack of pool habitat within the project area. The bottom figure is the longitudinal profile of the constructed stream channel thalweg in 2005 (as built. The stream channel prior to channel construction was not located within the same general plan view as the newly constructed stream channel. Therefore, the two longitudinal profiles are presented on separate figures. Differences in stream channel length that resulted from an overall increase in overall channel sinuosity and length after project construction.

Table 9. Pool dimensions including mean bankfull width, depth, maximum bankfull depth, length and total volume of the four pools in 2004 (pre-existing) and 18 pools in 2005 (as built) 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. Mean bankfull depth was used to calculate total area and volume.

	Mean Bankfull Width (ft)	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Length (ft.)**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2004 (existing)	42.2 (44.2)	2.33 (0.34)	4.2 (1.05)	42.75 (131.6)	7,260.4	16,185.5
2005 (As Built)	39.6 (63.9)	2.84 (0.34)	5.32 (0.85)	38.8 (95.1)	28,249.4	84,023.4
Percent Change 2004/2005	-6.17%	22.29%	26.72%	-9.28%	289.1%	419.1%

Table 10. Riffle dimensions including mean bankfull width, depth, maximum bankfull depth and width to depth ratio in 2004 (pre-existing) and (as built) for the Libby Creek Lower Cleveland Phase I Restoration Project. Variance estimates for annual mean values are presented in parentheses. A student's t-test was preformed for each parameter, the P value is presented. 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 (0.019)
P-value		0.0006	0.111	0.188	0.0003	
Percent Change 2004/2005	28.6%	-51.1%	14.1%	7.3%	-61.1%	

Young Creek State Lands Restoration Project

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 Montana portion of the Kootenai Subbasin. 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. Therefore, to improve the function and stability of this 1,200 foot section of Young Creek, MFWP reconstructed the stream channel in the fall of 2003.

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, dimensions, and profile 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 2005 were relatively small. We measured the cross sectional area, bankfull width, depth, maximum bankfull depth, width to depth ration, and mean gradient within each riffle that existed within the project area before (2002), during (2003; as built), and after (2004 and 2005) project construction (Table 11). We established the transect location at each riffle at the longitudinal mid-point of each riffle. Mean cross sectional area, mean bankfull width, maximum bankfull depth, and width to depth ration all decreased from 2004 to 2005, listed in descending order (Table 11). However, changes were generally small (<10% change) between years (Table 11). Mean bankfull depth was the only parameter that decreased since 2004, but the overall decrease was less than 4%. Cross sectional area within the riffles showed the sharpest relative annual increase from 2004 to 2005 (17.2%; Table 11). 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. Therefore, given the data collected since project completion, it appears that the channel dimensions in the riffles of this project are maintaining through time.

The Young Creek State Lands Restoration Project also increased the quality and quantity of pool habitat for native salmonids. As a result of project construction, we realized increases of 500%, 537%, and 1,295% in the total number of pools, total pool area and total pool volume, respectively, present in this section of Young Creek (Dunnigan et al. 2005). 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. In order to ensure that these increases were maintained through time, we resurveyed each pool in the project area again in 2005. 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 (Table 12), 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 2004 and 2005. All the pool dimensions we measured decreased from 2004 to 2005. However changes were relatively small (<10%), with the exception of maximum bankfull depth, with the mean decreasing by 0.55 feet since 2004 (15.2%; Table 12). Total pool surface area and volume has changed little (<6%) since project, maintaining the large initial increases over pre-existing conditions (Table 12). Despite the slight changes in pool dimensions since the project was completed, the constructed pool habitat continues to provide an improvement in the amount of depth and cover that existed prior to the project (Table 12). 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 increased channel diversity, stream length, and sinuosity within the project area. Total stream length within this section of Young Creek was similar from 2003 to 2004 (Dunnigan et al. 2005). However, a longitudinal profile for the Young Creek State Lands Restoration Project was not collected in 2005.

Table 11. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for the total number of riffles (n) 2002-2005 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 for each parameter is relative to 2005.

Riffle Cross Sections	n	Cross Sectional Area (ft^2)	Mean Bankfull Width (ft)	Mean Bankfull Depth (ft)	Maximum Bankfull Depth (ft)	Width to Depth Ratio
2002 (Existing)	4	16.75 (1.58)	27.88 (22.73)	0.60 (0.008)	1.05 (0.017)	48.3 (239.6)
2003 (As Built)	10	21.99 (10.07)	16.3 (9.18)	1.24 (0.05)	1.99 (0.09)	13.7 (21.2)
2004	11	18.71 (6.25)	14.83 (3.63)	1.28 (0.07)	1.85 (0.13)	12.29 (17.30)
2005	11	21.93 (22.04)	16.14 (4.38)	1.37 (0.08)	1.79 (0.09)	12.34 (11.40)
Percent Change						
2002/2005	175%	30.9%	-42.1%	70.6%	129.4%	-74.5%
2003/2005	10%	0.3%	-1.0%	-9.8%	10.6%	9.9%
2004/2005	0%	17.2%	8.8%	-3.4%	6.8%	0.4%

Table 12. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, width to depth ratio, and total length measured for the total number of pools (n) 2002-2005 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 for each parameter relative to 2005 is also presented.

Pool Cross Sections	**n**	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Width to Depth Ratio**	**Total Area (ft^2)**	**Total Volume (ft^3)**
2002 (Existing)	2	19.25 (3.13)	23.5 (24.5)	0.79 (0.005)	2.35 (0.13)	30.14 (80.15)	1,998	1,578
2003 (As Built)	8	37.68 (65.09)	21.8 (18.0)	1.73 (0.084)	3.23 (0.42)	12.99 (12.78)	8,480	14,671
2004	14	31.81 (36.96)	19.16 (24.73)	1.73 (0.23)	3.63 (0.53)	12.44 (45.12)	8,602	14,881
2005	15	29.07 (48.63)	17.75 (12.76)	1.71 (0.28)	3.08 (0.67)	11.97 (45.68)	8,218	14,053
Percent Change								
2002/2005	650.0%	51.0%	-24.5%	116.5%	31.1%	-60.3%	311.4%	790.6%
2003/2005	87.5%	-22.9%	-18.6%	-1.2%	-4.6%	-7.9%	-3.1%	-4.2%
2004/2005	7.1%	-8.6%	-7.4%	-1.2%	-15.2%	-3.8%	-4.5%	-5.6%

Discussion

Within this report, we presented physical monitoring from five stream restoration projects on three separate streams ranging from one to three years after completion. Restoration techniques were generally similar between projects, consisting primarily of stream channel reconstruction with the use of large rock and woody debris 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) although they differed in discharge capacity. Results were generally similar for the stream restoration projects monitored thus far.

These restoration projects unequivocally changed the pattern, profile and dimension of the stream within the project area. Within the riffle habitats several conditions were generally evident for all five restoration projects. We documented a significant increase in mean bankfull depth, a decrease in stream bankfull width, and the change in channel dimensions were generally less than 10% annually. Pool-type habitats generally changed more so than riffle habitats after construction. All five of 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 five 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.

Stream geomorphology, stream habitat, salmonid abundance and standing crop are related and significantly correlated (Kelly et al. 1989; Lanka et al. 1987; Kozel and Hubert 1989). Muhlfeld et al. (2001a; 2001b) found that redband trout in a third-order tributary to the Kootenai River relied on large complex pools for both summer and overwintering habitat. Pool habitat has also been identified as critical habitat for cutthroat trout (Schlosser 1991; Irving 1987; Pratt 1984; Dunnigan et al. 1998). Complex habitat associated with pool-type habitat has also been shown to be an important factor influencing the distribution of bull trout during summer (Pratt 1992) and winter (Thurow 1997, and Bonneau 1994) periods. Streams that are hydraulically complex as a result of varied and complex habitat have been shown to lose proportionally fewer fish, have fish assemblages that are generally more resilient, and have generally higher fish diversities compared to hydraulically simple streams after floods (Pearsons et al. 1992). The physical changes to the habitats within these five restoration projects are consistent with conventional scientific principals related to the abundance and distribution of stream dwelling salmonids as they relate to physical habitat conditions. Therefore, based on the condition of the physical habitat that resulted from these five restoration projects, they were a success. However, the continued sustainability of the current conditions must be sustained through time in order to translate into increased abundance of resident salmonids. 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. Given this lengthy period of time, it is unreasonable to expect immediate increases in abundance. We are 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.

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Appendix

Table A1. Therriault Creek depletion population estimates for fish $\geq$ 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
Section 1							
Rainbow Trout	123 (261)	130 (151)	82 (89)	-----	56 (57)	108 (111)	106 (119)
Brook Trout	41 (47)	49 (56)	60 (64)	-----	59 (66)	11 (13)	66 (73)
Bull Trout	0	0	0	-----	0	92 (95)	10 (n/a)
Total Population[A]	149 (214)	182 (207)	141 (149)	-----	115 (122)	200 (203)	175 (201)
Section 2							
Rainbow Trout	36 (41)	79 (82)	76 (83)	93 (102)	84 (n/a)	102 (107)	32 (34)
Brook Trout	56 (58)	125 (137)	72 (80)	82 (87)	58 (61)	24 (27)	67 (91)
Bull Trout	47 (49)	15 (16)	3 (n/a)	2 (n/a)	40 (42)	49 (53)	4 (n/a)
Total Population[A]	92 (96)	205 (217)	149 (163)	180 (193)	144 (151)	153 (160)	95 (107)
Section 3							
Rainbow Trout	54 (58)	164 (170)	177 (205)	-----	99 (104)	112 (117)	99 (109)
Brook Trout	74 (77)	82 (88)	110 (117)	-----	67 (72)	41 (45)	82 (90)
Bull Trout	0	0	0	-----	10 (n/a)	3 (n/a)	15 (17)
Total Population[A]	66 (93)	248 (257)	284 (308)	-----	170 (180)	118 (124)	183 (201)

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

Table A2. Lower Grave Creek Demonstration Project area electrofishing. Numbers are total catch within the 1,000 foot section.

Year	2000[A]	2001[B]	2002[C]	2003	2004	2005
Westslope Cutthroat	4	18	3	13 (n/a)	4 (n/a)	14 (15)
Rainbow Trout	1	17	26	25 (29)	41 (45)	63 (66)
Brook Trout	1	10	5	9 (18)	1(n/a)	3 (7)
Bull Trout	9	33	5	41 (144)	63 (67)	63 (66)
Mountain Whitefish	54	3	33	21 (22)	70 (73)	60 (62)
Long Nose Dace	6	-----	-----	-----	-----	-----
Water Temp. ^{0}C	-----	17	-----	-----	-----	10
Effort (minutes)	44	56.9	NA	NA		

A) Four bull trout $\geq$ 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 $\geq$ 470 mm were likely lacustrine - adfluvial fish from Libby Reservoir moving into Grave Creek to spawn. Long nose dace were observed but not counted in 2001.

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. Long nose dace were observed but not counted.

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

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Section 1 (Tooley)										
Westslope Cutthroat[B]	-----	3	36 (37)	139 (148)	-----	55 (64	88 (96)	Not sampled	68 (70)	66 (72)
Rainbow Trout[B]	-----	19 (23)	62 (70)	3 (n/a)	-----	2 (n/a)	14 (19)		8 (n/a)	2 (n/a)
Brook Trout	-----	11 (17)	120 (124)	102 (105)	-----	36 (39)	30 (31)		20 (n/a)	72 (80)
Mountain Whitefish	-----	-----	-----	-----	-----	-----	2 (n/a)		2 (n/a)	4 (n/a)
Total Population [A]	12 (13)	36 (40)	220 (228)	248 (258)	-----	96 (107)	148 (158)		96 (98)	86 (96)
Section 3 (303 A Rd.)										
Westslope Cutthroat	-----	234 (246)	416 (452)	314 (336)	-----	-----	-----	Not sampled	Not sampled	Not sampled
Rainbow Trout	-----	-----	-----	-----	-----	-----	-----			
Brook Trout	-----	-----	-----	1 (n/a)	-----	-----	-----			
Total Population [A]	-----	234 (246)	416 (452)	316 (338)	-----	-----	-----			
Section 4 (303 Rd.)										
Westslope Cutthroat	155 (229)	100 (114)	439 (500)	352 (367)	-----	130 (142)	222 (237)	Not sampled	218 (228)	327 (351)
Rainbow Trout	-----	-----	-----	-----	-----	-----	-----		-----	-----
Brook Trout	-----	-----	-----	3 (n/a)	-----	6 (12)	4 (n/a)		10 (12)	12 (17)
Total Population [A]	155 (229)	100 (114)	439 (500)	358 (373)	-----	136 (148)	232 (249)		230 (241)	338 (364)
Section 5 (State)										
Westslope Cutthroat	-----	-----	216 (227)	256 (290)	126 (153)	153 (174)	268 (290)	178 (183)	115 (118)	151 (164)
Rainbow Trout	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Brook Trout	-----	-----	62 (71)	52 (65)	19 (22)	25 (27)	46 (49)	35 (n/a)	60 (63)	142 (147)
Bull Trout	-----	-----	-----	-----	-----	-----	2 (n/a)	0	3 (n/a)	2 (n/a)
Total Population [A]	-----	-----	280 (294)	314 (353)	113 (119)	176 (195)	315 (335)	213 (183)	230 (241)	296 (309)

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 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
Section 1 – below Hwy 2								
Rainbow Trout	81 (127)	26	125	46 (51.09)	117 (130)	84 (96)	113 (118)	169 (191)
Brook Trout	6 (8)	6	13	10 (12.33)	16 (24)	5	9 (15)	57 (64)
Bull Trout	-----	-----	-----	-----	3	0	1 (n/a)	1 (n/a)
Mountain Whitefish	-----	-----	-----	-----	3	1	-----	-----
Total Population [B]	90 (116)	32	138	57 (63.79)	138 (153)		138 (144)	227 (256)
Section 2 –above Hwy 2								
Rainbow Trout	203 (225)	-----	-----	148 (193)	-----	100 (108)	120 (128)	76 (92)
Brook Trout	7	-----	-----	2	-----	2	30 (34)	25 (28)
Bull Trout	5 (6)	-----	-----	-----	-----	2.08	-----	2 (n/a)
Total Population [B]	208 (228)	-----	-----	160 (213)	-----		150 (160)	105 (116)
Section 3 – upper Cleveland								
Rainbow Trout	-----	-----	170 (194)	172 (182)	163 (183)	112.3 (127)	88 (104)	63 (75)
Brook Trout	-----	-----	-----	-----	-----	------	------	------
Bull Trout	-----	-----	3	8 (11)	7	11 (14)	2 (n/a)	2 (n/a)
Mountain Whitefish	-----	-----	-----	-----	1	-----	-----	-----
Total Population [B]	-----	-----	170 (194)	172 (182)	163 (183)		88 (104)	63 (75)

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	1998	1999[A]	2000	2001	2002	2003	2004	2005
Section 4 – below lower Cleveland								
Rainbow Trout							352 (365)	273 (283)
Brook Trout							------	2 (n/a)
Bull Trout							5 (n/a)	------
Total Population [B]							355 (368)	276 (286)
Section 5 –above lower Cleveland								
Rainbow Trout							172 (185)	173 (183)
Brook Trout							------	------
Bull Trout							6 (n/a)	------
Total Population [B]							172 (185)	173 (183)
Section 6 – lower Cleveland								
Rainbow Trout							218 (234)	221 (250)
Brook Trout							1 (n/a)	------
Bull Trout							------	4 (n/a)
Total Population [B]							219 (235)	221 (250)

Table A5. Pipe Creek depletion population estimate for fish $\geq$ 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
Rainbow Trout	42 (46)	73 (85)	39 (43)	25 (27)	21 (25)
Brook Trout	-----	3	7 (8)	4 (n/a)	6 (10)
Bull Trout	-----	-----	------	------	------
Total Population [A]	42 (46)	73 (85)		27 (29)	27 (31)
Water Temp. ^{0}C	18	17	------	------	

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 in length.

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 2005. Epischura and Leptodora were measured as number per m3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.18	0.34	0.06	4.23	0.00	0.00	0.00
		0.02	0.20	0.00	0.49	0.00	0.00	0.00
May	(3)	0.59	7.30	0.09	20.21	0.24	0.00	0.00
		0.13	4.01	0.00	20.67	0.17	0.00	0.00
June	(3)	1.61	20.62	0.01	8.42	0.94	27.82	0.06
		0.97	174.77	0.00	24.85	2.67	2,321.86	0.00
July	(3)	2.50	0.15	0.08	4.52	3.06	158.44	0.01
		0.93	0.02	0.00	1.32	2.17	4,706.52	0.00
August	(3)	1.18	1.08	0.66	4.71	1.42	262.65	0.64
		0.08	0.23	0.11	0.24	1.50	40,767.66	0.09
September	(3)	1.17	0.85	1.00	7.36	3.53	125.90	1.15
		0.65	0.33	0.51	61.13	1.50	3,375.66	0.11
October	(3)	1.21	0.23	1.27	3.46	0.71	175.13	0.16
		1.11	0.01	0.24	6.25	0.50	15,423.04	0.01
November	(3)	0.51	0.33	0.79	1.61	0.00	61.11	0.06
		0.13	0.04	0.22	4.12	0.00	4,392.03	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 2005. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.08	0.78	0.11	8.66	0.00	37.91	0.01
		0.00	0.16	0.01	24.68	0.00	1,199.65	0.00
May	(3)	0.69	12.40	0.60	31.20	0.94	271.61	0.09
		0.53	266.17	0.09	700.27	2.67	57,377.01	0.02
June	(3)	3.44	9.34	0.06	11.25	2.83	9.43	0.11
		3.90	21.55	0.00	76.69	0.50	266.77	0.00
July	(3)	4.70	0.02	0.14	8.60	5.42	71.11	0.02
		2.22	0.00	0.00	17.49	10.19	8,676.39	0.00
August	(3)	1.02	0.17	0.57	8.36	0.00	265.29	0.87
		0.49	0.07	0.08	3.05	0.00	3,554.38	0.01
September	(3)	0.48	0.72	0.55	2.70	1.41	149.57	0.75
		0.18	0.11	0.12	4.17	0.00	2,057.86	0.24
October	(3)	0.39	0.60	0.85	3.38	0.71	38.53	0.15
		0.04	0.02	0.04	0.65	0.50	128.90	0.00
November	(3)	0.62	0.77	1.14	4.88	0.00	35.46	0.07
		0.11	0.08	0.01	4.86	0.00	271.88	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 2005. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.02	0.08	0.03	1.44	0.00	220.61	0.07
		0.00	0.00	0.00	2.50	0.00	96,712.15	0.01
May	(3)	0.08	0.33	0.06	2.58	0.00	91.58	0.04
		0.01	0.08	0.00	4.48	0.00	6,396.21	0.00
June	(3)	2.72	2.54	0.00	7.39	9.20	58.86	0.08
		8.62	5.18	0.00	67.53	91.48	3,254.69	0.01
July	(3)	7.33	0.00	0.11	11.27	9.31	0.00	0.31
		19.96	0.00	0.01	25.94	1.29	0.00	0.06
August	(3)	1.22	0.05	0.36	12.18	2.36	114.30	1.03
		0.28	0.00	0.00	126.36	0.67	3,577.15	0.62
September	(3)	1.34	1.54	0.73	4.77	3.12	17.38	0.80
		0.27	2.13	0.05	0.97	15.18	906.19	0.31
October	(3)	2.07	0.80	1.13	5.91	1.39	0.00	0.31
		3.21	1.83	2.15	84.85	5.77	0.00	0.25
November	(3)	0.94	1.87	1.77	6.63	11.75	0.00	0.30
		2.04	9.90	8.69	122.31	414.42	0.00	0.26

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*	*Epischura*	*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