B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Mitigation for the Construction and Operation of Libby Dam

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MITIGATION FOR THE CONSTRUCTION AND OPERATION OF LIBBY DAM

ANNUAL REPORT
2004
(Work Activities July 1, 2004 – June 30, 2005)

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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 2003 to June 2004.

- Bull trout redd counts in Grave Creek and the Wigwam River have significantly increased since 1995. However, bull trout redds in Grave Creek in 2004 were lower (48%) than the previous year. 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 four adult bull trout population estimates below Libby Dam during the period April 2004 to April 2005. The four population estimates ranged from 906 – 1,068 adult fish. One estimate was made in August 2004, when mature bull trout would be expected to be in spawning tributaries. We recaptured 14 bull trout in April 2005 that were individually marked approximately one year earlier, which enabled us to calculate growth rates over the period. On average the bull trout grew 86.4 mm (total length) and gained 2,093.9 g.

- MFWP monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994. We captured a total of 3 burbot during the 04/05 trapping season, which represented a catch per effort of 0.015 burbot per trap day, which is similar to the past three years. The catch of burbot at this location has exhibited a significant exponential decline since 1994.

- MFWP continued a detailed field study on Libby Reservoir from mid-November 2004 to May 2005 to investigate the life history of burbot in Libby Reservoir. During this period, we expended a total effort of 962 days, catching a total of 66 fish at six trapping locations

throughout the reservoir. Burbot catch rate at all trapping sites averaged 0.073 fish per trap day during the 2004/2005 trapping season, with the highest catch per trap day near the mouth of Young Creek (0.128 fish per trap day) and the lowest catch rates observed near Big Creek (0.056 fish per trap day). Catch rates did not significantly differ between years, across trapping dates or locations. However, catch did significantly increase with trap depth.

- MFWP Libby Mitigation Staff continued to monitor the 28 coded acoustic and 12 combined radio/acoustic tags that were surgically implanted in burbot throughout the 2003-2004 trapping season. Six (15%) tagged burbot were never relocated after they were released. An additional seven (17.5%) of the tagged burbot either died or shed their tag within 60 days after release. We relocated the remaining 27 tagged burbot on at least 3 separate occasions (mean = 8.9) and used these data to estimate mean depths and home ranges within Libby Reservoir (named Lake Koocanusa). We estimated that the mean 50, 75 and 90% kernel home range estimates were 14.6 km^2, 22.6 km^2 and 32.3 km^2, respectively. We found no evidence that burbot home range differed within the year.

- 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 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 fifth straight year than the 17-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. This adjustment substantially improved the regression model's fit to the data in previous years, but did not improve the fit with the addition of the 2004 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* and *Daphnia* have been the first and second most abundant genera of zooplankton present in the reservoir since 1997.

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, CSKT and KTOI 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 2004 to evaluate the effectiveness of three stream restoration projects.

- 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 after the first spring freshet of 2004. The steam channel dimensions within the riffles of this section of Young Creek changed only slightly, with an overall decrease in cross sectional area and bankfull width, and an increase in overall bankfull depth. Pool volume and area within the project area was essentially unchanged between years.

- The Grave Creek Phase I Restoration Project 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 found no evidence that the stream channel dimensions changed significantly at any of our survey locations. However, pool width, depth and length did decrease within the project area from 2003 to 2004, but these changes were generally small and averaged between 10-15%.

- The stream channel dimensions and the quality and quantity of pool habitat within the Libby Creek Demonstration Project area did not change substantially since construction during fall of 2001. This project also substantially decreased erosion rates within the project area. However, channel erosion rates and channel instability above and below the project area remain high.

ACKNOWLEDGEMENTS

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

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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.

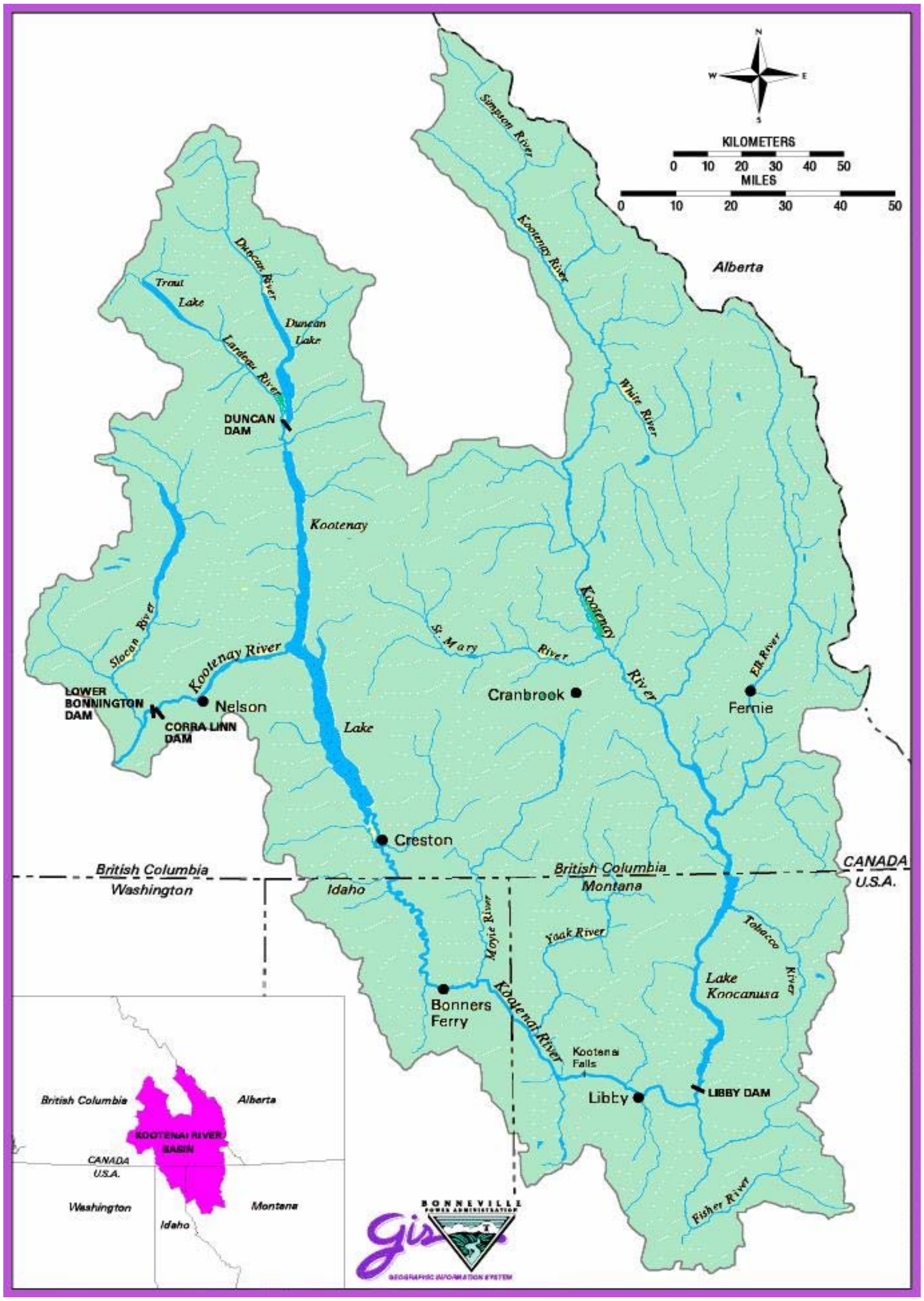

Figure 1. Kootenai River Basin (Montana, Idaho and British Columbia, Canada).

PROJECT HISTORY

Montana Fish, Wildlife and Park's (MFWP) 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 rehabilitated 200' of Pipe Creek stream bank in cooperation with a private landowner to prevent further loss of habitat for bull trout and westslope cutthroat trout. Pipe Creek is a primary spawning tributary to the Kootenai River.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ASSOCIATIONS

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

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

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

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

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

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

DESCRIPTION OF STUDY AREA

Subbasin Description

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

Drainage Area

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

Hydrology

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

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

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

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

Fish Species

Eighteen species of fish are present in Libby Reservoir and the Kootenai River (Table 1). The reservoir currently supports an important fishery for kokanee *Oncorhynchus nerka* and rainbow trout *Oncorhynchus mykiss*, with annual fishing pressure over 500,000 hours (Chisholm and Hamlin 1987). Burbot *Lota lota* are also important game fish, providing a popular fishery during winter and spring. The Kootenai River below Libby Dam is a “blue ribbon” trout fishery, and the state record rainbow trout was harvested there in 1997 (over 38 pounds). Although bull trout *Salvelinus confluentus* fishing was banned in the Kootenai River, “incidental captures” provide a unique seasonal fishery.

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

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

* Native species are designated Y, and nonnatives N

Reservoir Operation

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

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

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

Table 2. Morphometric data for Libby Reservoir.

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

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

Also, barriers have been deposited in critical spawning tributaries to the Kootenai River through the annual deposition of bedload materials (sand, gravel, and boulders) at their confluence with the river (Marotz 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.

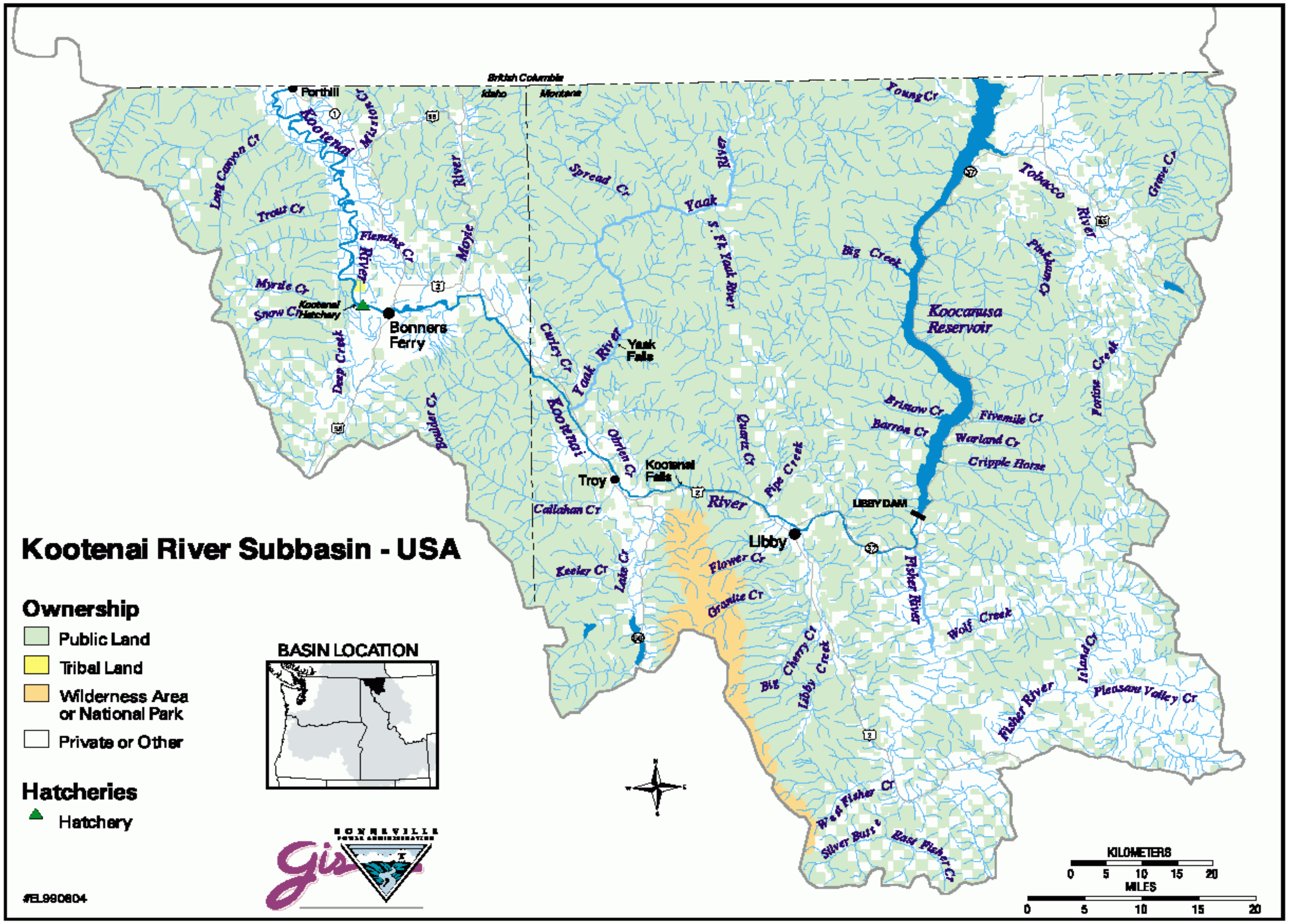

Figure 2. Kootenai River Basin, Montana.

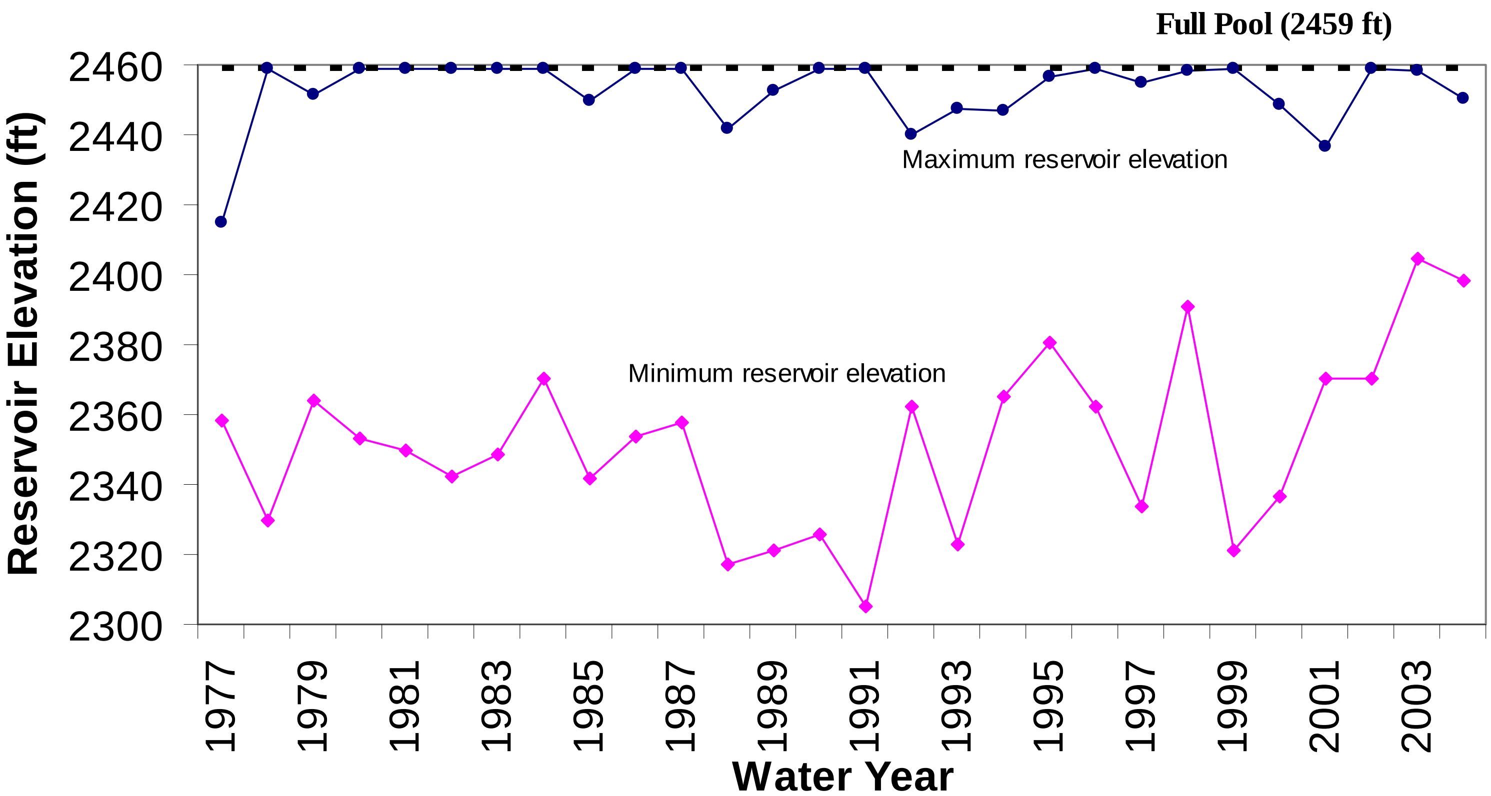

Figure 3. Libby Reservoir elevations (minimum, maximum), water years (October 1 – Sept. 30), 1976 through 2004.

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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 for the Koocanusa population include Grave and Skookumchuck creeks and the Wigwam and White rivers, with the majority of the spawning located in the 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 decreased in 2004 relative to the previous year.

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. MFWP conducted four adult bull trout population estimates below Libby Dam during the period April 2004 to April 2005, including an estimate conducted in August, 2004, when mature bull trout would be expected to be in spawning tributaries. The four population estimates ranged from 906 – 1,068 adult fish. We also recaptured 14 bull trout in April 2005 that were individually marked approximately one year earlier, which enabled us to calculate growth rates over the period.

We monitored the relative abundance of burbot in the stilling basin below Libby Dam using hoop traps since 1994. We captured a total of 3 burbot during the 2004/2005 trapping season, which represented a catch per effort of 0.015 burbot per trap day, which is similar to the past three years. The catch of burbot at this location has exhibited a significant exponential decline since 1994. MFWP continued a detailed field study on Libby Reservoir from mid-November 2004 to May 2005 to investigate the life history of burbot in Libby Reservoir. During this period, we expended a total effort of 962 days, catching a total of 66 fish at six trapping locations throughout the reservoir. Burbot catch rate at all trapping sites averaged 0.073 fish per trap day during the 2004/2005 trapping season, with the highest catch per trap day near the mouth of Young Creek and the lowest catch rates observed near Big Creek. Catch rates did not significantly differ between years, across trapping dates or locations. However, catch did significantly increase with trap depth. The Libby FWP Mitigation Staff continued to monitor the 28 coded acoustic and 12 combined radio/acoustic

tags that were surgically implanted in burbot throughout the 2003-2004 trapping season. Six (15%) tagged burbot were never relocated after they were released. An addition seven (17.5%) of the tagged burbot either died or shed their tag within 60 days after release. We relocated the remaining 27 tagged burbot on at least 3 separate occasions (mean = 8.9) and used these data to estimate mean depths and home ranges within Libby Reservoir. We estimated that the mean 50, 75 and 90% kernel home range estimates were 14.6 km^2, 22.6 km^2 and 32.3 km^2, respectively. We found no evidence that burbot home range differed within the year.

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 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 fifth straight year than the 17-year average. 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. Since 1997, *Cyclops* and *Daphnia* have been the first and second most abundant genera of zooplankton present in the reservoir.

Introduction

The primary objectives of the Libby Mitigation Project are to 1) Correct deleterious effects caused by hydropower operations and mitigate for fisheries losses attributed to the construction and operation of Libby Dam using watershed-based, habitat enhancement, fish passage improvements, and offsite fish recovery actions, 2) Integrate computer models into a watershed framework using MFWP's quantitative reservoir model (LRMOD), Integrated Rule Curves (IRC), Instream Flow Incremental Methodology (IFIM) and Libby Dam fish entrainment model (ENTRAIN), to improve biological production by modifying dam operation, and 3) Recover native fish species including the endangered Kootenai River white sturgeon, threatened bull trout, westslope cutthroat trout, interior redband rainbow trout, and burbot. A loss statement, site-specific mitigation actions and monitoring strategies were documented in the Libby Mitigation and Implementation Plan (MFWP, CSKT and KTOI. 1988) and Kootenai Subbasin Plan (MFWP, CSKT and KTOI (2004).

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

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

In addition, habitat enhancement and fish passage improvement measures may be the most promising methods for recovering native resident stocks. This project has embraced this approach and implemented several restoration projects on a basin wide priority basis using a step-wise, adaptive management approach to correct limiting factors for bull trout, burbot, 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 Since 1993, only "positive" redds have been counted, and are included in tables and figures for this report. In addition to counting redds, size and location of redds were also noted. Surveyors recorded suitable habitat and barriers to spawning bull trout when a stream was surveyed for the first time. We used linear regression of redd counts to assess population trends.

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 operated two jet boat electrofishing crews during each sampling event. 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 marked bull trout on the evenings of 4/8/04, 4/15/04, 4/21/04, 4/22/04, 5/5/04, 5/6/04, 8/18/04, 8/19/04, 4/20/05 and 4/21/05.

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.

Burbot Monitoring in Libby Reservoir

MFWP continued a detailed field study on Libby Reservoir throughout November 2004 through to June 2005, to investigate the life history of burbot in the reservoir. It was the continued effort of this project to aid in gathering information on life history, spawning distribution, home range, abundance or status of burbot populations upstream of Libby Dam. The field investigations utilized trapping efforts with baited hoop traps and sonic and radio telemetry.

We captured burbot using baited hoop traps measuring 2-feet diameter, approximately 6-8 feet in length with ¾ inch net mesh, baited with cut bait (kokanee salmon, dependent on availability). Sash weights, attached to the cod-end of each trap secured their position on the bottom, ranging at depths of 7.4 – 32 meters (mean = 20 m). Traps were fished within the general vicinity of six tributary confluences throughout the reservoir, ranging from river mile 222.5 to 268.4 (Table 1). During this season we fished traps near Canyon Creek, Cripple Horse Creek, Big Creek, Sutton Creek, Tobacco River and Young Creek. We did not trap at the Barron Creek, Bristow Creek, Ten Mile Creek and Dodge Creek locations in 2004/2005 due to the low catch rates 2003/2004 (Dunnigan et al. 2004). Captured burbot were enumerated, examined for a passive-integrated-transponder (PIT) tag, measured, tagged with a 134 (ISO) KHz PIT tag if not already tagged and released. PIT tags were inserted with an eight-gauge hypodermic needle into the musculature of the left operculum. The catch for each trapping location was standardized to average catch per trap day, to compare burbot catch rates across locations and time. We evaluated burbot total length and length weight relationships between trapping season, and used linear regression to evaluate the relationship between burbot catch rates, trapping date and hoop trap depth. We also evaluated burbot catch rates between trapping locations and trapping seasons using analysis of variance.

The telemetry study continued through the 2004-2005 season, with search activities to relocate tagged fish conducted approximately bi-weekly on Libby Reservoir using a 23 foot long Wooldridge outboard motorized boat. No additional tags were implanted in the 2004-2005 trapping season. However we continued to monitor burbot that were tagged during the previous trapping season, which consisted of 12 tagged with coded acoustic and radio tags (Lotek CART16-2S) and 28 coded acoustic tags (Lotek CAFT16-1). Dunnigan et al. (2004) presents a detailed description of the tagging protocols we used. We used telemetry receivers manufactured by Lotek Inc. (Model SRX-400; W7 Firmware) for locating both coded acoustic and combined acoustic and radio tags. Each receiver unit consisted of a radio receiver, data processor, internal clock, and data logger. We used a tuned loop antenna for locating the radio component of the combined acoustic and radio tags. For locating the coded acoustic tags, we used an ultrasonic up-converter (model UUCN-150) and a hydrophone (model LHP-1) manufactured by Lotek Inc. that were connected to the SRX-400 telemetry receiver. The ultrasonic up-converter modified the 76.8 KHz signal transmitted by the acoustic tags and converted it 150.077 KHz, which was capable of being decoded by the telemetry receiver. We used triangulation methodology to estimate the position of each tagged fish. We recorded the date, time, approximate depth (m), general location, and used a Global Positioning System (GPS) to identify and geo-reference the location of each tagged fish. We determined home range through geographical information system analysis. We estimated home range for those burbot which we had at least 3 observations, using Home Range Extension (1.1C) for Arcview.

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 2001 and 2002 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.

Grave Creek

We established a representative sampling reach on Grave Creek to perform population estimates. The shocking section begins at the Vukonich property bridge 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 2004 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) 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^{o}C.

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

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

Fourteen to twenty-eight floating (ganged) and one or two single, sinking nets were set in the fall in the 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 2004. 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 141 bull trout redds in Grave Creek in 2004, which represented a 48% reduction from the previous year (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).

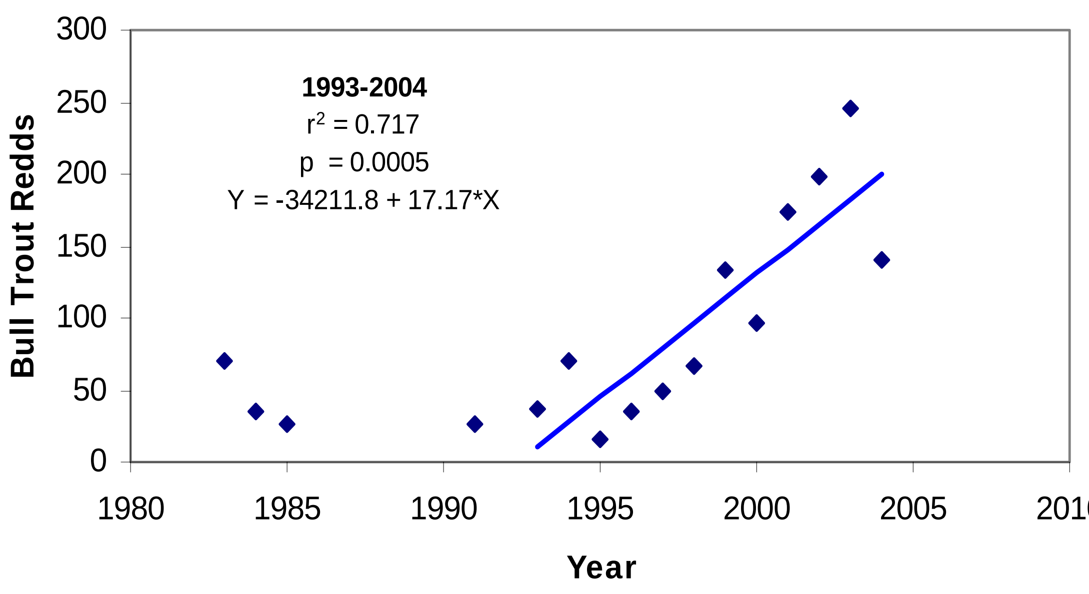

Figure 2. Bull trout redd counts and trend analysis in Grave Creek, 1993 through 2004.

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. A total of 2133 bull trout redds were observed in the Wigwam Drainage in 2004, which was a record high since counts began (Table 1). Bull trout redds in the Wigwam River have consistently increased each year since 1995 (Figure 3; $r^2 = 0.968$; $p = 2.83*10^{-7}$).

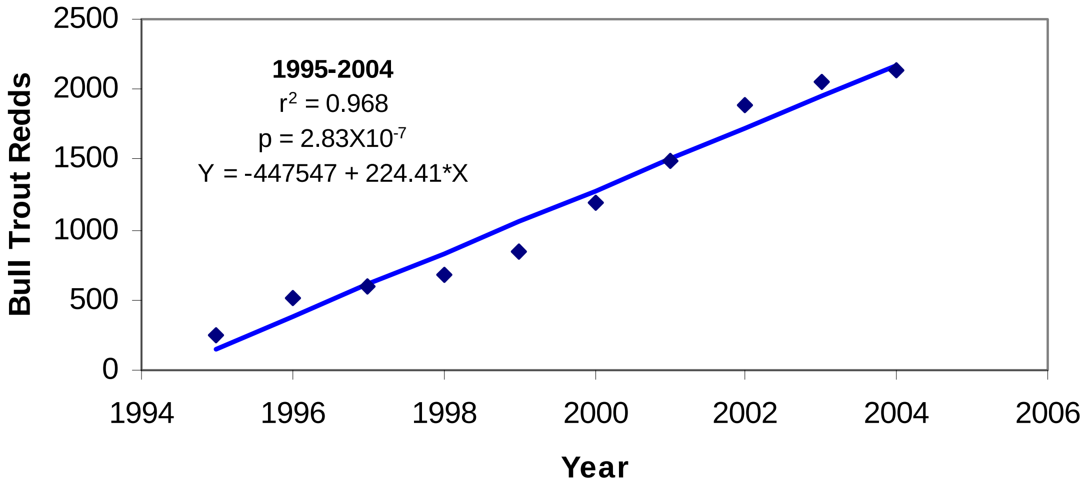

Figure 3. Bull trout redd counts and trend analysis for the Wigwam River (including Bighorn, Desolation, and Lodgepole creeks) 1995-2004.

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
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
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
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
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
	2003	14	4.25
	2004	6	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
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
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
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
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
White River (B.C.) Includes Blackfoot Creek in 2002 and 2003	2001	166	7.8
	2002	261	7.8
	2003	249	
	2004	190	8.1

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; $r^2 = 0.035$). Although overall trend is positive, annual variation limits our ability to statistically distinguish this relationship from a stable (zero slope) population (Figure 4; $p = 0.498$). We observed a total of 49 redds in Quartz and West Fork Quartz creeks in 2004 (Table 1). The average number of redds of the period of record was 74.9 redds. The 2004 observation of 49 redds was 34.5% lower than the average 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. This log jam was removed prior to adult bull trout upstream migration in 2004.

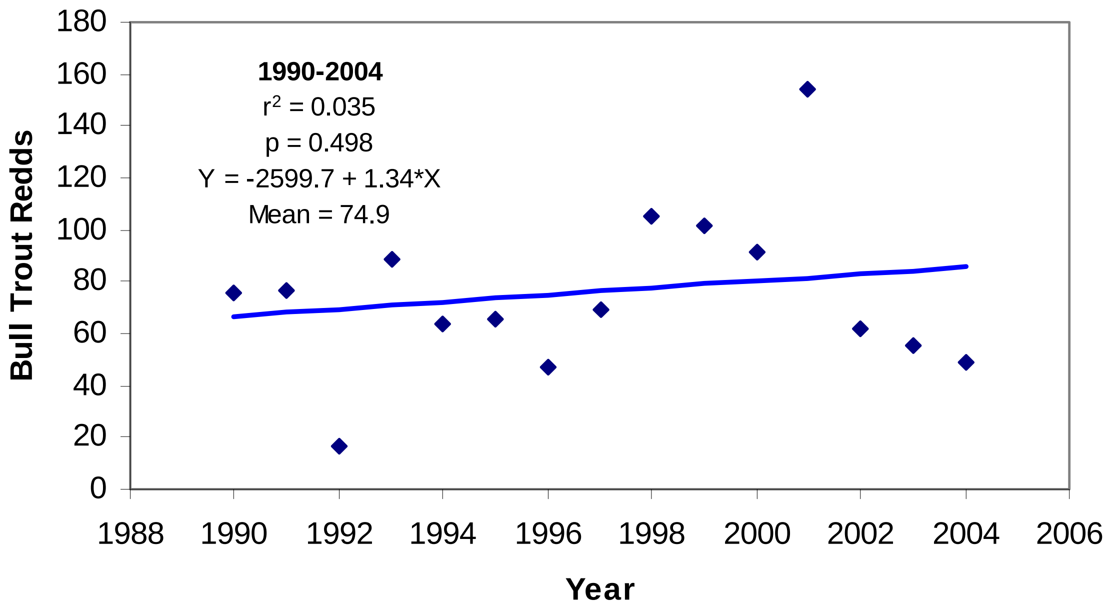

Figure 4. Bull trout redd counts and trend analysis (blue line) for Quartz Creek (including West Fork Quartz) 1990-2004.

Pipe Creek

Bull trout redd counts in Pipe Creek peaked in 1999 with 36 redds, with redd numbers and have decreased since that peak. Despite the decreasing trend of bull trout redds during the last five years, the overall general trend during the time period 1995-2004 has been variable, with a slope that is not significantly different than a stable population (Figure 5; $r^2 = 0.075$; $p = 0.324$). The mean number of bull trout redds since 1990 has been 14.5 redds. The 8 redds we observed in Pipe Creek in 2004 was 45% lower than the 14 year average. Low water conditions during the fall spawning season during the past four 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 1995-2004 (Figure 6; $r^2 = 0.001$). Although the overall general trend has increased since 1995, the relationship is not statistically different than a stable population (Figure 6; $p = 0.923$). Low water conditions in Bear Creek during the past four years also partially explain the low spawner escapement in Bear Creek. The average number of bull trout redds since 1995 in Bear Creek has been 15.1 redds. The 6 redds we observed in Bear Creek in 2004 was 60.3% less than the 9 year average.

O'Brien Creek

The general trend of bull trout redds in O'Brien Creek is generally increasing since 1995 (Figure 7; $r^2 = 0.647$; $p = 0.0005$). We observed a total of 51 bull trout redds in O'Brien Creek in 2004 (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 (1993-2004). 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 21 bull trout redds in the West Fisher River in 2004, which represented the second highest observation during the past 10 years. The overall trend was not significantly different than a stable (zero slope) population ($r^2 = 0.151$; $p = 0.211$). Given the amount of variation present within this dataset, the overall mean number of redds in the West Fisher (mean = 6.83 redds) does an equally good job at predicting redd numbers. Drought conditions during the recent summers/late fall periods may have contributed to the lower bull trout spawner escapement into the West Fisher River.

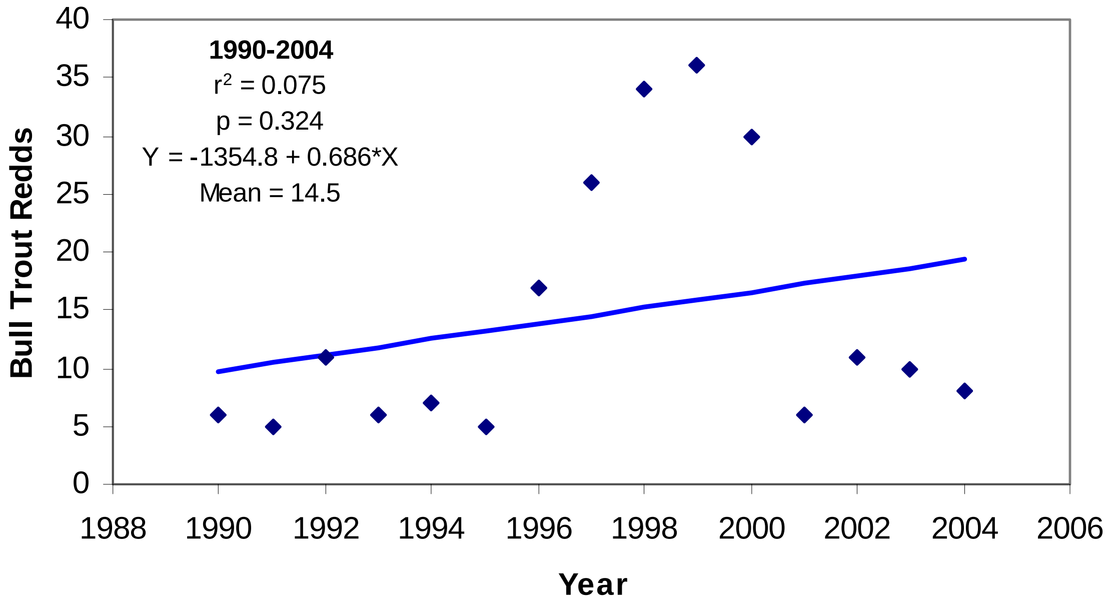

Figure 5. Bull trout redd counts and trend analysis (blue line) for Pipe Creek 1990-2004.

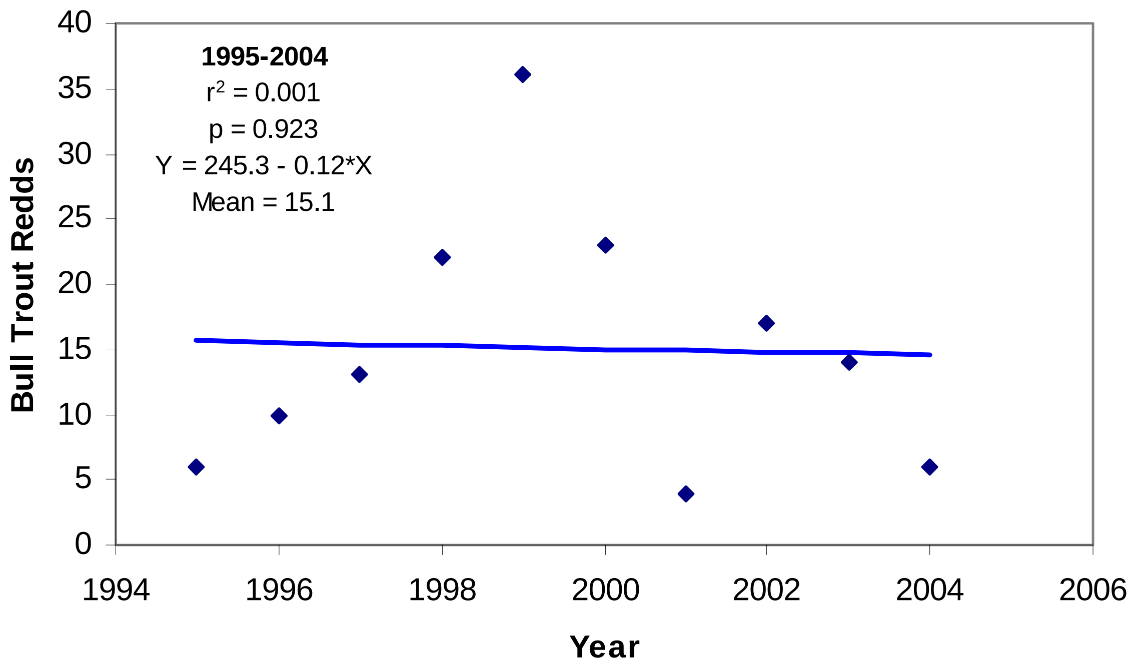

Figure 6. Bull trout redd counts and trend analysis (blue line) in Bear Creek, a tributary to Libby Creek, 1995-2004. The mean number of bull trout redds was 15.1.

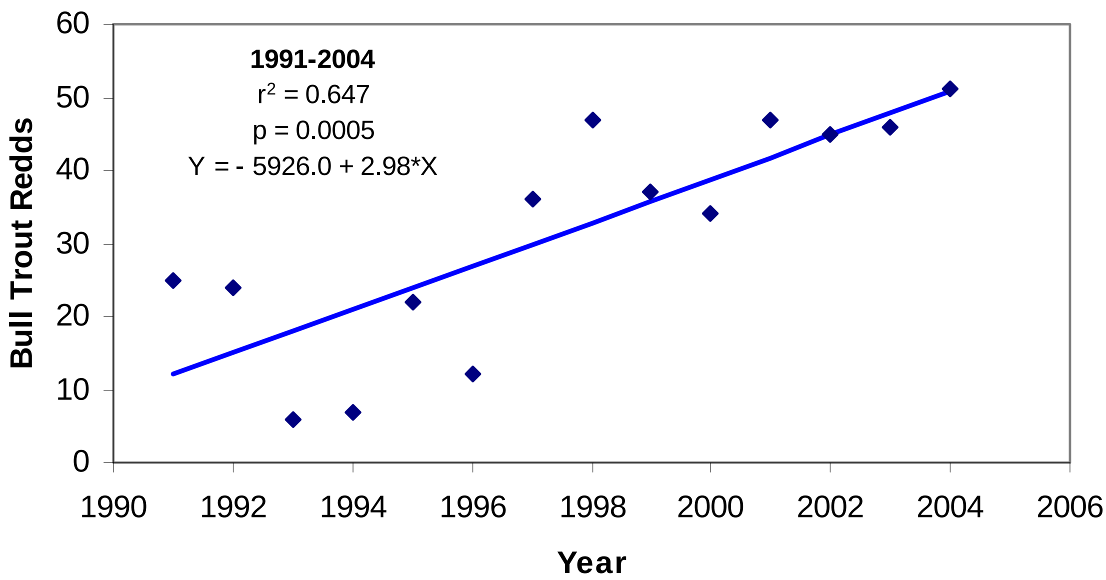

Figure 7. Bull trout redd counts and trend line (blue line) in O'Brien Creek 1991-2004.

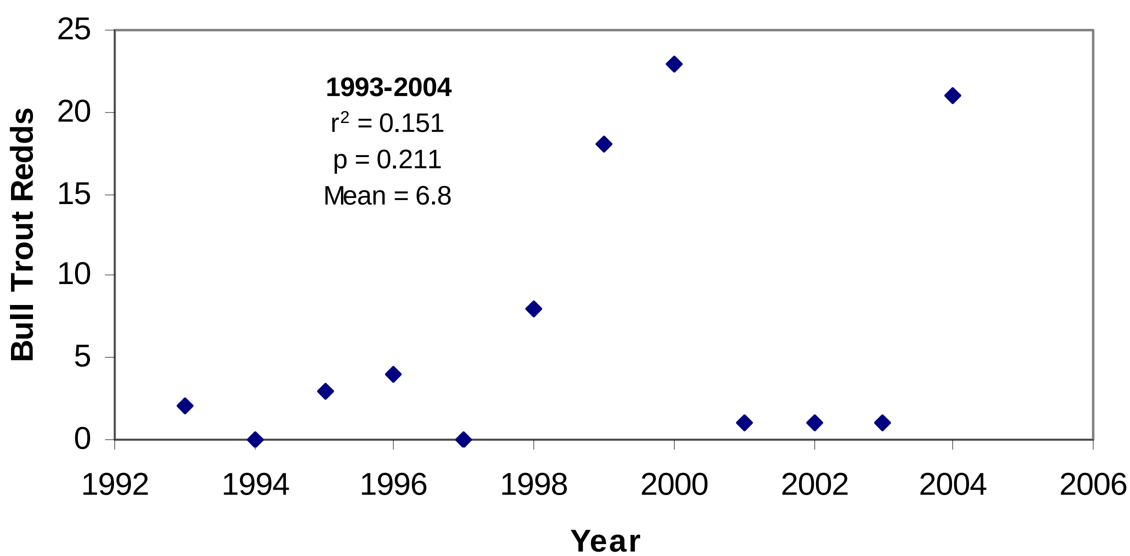

Figure 8. Bull trout redd counts in the West Fisher River, a tributary to the Fisher River, 1993-2004.

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 126 bull trout redds in Keeler Creek and associated tributaries in 2003 (Table 1), which represented a record high during our period of record. Bull trout redd counts in Keeler Creek have exhibited a positive trend since 1996, although the trend is not significantly different from a stable population (Figure 9; $p = 0.397$). Given this relationship, the annual mean (82.4 redds) does an equally good job of prediction. The 2004 observation represents a 52% increase relative to the annual mean.

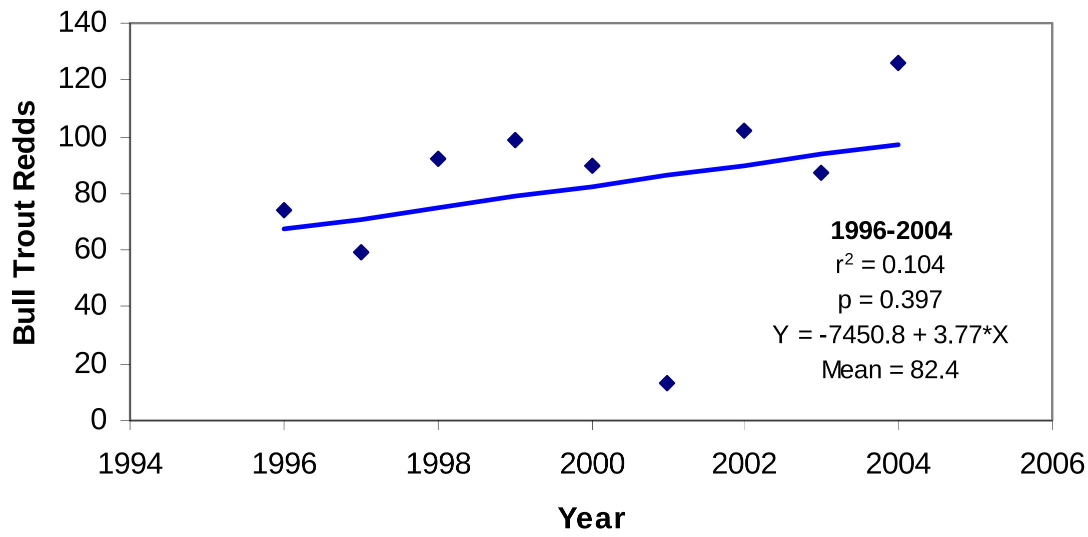

Figure 9. Bull trout redd counts and trend line (blue line) in Keeler Creek, a tributary to Lake Creek, 1996-2004.

Kootenai River Adult Bull Trout Population Estimate

We conducted a total of five individual fish marking episodes on the Kootenai River below Libby Dam. Each marking episode consisted of 2 nights of capturing fish via jetboat electrofishing that ranged between 1 to 7 days between nights (Table 2). Population estimates and associated 95% confidence intervals were calculated after each episode, excluding the first episode (Table 2). The mean population estimate for all samples periods over the one-year period was 976 adult bull trout, ranging from 906 to 1,068. The population estimate for each sampling episode varied by less then 10% compared to the mean (Table 2). We estimated that recapture rates ranged between 4 and 12% for each sampling episode. The average bull trout total length was 647 mm (range = 343 – 861 mm; Figure 10). We standardized each population estimate and 95% confidence interval into fish per mile, with a mean of 279 bull trout per mile (95% confidence interval = 158-400).

We recaptured 14 bull trout during our sampling period April 20 and 21, 2005. All the recaptured fish during this sampling episode were originally captured and marked approximately one year prior (+/- 1 to 12 days). The recaptured bull trout grew an average of 86.4 mm (range 42 – 179 mm; total length; Table 3), and gained an average of 2094 g (range 1,421 – 3,550 g; 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. 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 8 & 15 2004	109	N/A		
April 21 & 22, 2004	103	13	918 (511 – 1,326)	262 (146 – 379)
May 5 & 6, 2004	61	14	1,068 (600 – 1,537)	305 (176 – 434)
August 18 & 19, 2004	28	11	906 (494 – 1,318)	259 (144 – 374)
April 20 & 21, 2005	38	13	1,012 (608 – 1,415)	289 (177 – 401)
Total	**339**	**51**		
Mean	**68**	**13**	**976 (553 – 1,399)**	**279 (158 – 400)**

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.

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)
4/8/2004	4/20/2005	3D9.1BF1C59ED4	689	3878	765	5979	76	2101
4/8/2004	4/20/2005	3D9.1BF1C4F0B6	672	3209	740	4630	68	1421
4/8/2004	4/21/2005	3D9.1BF1C725D0	558	1591	668	3444	110	1853
4/8/2004	4/21/2005	3D9.1BF1C63390	551	1582	730	3262	179	1680
4/15/2004	4/20/2005	3D9.1BF1C68E63	700	3336	778	5364	78	2028
4/15/2004	4/20/2005	3D9.1BF1C679AA	697	2780	739	4303	42	1523
4/15/2004	4/21/2005	3D9.1BF1C6798C	593	1903	705	3915	112	2012
4/15/2004	4/21/2005	3D9.1BF1C6816B	735	4366	763	6244	28	1878
4/21/2004	4/20/2005	3D9.1BF1C70756	744	3975	803	5818	59	1843
4/22/2004	4/20/2005	3D9.1BF1C68F1E	745	5056	828	8606	83	3550
4/22/2004	4/21/2005	3D9.1BF1C479C2	820	6631	875	9305	55	2674
4/22/2004	4/21/2005	3D9.1BF1C5A309	446	755	604	2660	158	1905
4/22/2004	4/21/2005	3D9.1BF1C633C6	644	2715	733	5310	89	2595
4/22/2004	4/21/2005	3D9.1BF1C5A804	657	2814	730	5065	73	2251
Mean			**660.8**	**3185.1**	**747.2**	**5278.9**	**86.4**	**2093.9**

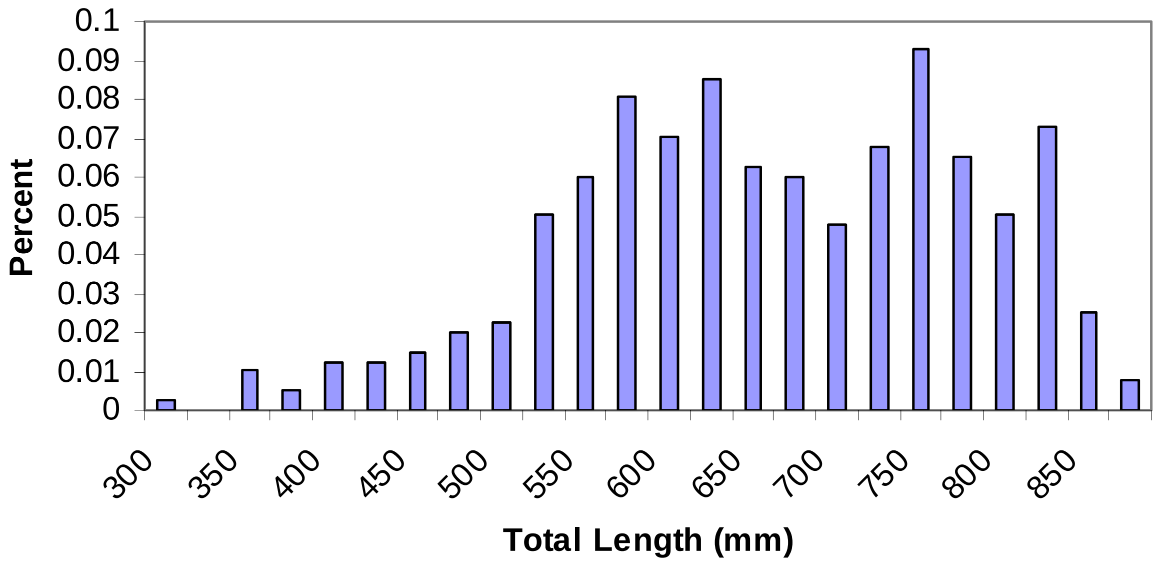

Figure 10. Length frequency distribution of bull trout captured via jet boat electrofishing on April 8, 2004 to April 21, 2005 below Libby Dam. Mean length for all fish captured was 647 mm.

Burbot Monitoring Below Libby Dam

The burbot catch in our hoop traps below Libby Dam has declined precipitously since 1996/1997 (Figure 12). A total of three burbot were captured during the 04/05 trapping season, which represented a catch per effort of 0.015 burbot per trap day. 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 0.656 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).

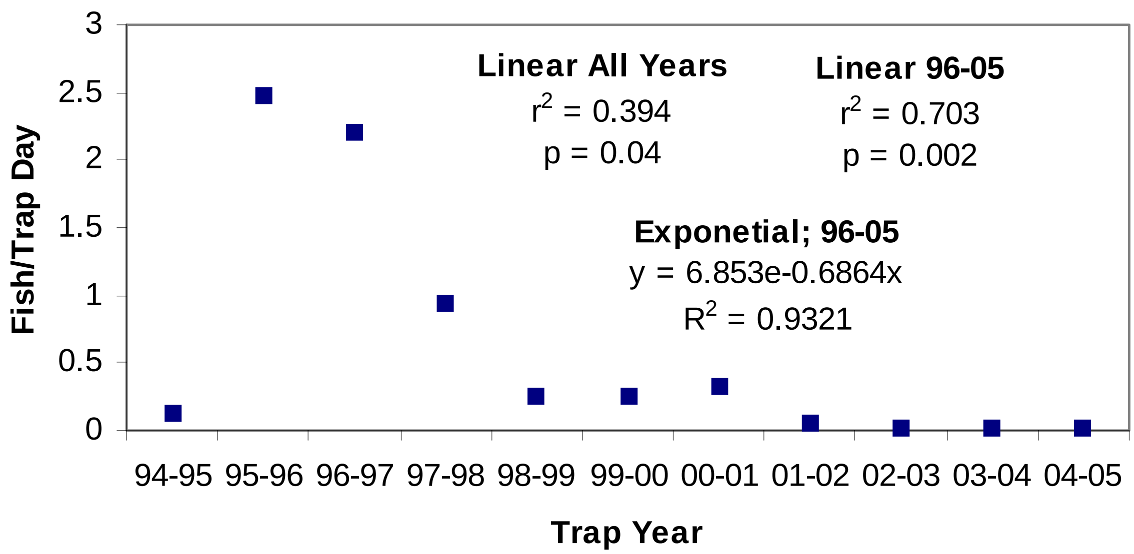

Figure 11. Total catch per effort (burbot per trap day) of baited hoop traps in the stilling basin downstream of Libby Dam 1994/1995 through 2004/2005. The data were fit with linear regression for all years and with an exponential model for 1995/1996 – 2004/2005. The traps were baited with kokanee salmon and fished during December and February.

Burbot Monitoring Libby Reservoir

During the period from November 22 to June 8, 2005 MFWP expended 962 days to catch a total of 66 fish (as of the compilation of this report on May 17, 2005) at six trapping locations throughout the reservoir (Table 4).

Burbot catch rate at all trapping sites averaged 0.073 fish per trap day during the 2004/2005 trapping season, with the highest catch per trap day near the mouth of Young Creek (0.128 fish per trap day) and the lowest catch rates observed near Big Creek (0.056 fish per trap day; Table 1). We found no evidence that catch rates differed between sites during the 2004/2005 trapping season ($p = 0.72$) or between the 2003/2004 and 2004/2005 trapping seasons ($p = 0.77$).

The mean total length of burbot captured in the baited hoop traps during the 2004/2005 season was 625mm (range = 350-790 mm; Figure 12). Burbot lengths did not differ significantly between the six trapping locations within Libby Reservoir ($p = 0.27$). However, burbot captured during the 2004/2005 trapping season were approximately 54 mm longer and 254 g heavier than burbot captured during the 2003/2004 season. These differences were significant ($p = 0.001$ and 0.035, respectively). Regardless of the fact that the burbot that we captured during the 2004/2005 trapping season were on average larger, burbot captured during both seasons showed the similar length-weight relationship (Figure 13).

We used linear regression to evaluate trends between catch rate and trapping date (Figure 14), and we used analysis of variance to evaluate whether catch rates differed by month. However, we found no evidence that the burbot catch rates differed with trapping date ($p = 0.14$) or by month ($p = 0.73$), which was similar to the 2003/2004 trapping season Dunnigan et al. 2004). We also used linear regression analysis to evaluate trends in burbot catch rate with trapping depth during the 2004/2005 trapping season. Burbot catch rates were positively and significantly correlated to trap depth ($r^2 = 0.422$; $p = 0.058$; Figure 15). The fit of this relationship was further improved when we combined data from the 2004/2005 and 2003/2004 trapping seasons (Figure 16; $r^2 = 0.6024$, $p = 0.005$).

Table 4. Summary information for the 2004-2005 baited hoop trapping effort for burbot in Libby Reservoir.					
Sample Site	**River Mile**	**Dates Trapped**	**Total Trap Days**	**Total Burbot Catch**	**Catch per Trap Day**
Canyon Crk.	222.5	11/22 - 12/20 & 03/08 - 04/04	161	10	0.062
Cripple Horse Crk.	226.8	11/22 - 12/20 & 03/08 - 04/04	165	11	0.067
Big Crk.	248.7	01/26 - 03/03 & 05/09 - 06/08	162	4 *	0.056 **
Sutton Crk.	250.3	01/26 - 03/03 & 05/09 - 05/27	159	9 *	0.086 **
Tobbacco Riv.	264.0	11/22 - 12/22 & 04/04 - 05/02	159	12	0.075
Young Crk.	268.4	11/30 - 12/20 & 04/04 - 05/06	156	20	0.128

* Second trap phase still ongoing, Total Burbot Catch represents data from first trapping phase
** Second trap phase still ongoing, Catch per trap Day Represents data from first trapping phase

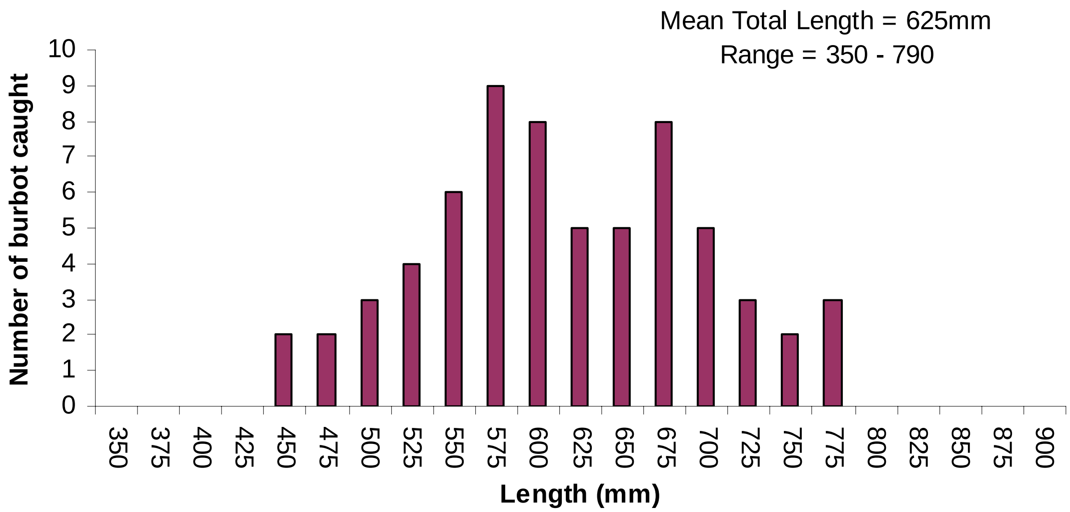

Figure 12. Length frequency distribution of burbot captured in baited hoop traps in Libby Reservoir, 2004-2005.

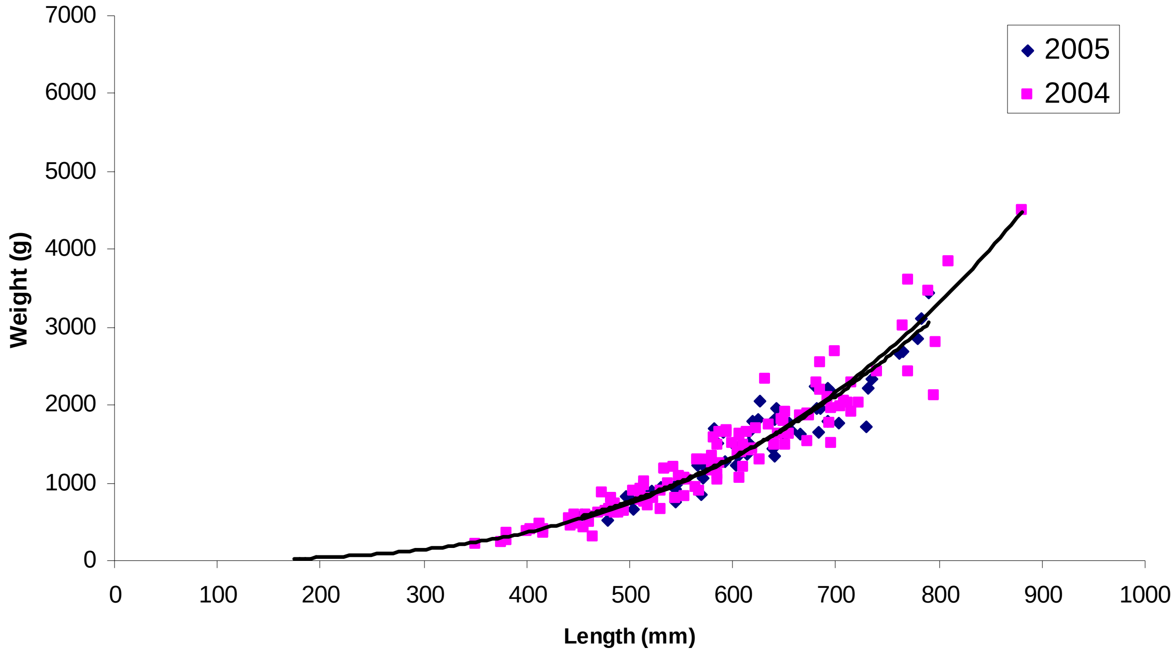

Figure 13. Length weight relationship for burbot captured in hoop traps in Libby Reservoir 2003-2004 and 2004-2005.

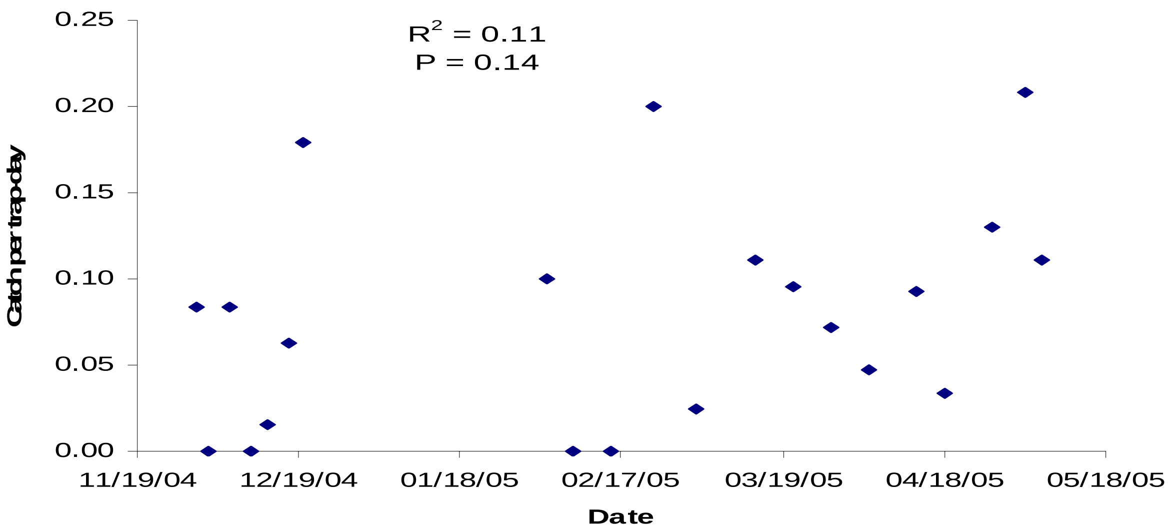

Figure 14. Scatter plot of mean burbot catch rates (catch per trap day) by date during the 2004-2005 season.

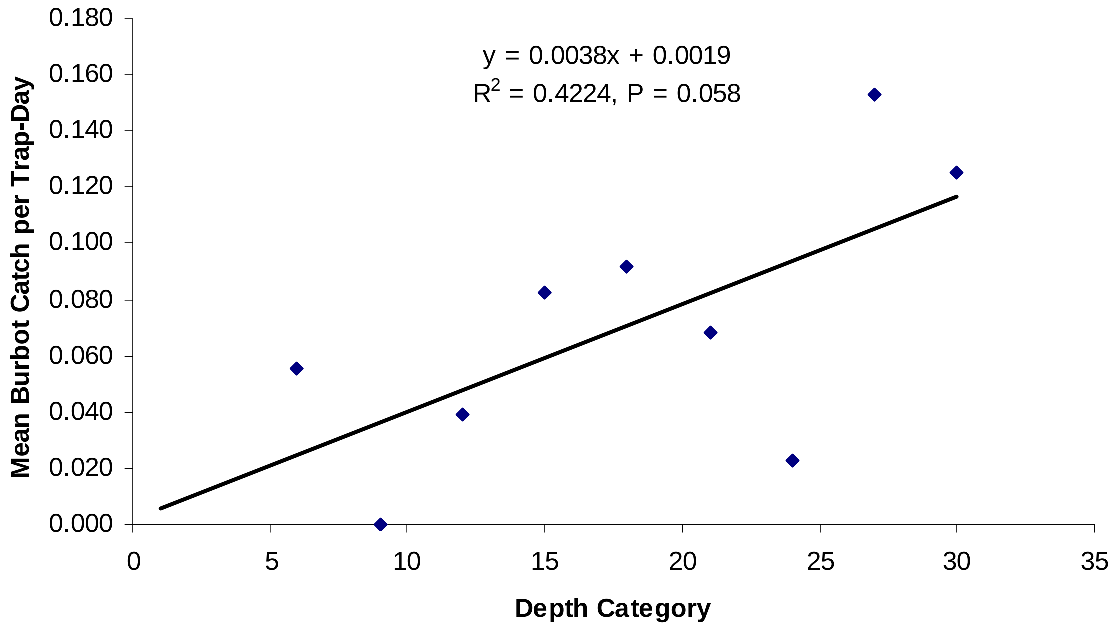

Figure 15. Scatter plot and regression of mean burbot catch rates (catch per trap day) for three-meter depth categories ranging from 3 to 30 m for the 2004-2005 trapping season.

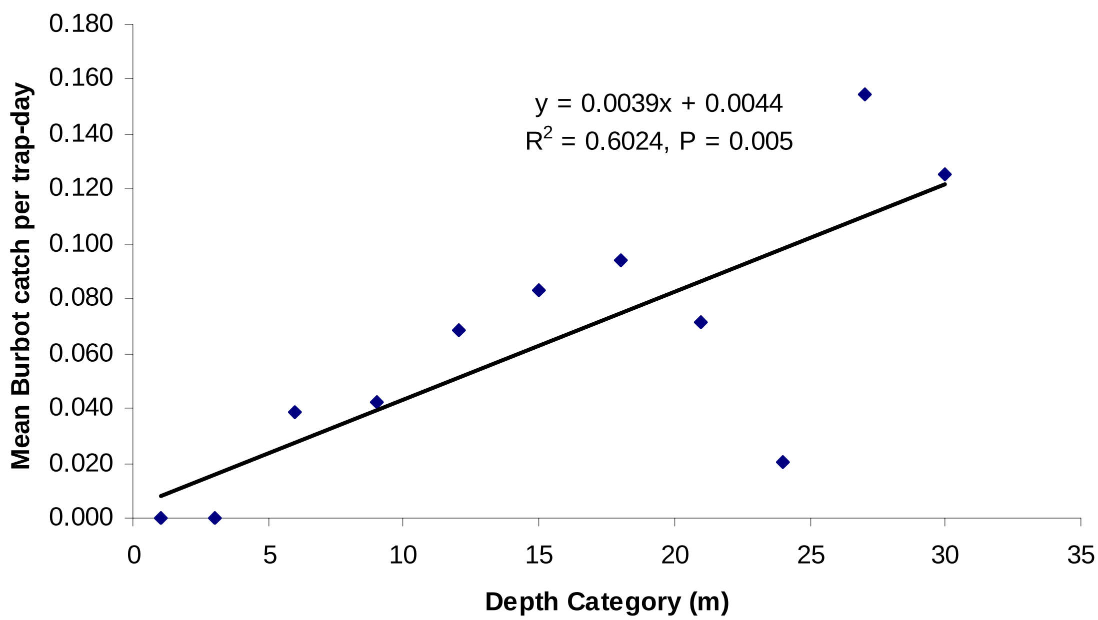

Figure 16. Scatter plot and regression of mean burbot catch rates (catch per trap-day) for three-meter depth categories from 1 to 30 m for both the 2003-2004 and 2004-2005 seasons.

The Libby MFWP Mitigation Staff continued to monitor the 28 coded acoustic and 12 combined radio/acoustic tags that were surgically implanted in burbot throughout the 2003-2004 trapping season. We searched approximately 1-2 days biweekly since trapping efforts began in November 2003 to search for the 40 tagged fish, primarily using acoustic gear (Figure 17).

Nearly all of our tracking effort was performed using the acoustic gear because most burbot were located at depths greater than 5 m, which is the maximum effective depth of the radio telemetry gear. Six (15%) tagged burbot were never relocated after release, and an additional seven (17.5%) tagged burbot either died or shed their tag within 60 days after release. The tags that were never observed after release were: Big Creek: code 14, Tobacco River: code 11, Young Creek: codes 4, 40, 129 and, 121. The reason why we didn't relocate these fish was likely due either to tag failure or angler mortality. We relocated 27 tagged burbot on at least three separate occasions and used these data to estimate mean depths and home ranges within Koocanusa Reservoir. We relocated the remaining 27 tagged burbot tagged an average of 8.9 times per fish (Table 6). Although the burbot tagged with the combined radio/acoustic tags were located on average fewer times than fish tagged with acoustic tags (means = 7.8 and 11.3, respectively; Table 2), this difference was not significant ($p = 0.107$ for a 2-tailed t-test). The mean depth of all our burbot relocations was 45.5 m (Table 5), which was significantly deeper than the mean depth which we fished the traps (16.2 m; $p < 0.0001$). We used linear regression to investigate the temporal trend of observed depth by month, and found no evidence that the mean depth of burbot at time of relocation differed by date ($r^2 = 0.07$; $p = 0.78$; Figure 18). In a similar analysis, we used an analysis of variance to test for differences in the mean observed depth for tagged burbot by month, and found no significant difference in observed depths by month ($p = 0.208$). The power of this test was 0.710.

We estimated home ranges for the tagged burbot using kernel analysis based on the relocation of tagged burbot throughout the year obtained from mobile tracking efforts. Home ranges were determined for the 50, 75 and 90 percent kernel estimates of home range for fish with at least 3 observations over a minimum period of at least 3 months. The kernel estimates of home range that were generated by Home Range Extension (1.1C) for Arcview do not take into account the area of the reservoir. Therefore, we only included that portion of a given kernel home range area that coincided with the reservoir area, as calculated using a graphical information system (GIS). For example, Figure 18 illustrates the procedure we used to estimate the 75% kernel home range estimate for acoustic tag code 11. We estimated that the mean 50, 75 and 90% kernel home range estimates were 14.6 km^2, 22.6 km^2 and 32.3 km^2, respectively (Table 6). We tested the hypothesis that home ranges differed by tagging location using analysis of variance and concluded that home range did not differ by tagging location for either the 50, 75 or 90% kernel home ranges (p values = 0.69, 0.87, and 0.67, respectively). We also measured the maximum upstream and downstream distances we relocated individual tagged burbot from the original capture location, as measured along the inundated Kootenai River thalweg. The mean maximum detected distance traveled up and downstream for each burbot was 8.1 and 10.6 km, respectively (Table 6). The mean total distance (up and downstream) for all tagged burbot was 16.4 km. The maximum distance that we relocated an individual burbot from the original capture location was 42.6 km upstream and 39.1 km downstream (Burbot tag codes 183 and 9, respectively; Table 6), and a maximum total distance (up and downstream) of 64.3 km.

To evaluate the hypothesis that burbot movement and home range differed within the year, we estimated burbot 75% kernel home ranges for tagged burbot within the periods January to March, April to June, July to September and October through December for burbot with at least 3 relocation observations within each period. We compared the mean 75% kernel home ranges for each period using analysis of variance (Table 7), and found no evidence that mean home range differed between any of the seasonal periods ($p = 0.42$). However, the power of this test was only 0.27.

We also evaluated site or regional fidelity of the tagged burbot which had a minimum of three relocations by calculating the proportion of the fish that never crossed the submerged Kootenai River thalweg, as located on the USGS 7.5 minute quadrangle map. Libby Reservoir burbot appear to have relatively high fidelity to the particular side of the reservoir. We found that 45.5% of our tagged burbot were never relocated on the on opposite side of the Kootenai River channel in which they were originally captured, tagged and released. Those that did cross the submerged channel do so infrequently. We found that on average, 88% (variance = 0.019) of our burbot relocation observations, the fish was found on the same side (or within the channel thalweg) of the river where it was originally, captured, tagged and released.

One of the burbot we tagged was entrained through Libby Dam. We tagged and released a 645 mm long burbot that was captured in a hoop trap near Canyon Creek located approximately 0.8 miles upstream of Libby Dam. The burbot was tagged with a combined radio/sonic tag on January 26, 2004, and subsequently relocated on four occasions prior to being entrained. We relocated the fish in the vicinity of the Canyon Creek confluence on February 2 and 11, 2004, and also near Yarnell Island (3.8 miles upstream of Libby Dam) on May 27 and June 8, 2004. The next time we located this tag was on October 28, 2004 in the Kootenai River directly downstream of Libby Dam. We believe the fish was dead at this time. Discharge at Libby Dam during the period when this fish was entrained was variable ranging between 16 and 4 kcfs, but was generally a stepped descending pattern (Figure 20).

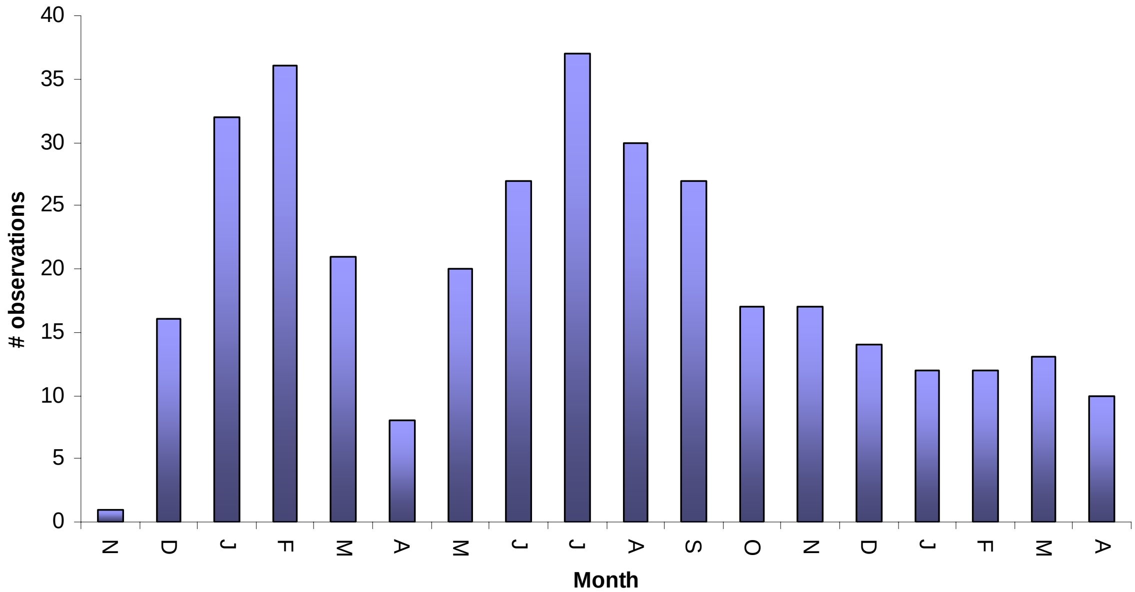

Figure 17. Histogram of the total number of observations of burbot tagged with acoustic and radio/acoustic tags by month in Koocanusa Reservoir 2003-2005.

Table 5. Capture location and summary observation information for the 23 acoustic (S) and 10 combined radio/acoustic (C) tagged burbot in Libby Reservoir for which there were at least 3 relocation observations.

Capture Location	Tag Code	Tag Type	Number of Observations	Observation Average Depth (m)	Depth Range (m)
Cripple Horse Creek.	10	S	3	47.6	25.6 - 69.5
Cripple Horse Creek.	12	S	4	34.1	20.0 - 43.4
Cripple Horse Creek.	16	S	13	62.8	18.3 - 90.0
Cripple Horse Creek.	45	S	16	58.2	20.0 - 89.2
Cripple Horse Creek.	111	S	13	43.8	17.4 - 76.0
Cripple Horse Creek.	138	S	5	50.7	12.2 - 66.8
Cripple Horse Creek.	143	S	19	55.9	37.5 - 77.8
Cripple Horse Creek.	178	S	9	74.6	36.3 - 90.0
Cripple Horse Creek.	183	S	10	64.1	48.5 - 94.3
Cripple Horse Creek.	193	S	14	52.4	15.0 - 79.9
Cripple Horse Creek.	204	S	21	30.7	3.0 - 85.0
Canyon Creek.	2	C	5	19.7	3.0 - 36.5
Canyon Creek.	100	C	4	56.1	20.0 - 77.0
Bristow Creek.	5	S	3	30.3	13.1 - 57.9
Bristow Creek.	114	C	12	59.8	25.0 - 96.3
Bristow Creek.	44	C	7	44.9	20.2 - 80.6
Ten Mile Creek	8	S	11	40.3	9.2 - 69.4
Ten Mile Creek	34	C	6	58.2	31.4 - 80.5
Ten Mile Creek	29	C	16	80.2	70.8 - 87.0
Big Creek.	7	S	19	56.4	32.9 - 72.7
Big Creek.	9	S	13	55.2	31.0 - 79.0
Big Creek.	22	S	16	23.8	14.6 - 45.1
Big Creek.	30	S	9	58.7	39.2 - 88.0
Big Creek.	156	S	5	31.2	15.2 - 60.7
Big Creek.	169	S	19	53.6	30.2 - 62.3
Sutton Creek.	15	C	10	49.6	14.5 - 65.1
Sutton Creek.	109	C	4	40.6	24.7 - 48.7
Tobacco River.	6	S	11	25.1	10.5 - 30.9
Tobacco River.	101	S	13	55.5	46.2 - 75.6
Tobacco River.	203	S	3	30.9	21.8 - 40.0
Tobacco River.	1	C	11	25.9	20.0 - 31.4
Tobacco River.	18	C	3	20.4	14.0 - 30.0
Young Creek.	152	S	7	40.6	19.2 - 60.3
			11.1 (all tags)		
Mean			**7.8 (radio/acoustic)**	**45.5**	
			10.1 (acoustic)		

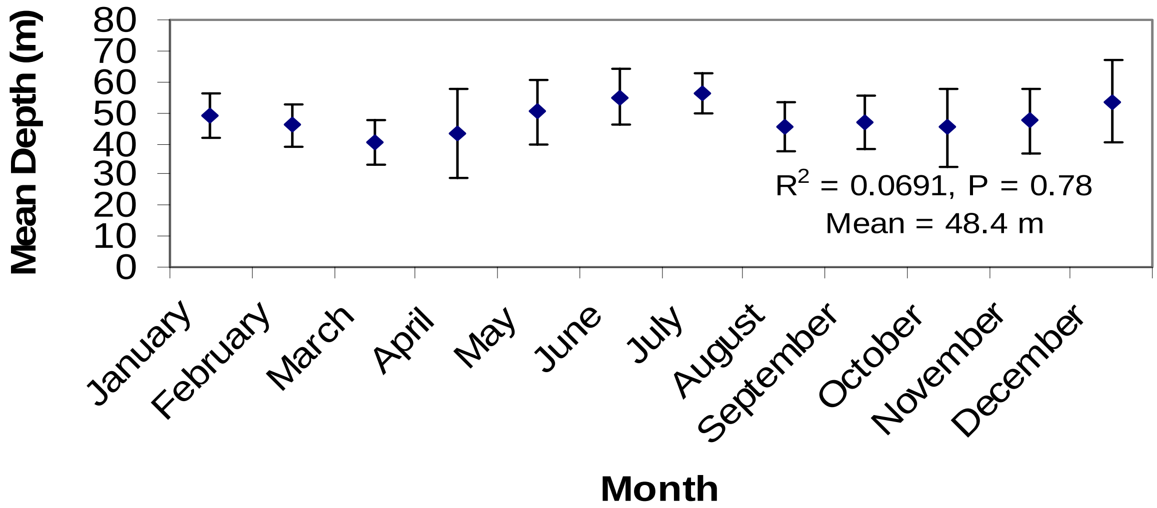

Figure 18. Scatter plot and regression of the mean depth of tagged burbot observed for each month in Koocanusa Reservoir, 2003-2005. The whisker bars represent the upper and lower 95% confidence intervals.

Table 6. Estimates of 50, 75, and 90% kernel home ranges for burbot marked with acoustic and combined radio/acoustic tags in Koocanusa Reservoir, 2003-2005 for fish with at least 3 observations.

Capture Location	Tag Code	No. Obs.	Date Range	Upstream Distance Moved (km)	Downstream Distance Moved (km)	50% Home range (km^2)	75% Home range (km^2)	90% Home range (km2)
Cripple Horse Crk.	16	13	12/03 – 4/05	17.4	7.2	17.01	24.97	31.69
Cripple Horse Crk.	45	16	12/03 – 3/05	33.7	8.8	14.83	20.44	23.02
Cripple Horse Crk.	111	13	1/04 – 2/05	9.6	4.2	8.90	19.56	30.21
Cripple Horse Crk.	138	5	12/03 – 3/04	0.6	5.0	4.62	9.67	14.29
Cripple Horse Crk.	143	6	12/03 – 6/04	17.0	0	18.81	28.07	34.39
Cripple Horse Crk.	178	7	1/04 – 1/05	0	5.3	7.14	12.36	15.19
Cripple Horse Crk.	183	10	1/04 – 12/04	42.6	7.1	20.60	42.09	69.41
Cripple Horse Crk.	193	14	1/04 – 2/05	0	5.7	3.46	6.33	10.45
Cripple Horse Crk.	204	10	1/04 – 8/04	0.2	2.8	1.86	3.50	5.82
Canyon Crk.	2	5	2/04 – 10/04	4.8	2.6	4.20	8.49	10.45
Canyon Crk.	100	4	3/04 – 6/04	14.4	0	27.39	39.43	42.05
Bristow Crk.	114	12	2/04 – 9/04	0	10.4	6.32	10.93	25.14
Bristow Crk.	44	7	2/04 – 8/04	4.7	9.8	19.94	26.69	40.93
Ten Mile Crk	8	11	2/04 – 4/05	4.2	22.8	28.34	36.16	44.58
Ten Mile Crk	34	6	2/04 – 9/04	0	20.1	35.87	41.78	43.75
Ten Mile Crk	29	6	3/04 – 8/04	0	4.7	1.88	3.19	6.55
Big Crk.	7	19	2/04 – 4/05	1.0	0.6	0.71	1.67	3.55
Big Crk.	9	13	2/04 – 9/04	1.1	39.1	18.11	29.38	49.34
Big Crk.	22	5	12/03 – 6/04	6.3	0	2.33	4.93	6.76
Big Crk.	30	9	12/03 – 9/04	30.8	33.5	42.31	50.66	116.08
Big Crk.	156	5	1/04 – 11/04	7.0	17.2	12.82	20.80	47.07
Big Crk.	169	6	12/03 – 6/04	0	27.5	30.69	58.64	64.48
Sutton Crk.	15	10	2/04 – 4/05	0	7.5	3.69	6.90	9.59
Tobacco Riv.	203	3	1/04 – 6/04	0	5.1	4.05	12.17	16.52
Young Crk.	152	7	1/04 – 10/04	7.1	17.3	29.54	45.43	47.42
Mean		**8.9**		**8.1**	**10.6**	**14.6**	**22.6**	**32.3**

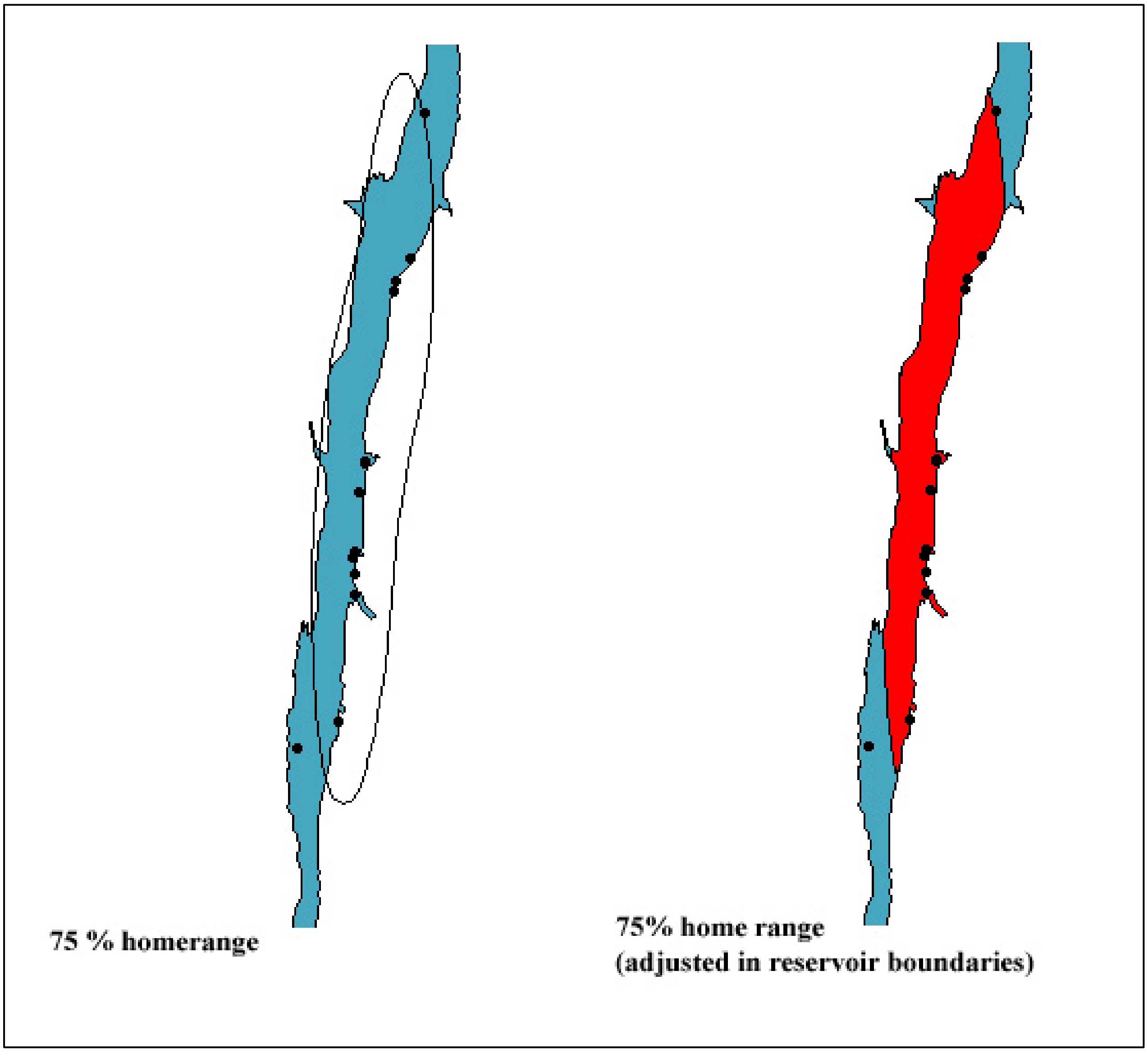

Figure 19. An example of the techniques used to estimate the 75% kernel home range for burbot within Koocanusa Reservoir. The figure on the left represents the 75% kernel home range area for acoustic tag code 111 in Koocanusa Reservoir, and the figure on the right represents the 75% kernel home range area that lies within the reservoir area. This adjusted home range area was calculated using GIS analysis. The black dots represent points of spatial relocation, used to calculate the home range.

Table 7. Mean 75% kernel home ranges for tagged burbot during 3 month long periods in Koocanusa Reservoir.

Period	**Number Tagged Burbot**	**Mean 75% Kernel Home Range**	**Variance**
January – March	18	11.5	206.8
April – June	4	10.9	309.7
July – September	12	22.7	1211.3
October – December	4	3.3	1.2

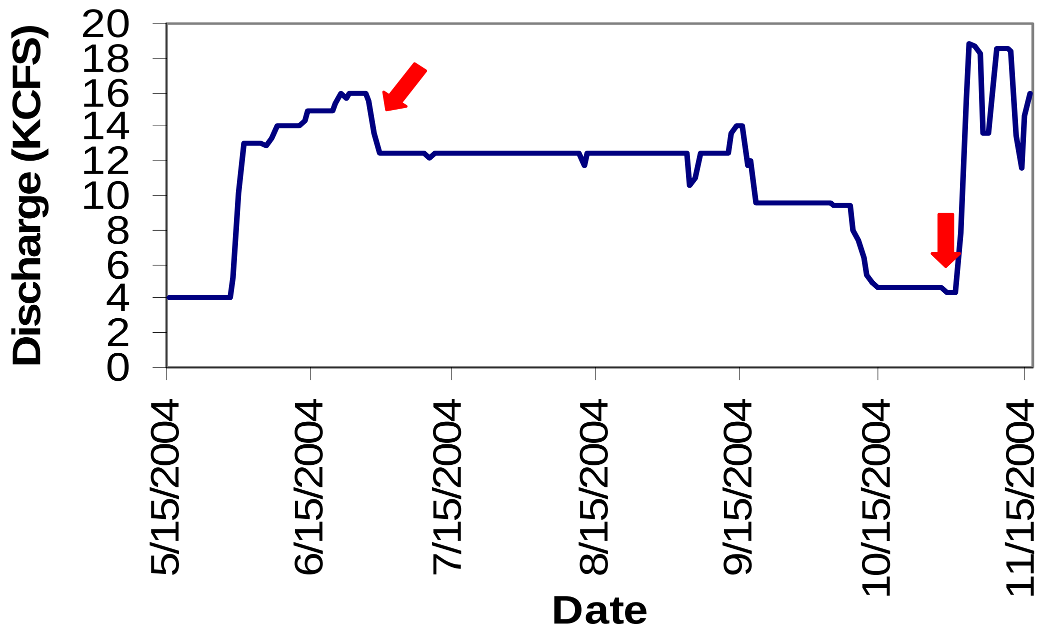

Figure 20. Libby Dam discharge (KCFS) during the period in which burbot tag code 2 was entrained through Libby Dam. The red arrows represent the last known observation near Yarnell Island before the fish was entrained and the first observation of the fish located below Libby Dam.

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 1997-2004, although this trend has not differed significantly from a stable population ($r^2 = 0.307$; $p = 0.333$; Figure 21; Table A1). 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 ($r^2 = 0.173$; $p = 0.486$; Figure 21; Table A1), and has averaged 44 brook trout per 1,000 feet. Juvenile bull trout abundance at this site in Therriault Creek has increased during the past 2 years. Bull trout were nearly as abundant at this site in 2004 as were rainbow trout (108 and 92 fish per 1000 feet, respectively). Despite the recent increase in bull trout abundance at this site over the past 2 years, the trend does not differ significantly from a stable population ($r^2 = 0.58$; $p = 0.136$; Figure 21).

Section 2 on Therriault Creek lies within the Therriault Creek Restoration Project area and was sampled in 1997-1999, 2001, 2003, and 2004. We observed rainbow, brook and bull trout at this site (Table A1). A linear regression used to evaluate population trends for each of these three species did not detect significant trends (Figure 22). Rainbow, brook and bull trout abundances at this site has averaged 74, 79 and 21 fish per 1,000 feet, respectively. These data will be used to characterize the fish community prior to construction within the Therriault Creek Restoration Project.

Section 3 on Therriault Creek is located upstream of the Therriault Creek Restoration Project area and was sampled in 1997-1999, 2003, and 2004 (Table A1). We observed rainbow and brook trout at this site each year, but bull trout were first observed in 2003 and again in 2004, with estimated abundances of 9.9 and 3.4 bull trout per 1,000 feet, respectively (Figure 23; Table A1). The trends of rainbow and brook trout abundance did not differ significantly from a population with zero slope ($p > 0.10$; Figure 23).

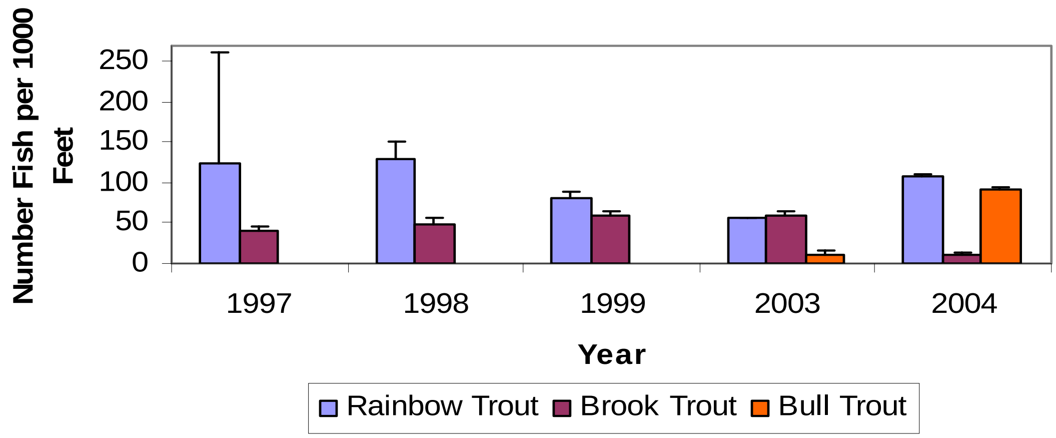

Figure 21. Cutthroat trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 1 monitoring site from 1997-1999 and 2003-2004 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

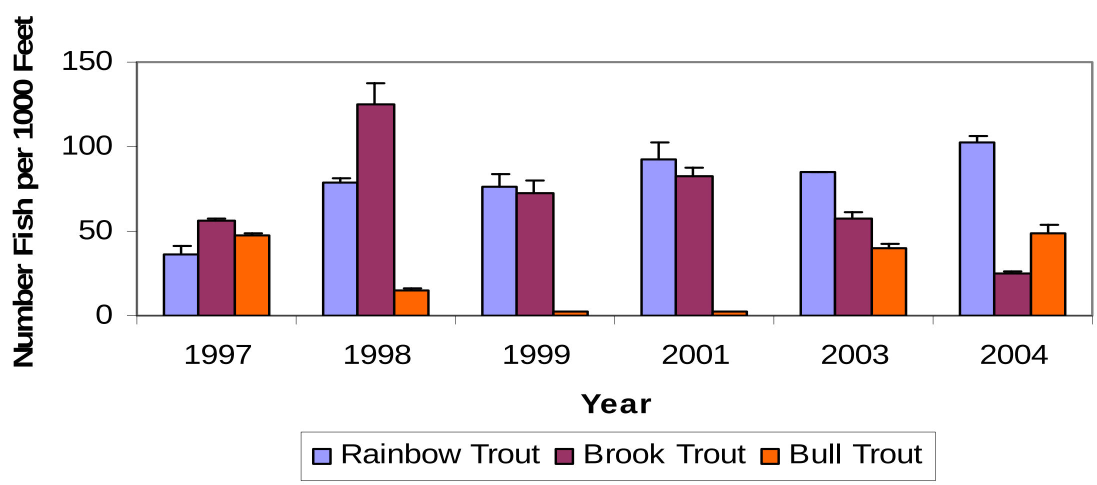

Figure 22. Cutthroat trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 2 monitoring site from 1997-1999, 2001 and 2003-2004 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

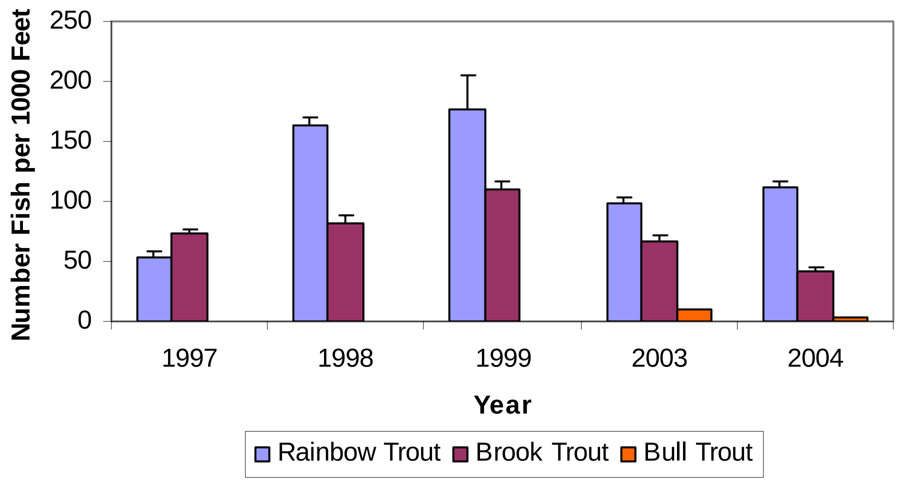

Figure 23. Cutthroat trout, bull trout and brook trout densities (fish per 1000 feet) within the Therriault Creek Section 3 monitoring site from 1997-1999 and 2003-2004 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

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 (2002-2004) restoration projects using t-tests (Figure 24). However, the variability in pre- and post-project fish abundance estimates is high (Figure 24 and 25), 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 ($p = 0.109$) after project construction (Figure 24). Brook trout and bull trout abundance also increased after at this site after project completion, although the differences were not significant (Figure 24). Mean westslope cutthroat trout abundance decreased slightly after project completion, although not significantly ($p = 0.56$; Figure 24). We used linear regression to assess whether there was a temporal trend in abundance for the four fish species at this site (Figure 25). Although the r^2 values for the regression analyses for rainbow, brook and bull trout all exceeded 0.50, only rainbow trout trends differed significantly from a zero slope ($p > 0.1$; Figure 25). The increasing trend of bull trout abundance at this site was also close to significance ($p = 0.12$). There was no apparent trend in westslope cutthroat trout abundance over the period 2000-2004 (Figure 25).

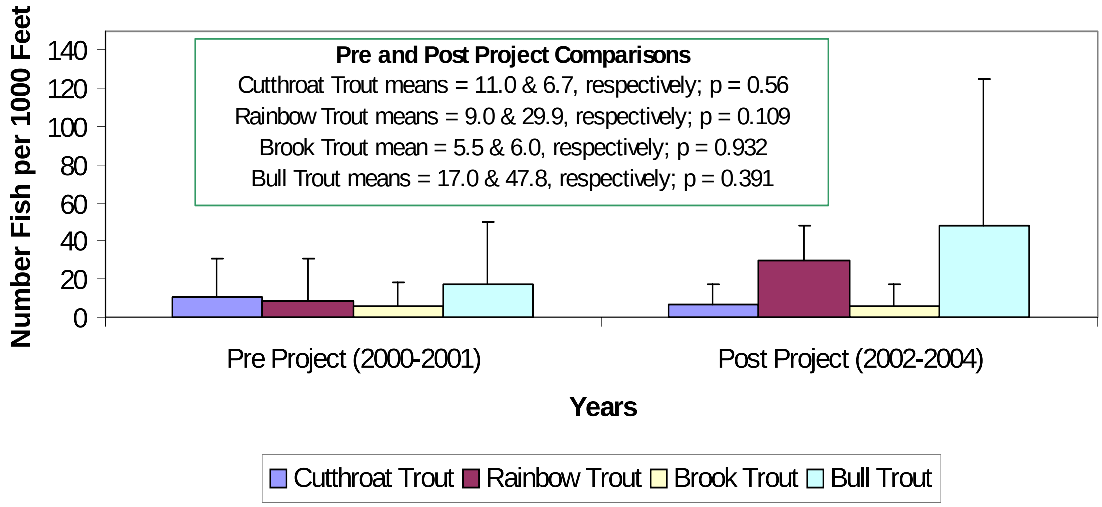

Figure 24. Mean cutthroat, rainbow, brook, and bull trout densities (fish per 1000 feet) within the Grave Creek Demonstration Project area prior to (2002-2001) and after (2002-2004) the completion of the Grave Creek Demonstration Restoration Project. Data collected during 2000 and 2001 represent pre-project 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.

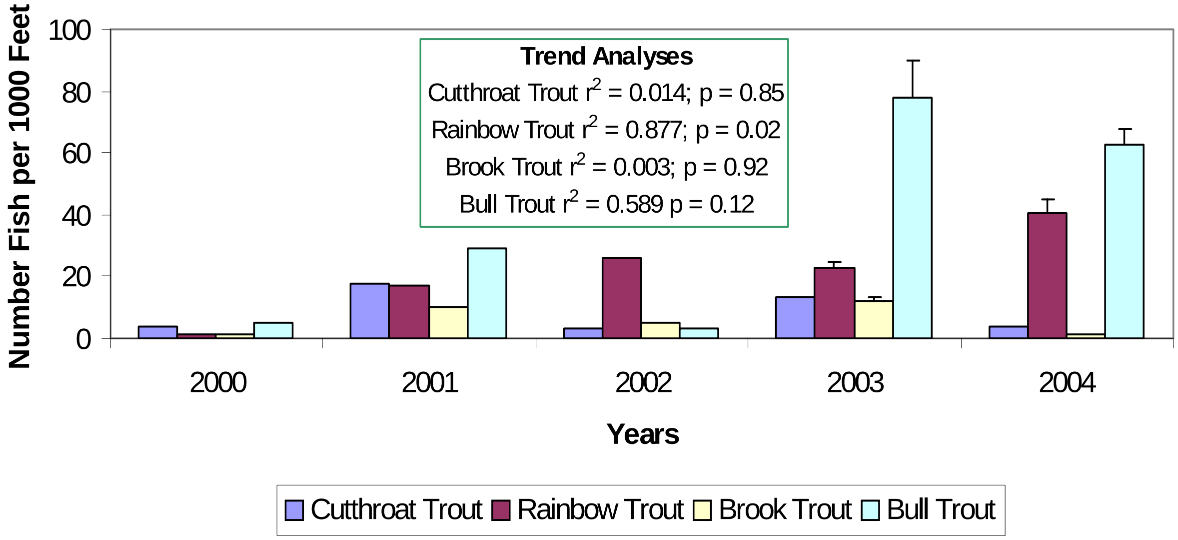

Figure 25. Cutthroat, rainbow, brook, and bull trout abundance estimates (fish per 1000 feet) and linear regression trend analyses within the Grave Creek Demonstration Project monitoring site from 2000-2004 collected by backpack electrofishing. The 2000 and 2001 data were collected using single pass electrofishing, the data collected in 2002 was collected via snorkel counts, and the 2003 and 2004 data was 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 1997-2002, and then again in 2004 (Table A3). There was no evidence of linear trends in abundance for cutthroat, rainbow or brook trout from 1997-2004 (Figure 26). 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 26). Cutthroat trout abundance at this section is slightly higher than brook trout abundance, although the difference was not significant ($p = 0.67$; mean densities 65 and 53 fish per 1000 feet, respectively). Bull trout were first observed at Section 1 in 2004, with an estimated abundance of 2 bull trout per 1000 feet.

The Young Creek Section 4 juvenile monitoring site was sampled consecutively from 1996-1999, and then again in 2001, 2002 and 2004 (Table A3). Westslope cutthroat trout dominated the fish community at this sampling location during all years, with cutthroat trout densities averaging approximately 70 fold higher than brook trout densities. Neither species exhibited a significant trend in abundance at this site (Figure 27). Over the period of record for this site, cutthroat trout densities averaged 231 fish per 1000, and brook trout densities averaged 3 fish per 1000 feet.

The Young Creek Section 5 lies entirely within the stream restoration project completed on State land in the fall of 2003. Therefore, all data collected through 2003 represents data gathered prior to the restoration project completion. Cutthroat trout and brook trout have exhibited relatively stable population trends in Section 5 of Young Creek since 1998, with annual mean abundance estimates of 199 cutthroat trout per 1000 feet and 40 brook trout per 1000 feet (Figure 28; Table A3). Abundance estimates for cutthroat trout have ranged from 126 fish per 1000 feet in 2000 to 268 fish per 1000 feet in 2002. Brook trout abundance was also variable, ranging from 19 to 62 fish per 1000 feet (Figure 28). There was no apparent trend in population abundance for either cutthroat or brook trout at this site during the period 1998-2004 ($r^2 < 0.17$; $p > 0.37$; Figure 28). Cutthroat trout abundance at this site in 2004 was 43% lower than the 6-year average prior to the implementation of the restoration project (mean densities = 114 and 199 fish per 1000 feet, respectively; Figure 29). However, brook trout abundance at this site increased by 50% the first year after project construction from a mean density of 40 fish to 60 fish per 1000 feet, respectively.

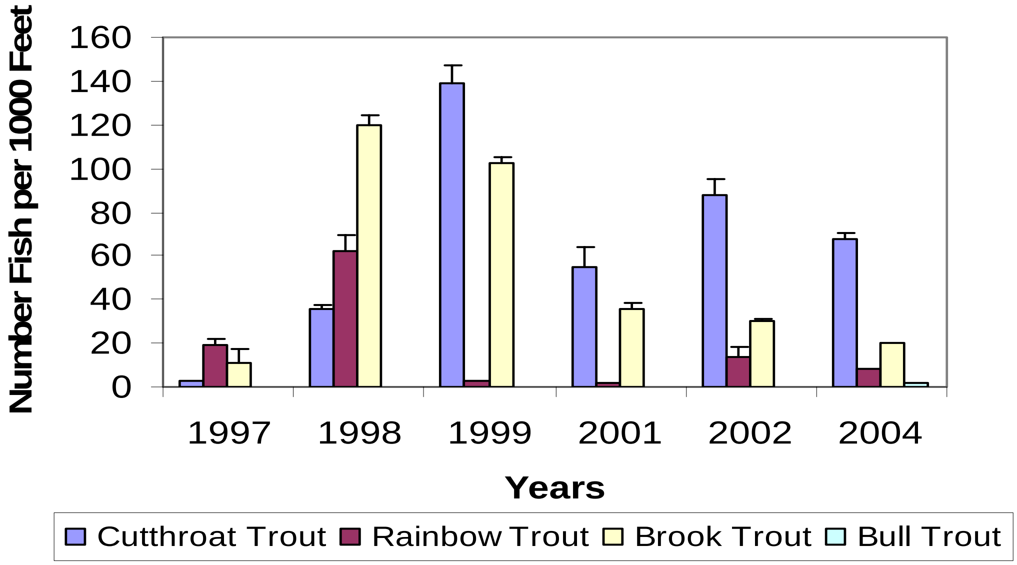

Figure 26. Cutthroat trout and brook trout densities (fish per 1000 feet) within the Young Creek Section 1 monitoring site from 1997-1999 and 2001, 2002 and 2004 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

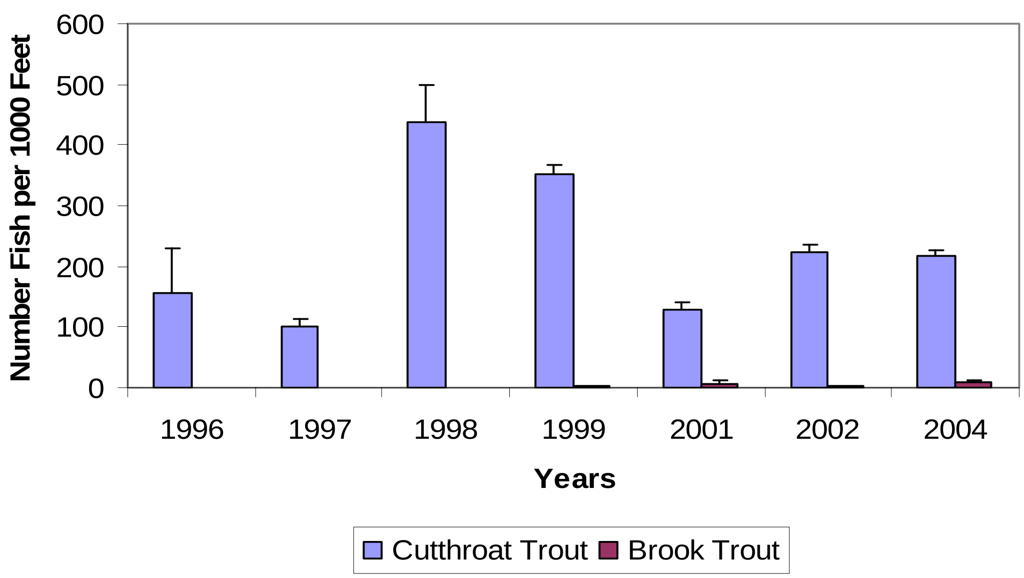

Figure 27. Cutthroat trout and brook trout densities (fish per 1000 feet) within the Young Creek Section 1 monitoring site from 1996-1999 and 2001, 2002 and 2004 collected by backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars.

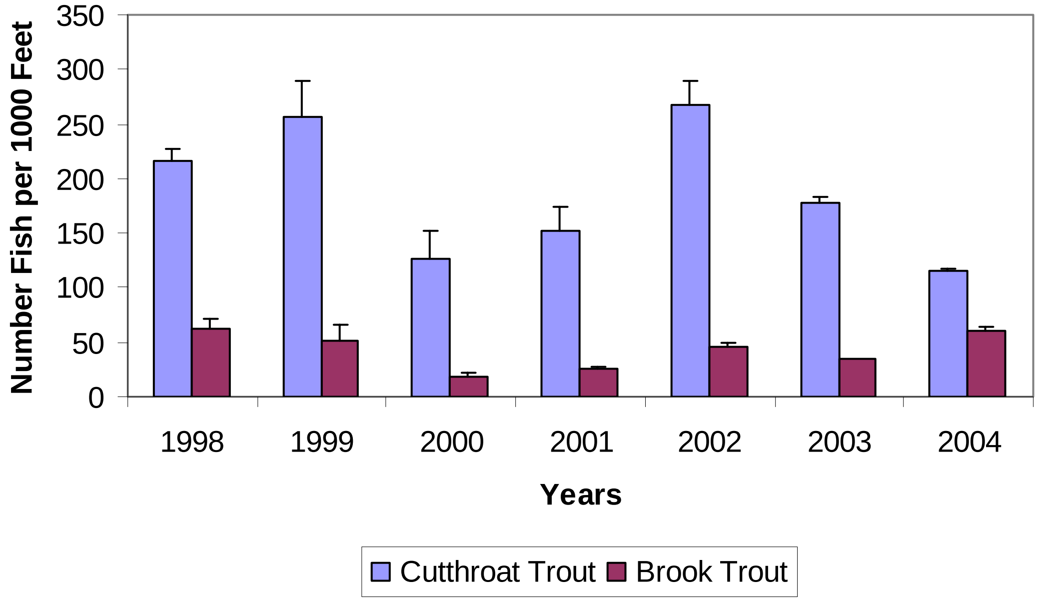

Figure 28. Cutthroat trout and brook trout densities (fish per 1000 feet) within the Young Creek Section 5 monitoring site from 1997-2004 collected by backpack electrofishing. The data presented for 2004 represent post restoration data. Upper 95% confidence intervals are represented by the whisker bars.

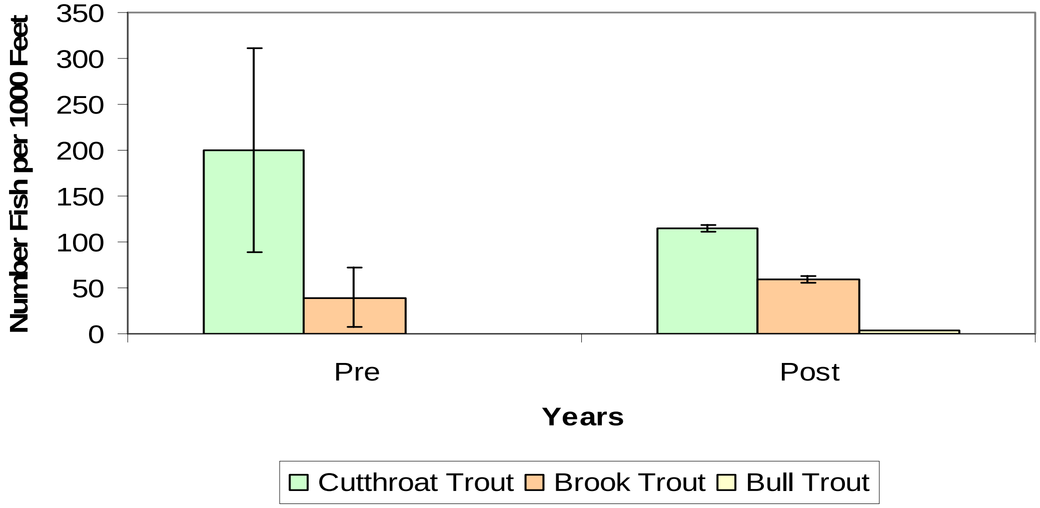

Figure 29. Cutthroat, brook and bull trout densities (fish per 1000 feet) within the Young Creek Section 5 (State Lands Restoration Project Area), comparing annual mean pre-project (1998-2003) data and post-project (2004) using mobile electrofishing gear. Upper and lower 95% confidence intervals are 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. Although 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 differences were not significant ($p = 0.127$). Similarly, mean brook trout abundance at this site before and after project completion were slightly higher after project completion (8.8 and 15.0 fish per 1,000 feet, respectively; Figure 30), but the differences were not significant ($p = 0.134$). Juvenile bull trout were only observed in this section in 2002, with an estimated abundance of 3 fish per 1000 feet. There is no apparent temporal trend in rainbow trout ($r^2 = 0.17$; $p = 0.35$) or brook trout abundance ($r^2 = 0.38$; $p = 0.14$) within this section (Figure 31; Table A4).

Section 2 of Libby Creek was sampled in 1998, 2001, 2003 and 2004 (Table A4). Rainbow trout were substantially more abundant at this section than brook trout and bull trout during all years (Figure 33). 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 ($r^2 = 0.888$; $p = 0.057$). Bull trout were only observed in this section in 1998 and 2003 (Figure 33; Table A4).

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 and 2004, however, our rainbow trout estimate was significantly lower than previous years (mean abundance 100.4 and 168.3 fish per 1,000 feet, respectively; $p = 0.006$; Figure 33). No brook trout were observed at this site during the past five years. We estimated 1.9 juvenile bull trout per 1000 feet in this section in 2004 (Figure 32). Estimates of juvenile bull trout abundance before and after project implementation were similar (means = 6.0 and 6.3 fish per 1000 feet, respectively), and did not differ significantly ($p = 0.933$; Figure 34).

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 2005 and 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 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 352 rainbow trout per 1000 feet. Rainbow trout abundance was similar between sections 5 and 6 where we estimated 172 and 218 fish per 1000 feet, respectively. Bull trout were encountered at relatively equal, but low abundance at all three sites. We estimated 5, 6 and 7 bull trout per 1000 feet at sections 4, 5 and 6, respectively. Brook trout were relatively scarce at these three sampling locations, and were only captured in sections 4 and 6, where we estimated 3 and 2 fish, respectively.

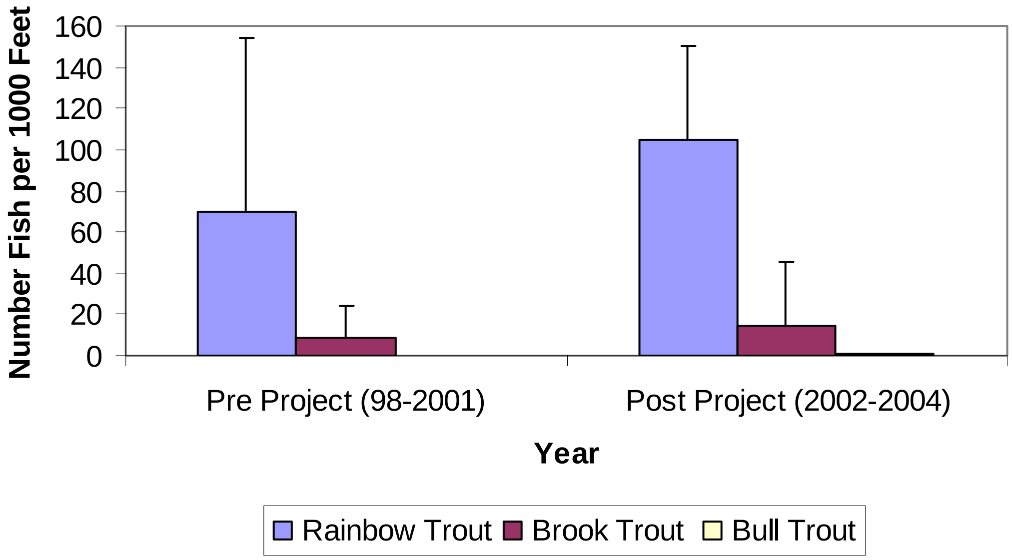

Figure 30. Rainbow trout and brook trout densities (fish per 1000 feet) within the Libby Creek Demonstration Project area, comparing annual mean pre-project (1998-2001) data and post-project (2002-2004) using mobile electrofishing gear. Upper 95% confidence intervals are represented by the whisker bars.

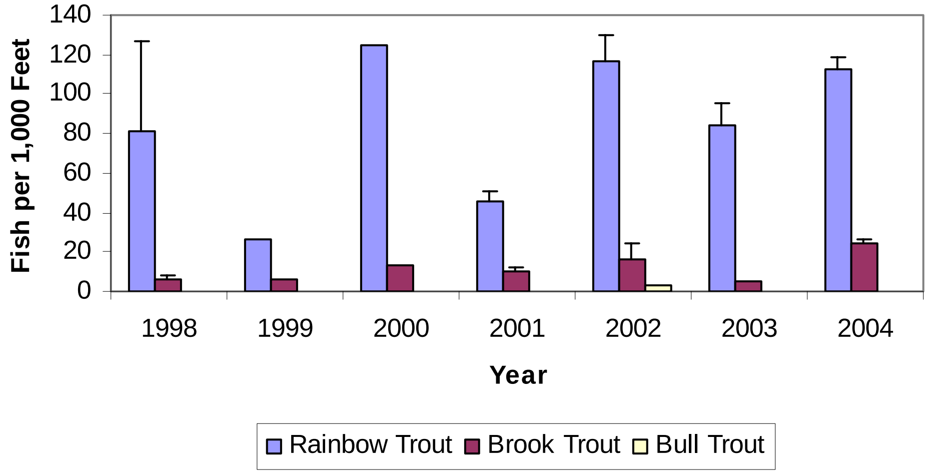

Figure 31. Rainbow trout, brook trout, and bull trout densities (fish per 1000 feet) within the Libby Creek Section 1 monitoring site 1998 through 2004 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. The site was sampled using single pass electrofishing in 1999 and 2000.

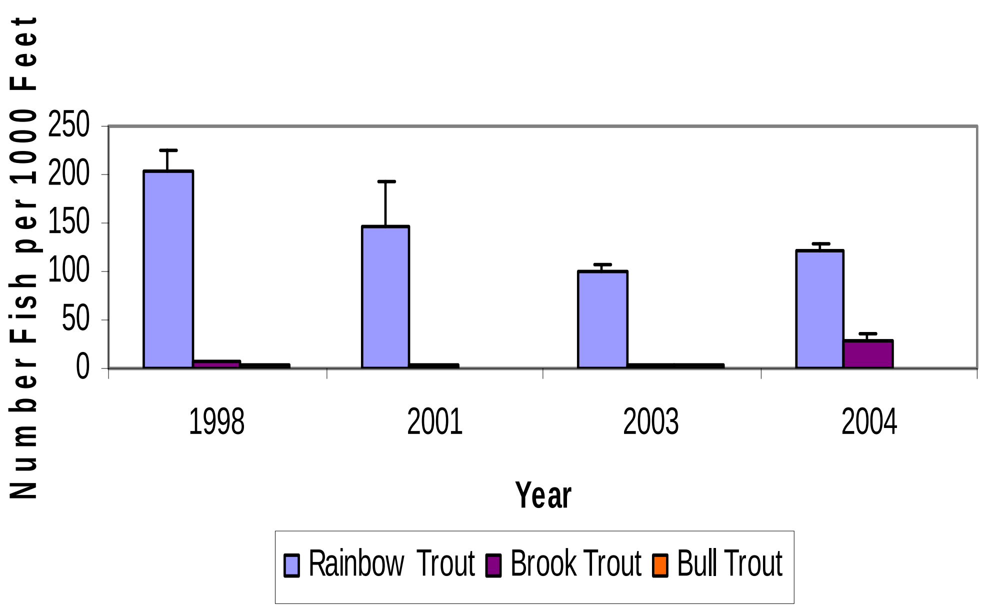

Figure 32. Rainbow trout, brook trout, and bull trout densities (fish per 1000 feet) within the Libby Creek Section 2 monitoring site sampled in 1998, 2001, 2003 and 2004 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars.

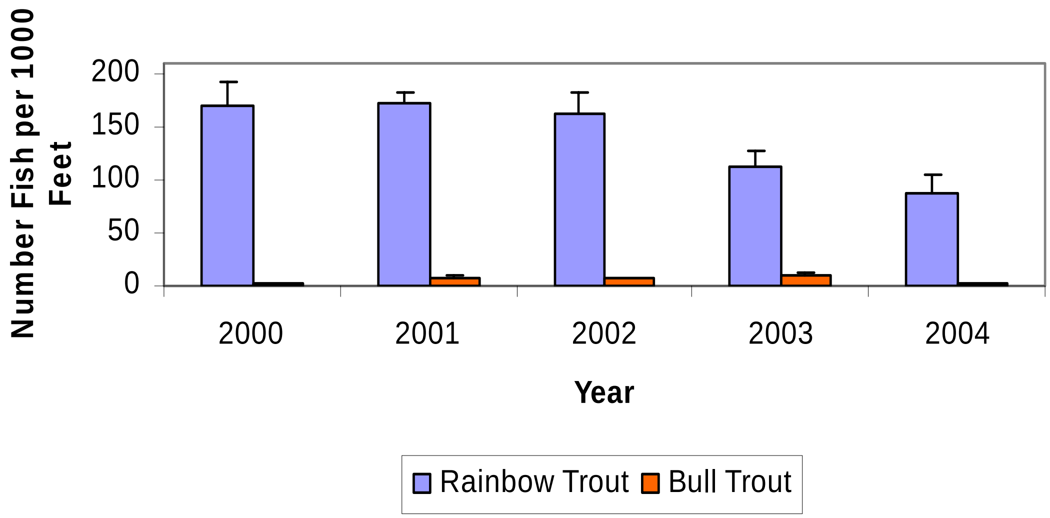

Figure 33. Rainbow trout and bull trout densities (fish per 1000 feet) within the Libby Creek Section 3 monitoring site in 2000-2004 using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. This site is located within the upper Libby Creek restoration project area. The data from 2000-2002 represent pre-project trends of fish abundance, and the 2003-2004 data represent data after project completion.

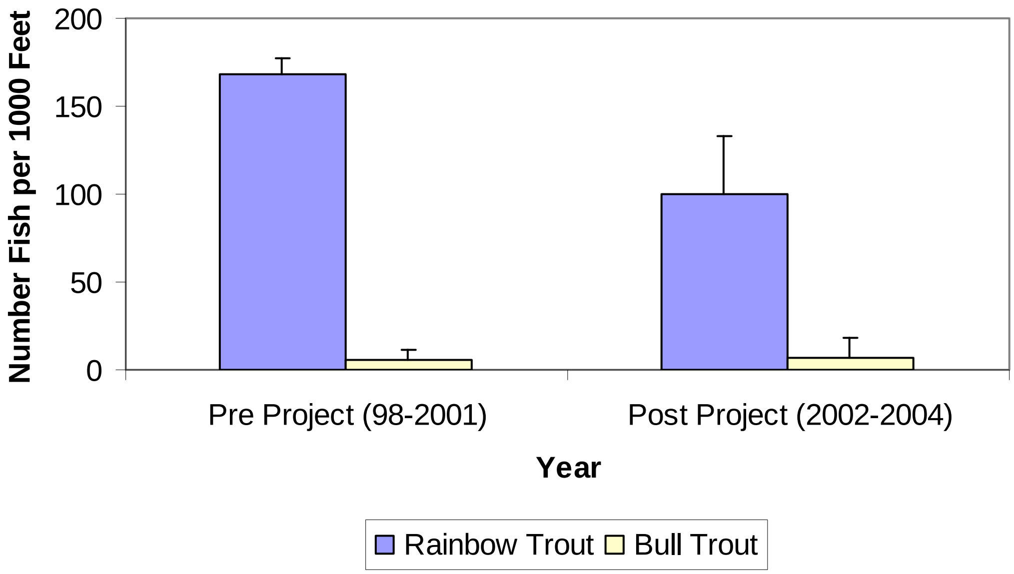

Figure 34. Rainbow trout and bull trout densities (fish per 1000 feet) within the Libby Creek Upper Cleveland's Stream Restoration Project area, comparing annual mean pre-project (2000-2002) data and post-project (2003-2004) using mobile electrofishing gear. Upper 95% confidence intervals are represented by the whisker bars.

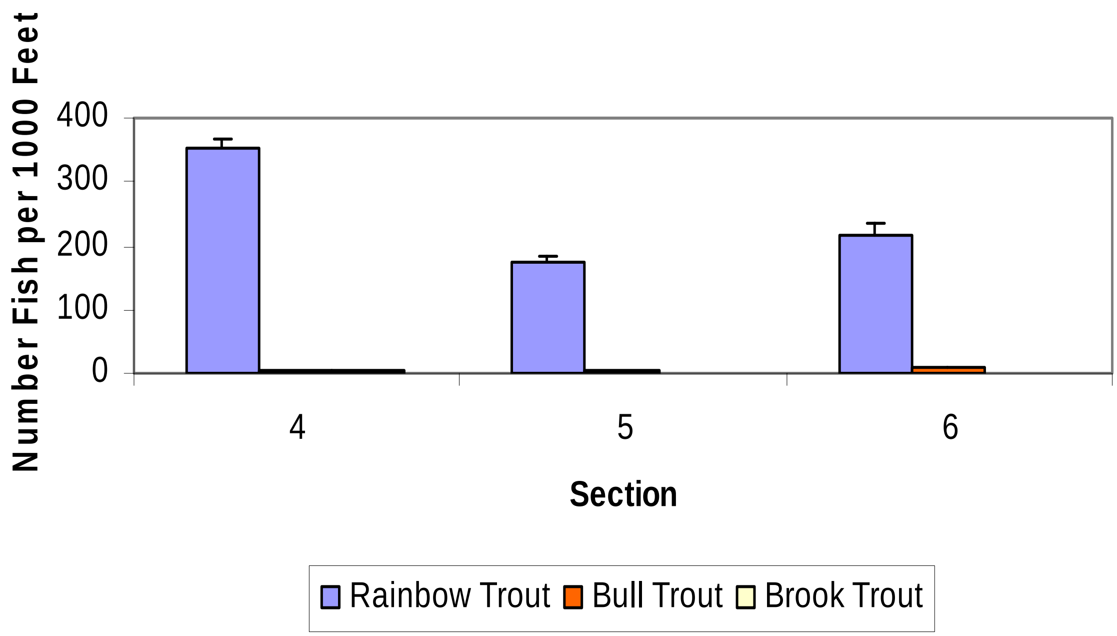

Figure 35. Rainbow, bull and brook trout densities (fish per 1000 feet) within the Libby Creek Sections 4-6 monitoring sites in 2004. These sites were first established in 2004 and were sampled using a backpack electrofisher. Upper 95% confidence intervals are represented by the whisker bars. These monitoring 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 1000 feet in 2002 to our lowest estimate of 25 fish per 1000 feet in 2004 (Figure 36; mean for all years = 44.8 fish per 1000 feet). The juvenile rainbow trout trend in abundance did not differ from a stable population ($r^2 = 0.28$; $p = 0.47$). 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 = 3.4 fish per 1000 feet). Although the overall general trend for brook trout increased through time, the trend was not significantly different from a stable population, based on the limited time interval we have sampled ($r^2 = 0.58$; $p = 0.24$).

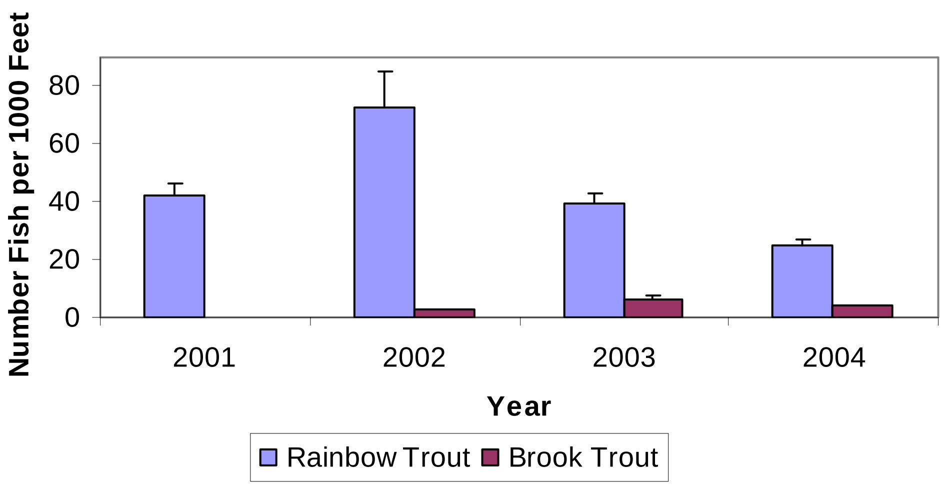

Figure 36. Rainbow trout and brook trout densities (fish per 1000 feet) within the Pipe Creek monitoring site during 2000, 2001, 2003, and 2004 collected by performing backpack electrofishing. Upper 95% confidence intervals are represented by the whisker bars. The site was not sampled in 2002.

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 1996-2004 (Figure 37). Average length of kokanee has varied among years. Average length and weight between 1988 and 2004 was 288.6 mm and 230.7 g respectively (Table 8). 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 8). This is likely attributable to density dependant growth exhibited by the species.

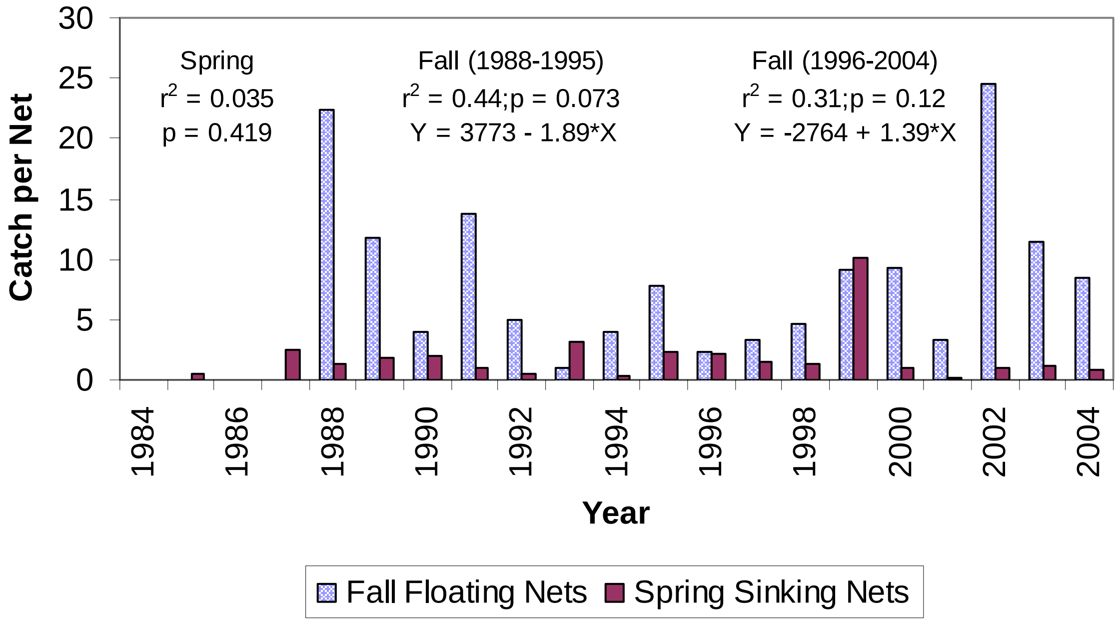

Figure 37. Average catch per net of kokanee for fall floating (1988-2004) and spring sinking (1984-2004) gill nets in Libby Reservoir.

Table 8. Average length and weight of kokanee salmon captured in fall floating gillnets (Rexford and Canada Sites) in Libby Reservoir, 1988 through 2004.

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	AVG.
Sample size (n)	2150	1259	517	624	250	111	291	380	132	88	76	200	342	120	357	263	194	432.6
Length (mm)	315.5	275	257.3	315.8	350	262.7	270.2	300.2	293.7	329.6	333.9	291.6	271.3	261.6	251.3	264.9	261.0	288.6
Weight (gm)	289.1	137.2	158.4	327.3	411.3	162.3	191.7	261.6	234.5	363.2	322.0	229.6	185.6	161.6	152.2	175.5	159.2	230.7

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; $r^2 = 0.598$, $p < 0.05$). 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 ($p = 0.0002$) equilibrium since 1989 with mountain whitefish catch rates averaging 0.79 fish per net ($r^2 = 0.07$; $p = 0.32$). Catch rates since 1988 remained low; with mountain whitefish comprising an average of 1.0% of the spring catch during 1988 through 2004. We attribute the initial (1975-1988) mountain whitefish decline in Koocanusa Reservoir to the loss of spawning habitat and rearing habitat that resulted from a conversion of lotic to lentic habitat 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 2004, where the average catch per net during this period (mean fish per net = 0.343) was not significantly different than a stable population (zero slope; Figure 38). Gill net catch of cutthroat trout in Libby Reservoir exhibit a similar pattern, with the exception that that cutthroat trout catch rates exhibit 3 general trends through the same period. The first is a significant and precipitous decline during the early years of impoundment from 1975 to 1986 (Figure 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 2004, characterized by a significantly lower level of abundance (0.130 fish per net; $p < 0.001$), at a somewhat stable level ($r^2 = 0.001$; $p = 0.917$). We believe that the period of general equilibrium during the period 1987-1993 may have been artificially elevated by the presence of hatchery cutthroat trout that were extensively stocked in the reservoir during this period (Table 9). Hatchery cutthroat trout were last stocked in the reservoir in 1994.

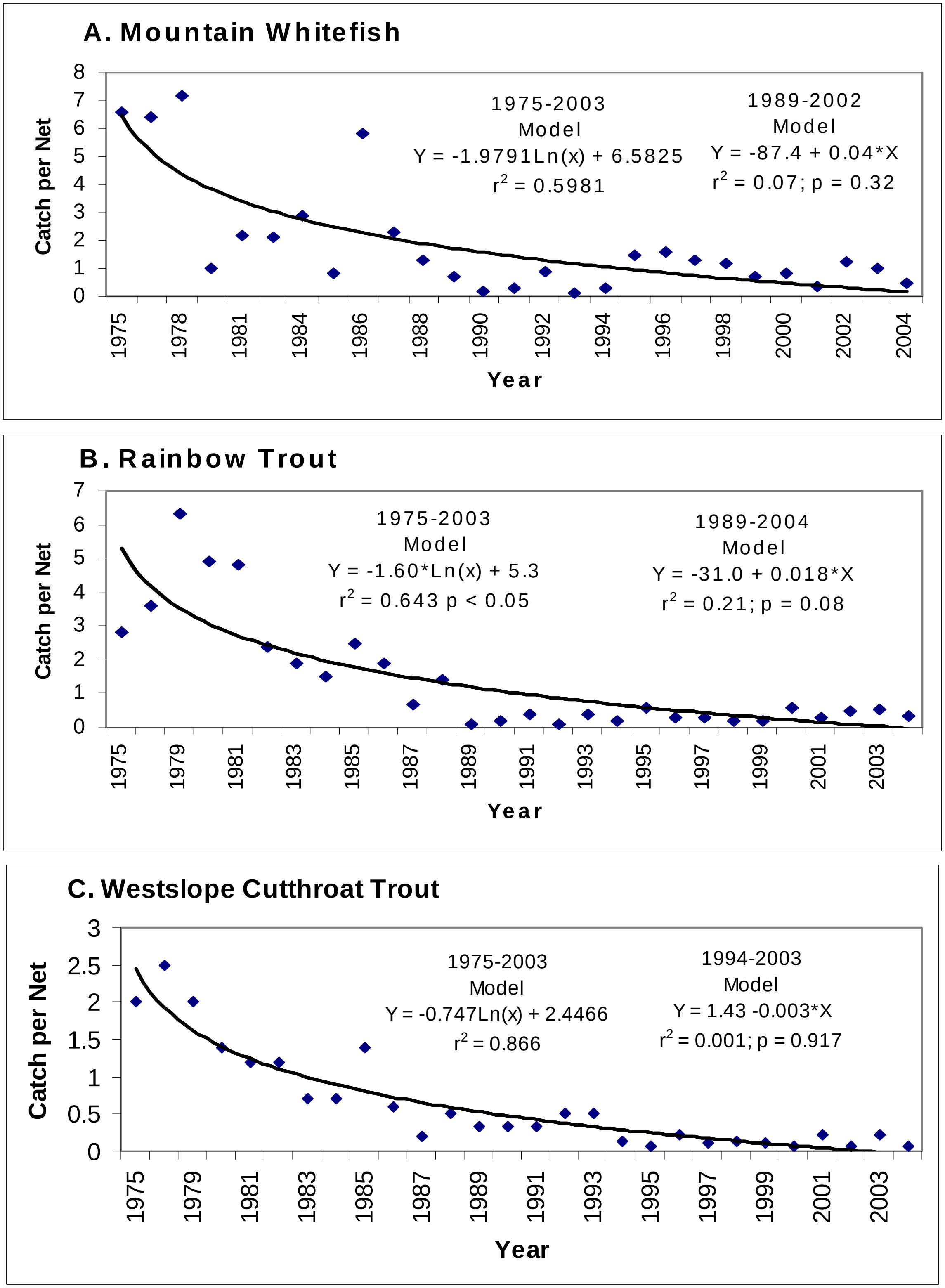

Figure 38. Mean catch rates (fish per net) of three native species (mountain whitefish (a) in spring sinking gillnets in the Rexford area, rainbow (b) and westslope cutthroat trout (c) in floating gillnets from Tenmile and Rexford areas in Libby Reservoir, 1975 through 2004. The Tenmile area was not sampled during the fall from 2001-2004.

Table 9. 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 2004. The Tenmile location was not sampled in 2000-2004.

	1988	1989	1990	1991	1992	1993	1994	1995	1996
No. Catch	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
No. Catch	0.11	0.14	0.11	0.07	0.21	0.07	0.21	0.07
Avg. Length (mm)	225	267	305	302	259	305	270	196
Avg. Weight (gm)	128	228	296	271	175	256	206	76
No. Stocked	none	none	none	none	none	none	none	none
Length (mm)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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 10). 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 ($p = 0.004$; $r^2 = 0.46$; Table 10) for 1989 through 2004. However, the catch rate of Kamloops rainbow trout in fall floating gillnets shows no significant trend (Figure 39; $r^2 = 0.13$; $p = 0.16$). Catch rates for Kamloops rainbow trout in fall gillnets has been low since 1996, averaging only 0.06 fish per gillnet.

Table 10. 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							
No. Caught	0							
Avg. Length (mm)	N/A							
Avg. Weight (gm)	N/A							
No. Stocked	63,099							
Length (mm)	76 - 178							

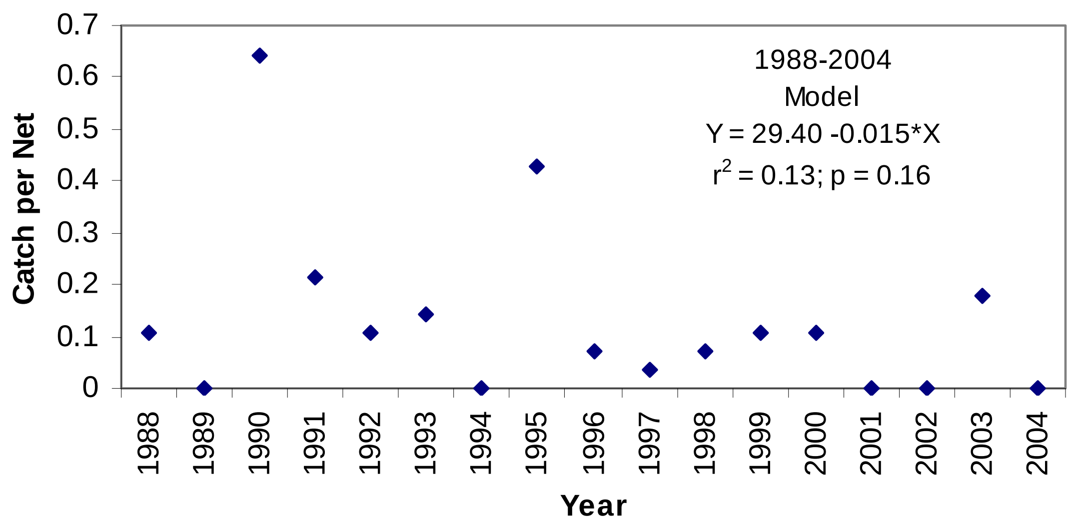

Figure 39. Average catch (fish per net) of Kamloops rainbow trout (Duncan strain) in fall floating gill nets in Libby Reservoir at the Rexford and Tenmile sites 1988-2004. The Tenmile site was not sampled in 2001-2004.

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 2004 (Figure 40; $r^2 = 0.808$; $p = 5.14*10^{-6}$). 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 2004 data (Figure 41; $r^2 = 0.806$; $p = 5.51*10^{-6}$). 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 adjusted for reservoir elevation (Figure 42; $r^2 = 0.738$; $p = 0.0007$).

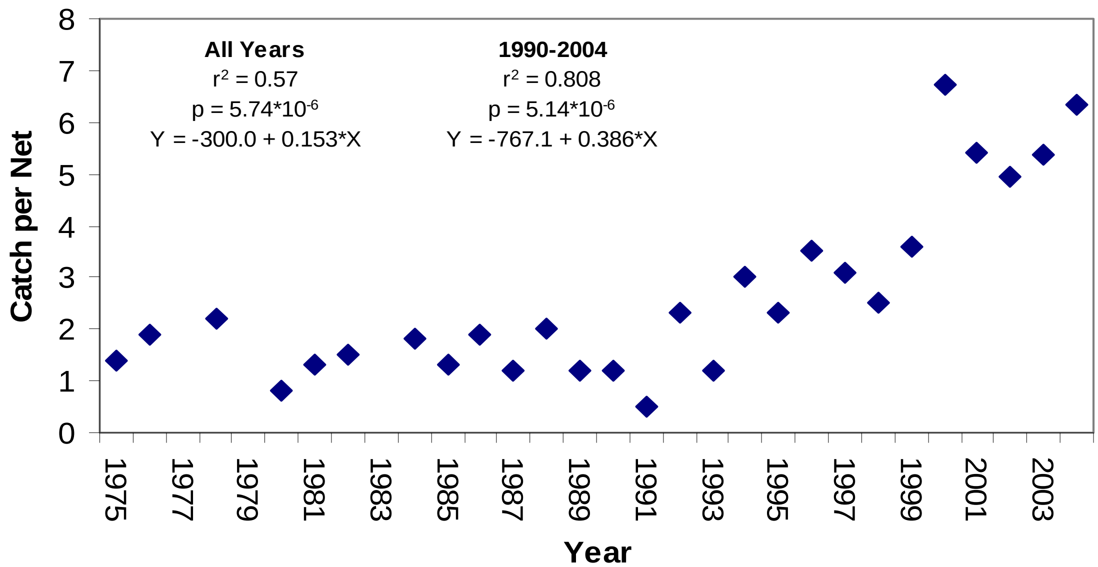

Figure 40. Average catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir 1975-2004.

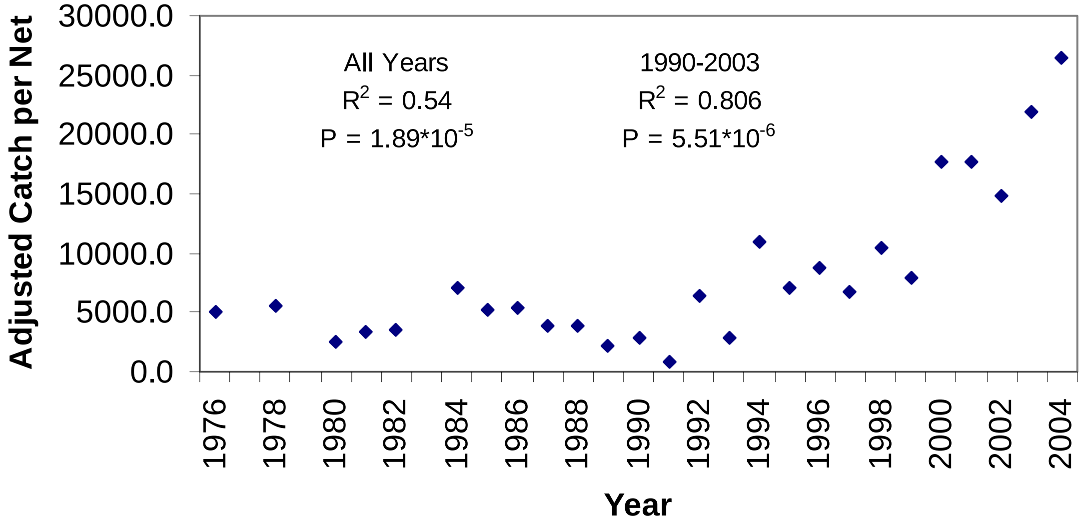

Figure 41. Average adjusted catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir. Average annual bull trout catch per net was adjusted by multiplying catch by reservoir volume at the time of gillnetting.

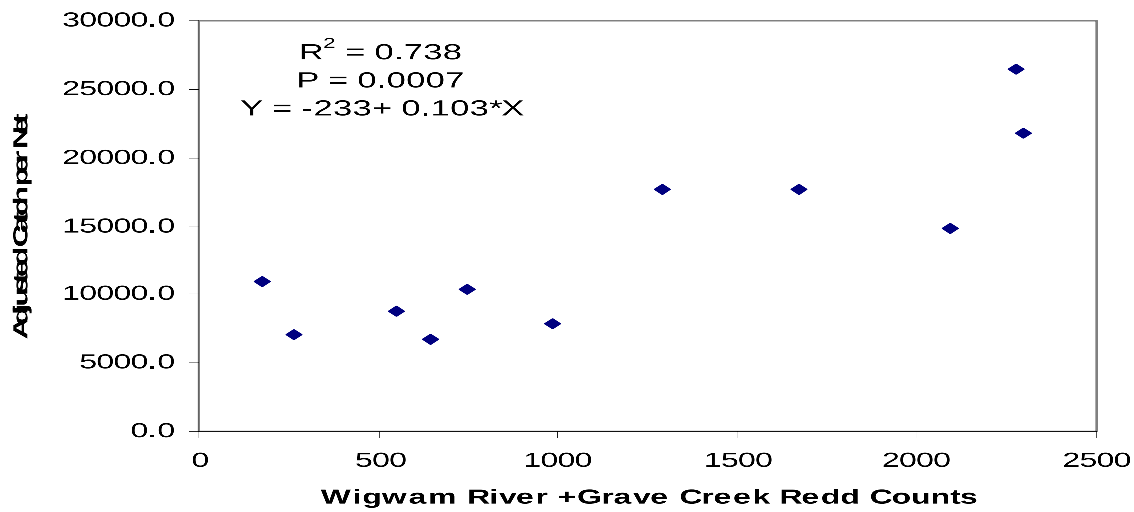

Figure 42. Average adjusted catch per net of bull trout in spring gill nets at the Rexford site on Libby Reservoir related to total annual bull trout redd counts for the Wigwam River and Grave Creek during the period 1994-2004. Average annual bull trout catch per net was adjusted by multiplying catch by reservoir volume at the time of gillnetting.

Burbot

Burbot catch rates in spring sinking gillnets since 1990 show no clear trend in abundance (Figure 43; r^2 = 0.14; p = 0.16). Burbot catch per net for spring sinking nets has averaged 0.29 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 = 0.47; P = 0.04; 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.

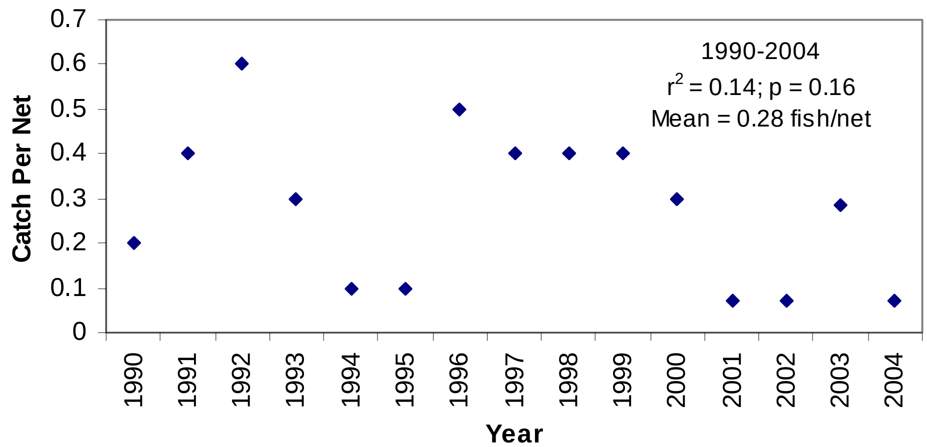

Figure 43. Mean catch per net of burbot in sinking gillnets during spring gillnetting at the Rexford site on Libby Reservoir, 1990-2004. The mean catch per net during the period was 0.28 fish per net.

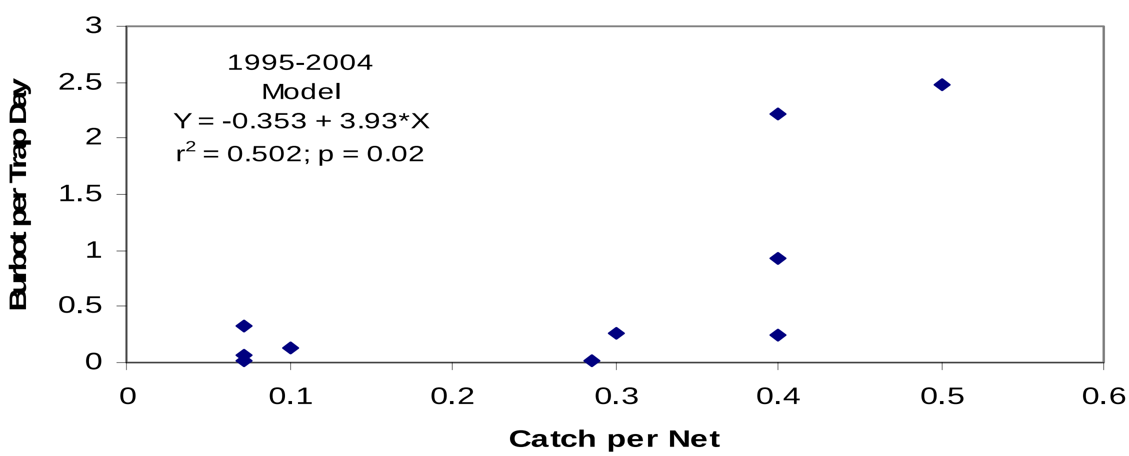

Figure 44. The relationship between mean burbot catch per net for spring sinking gillnets on Libby Reservoir and burbot catch rates (fish/trap day) of baited hoop traps in the stilling basin below Libby Dam 1995-2004.

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; $r^2 = 0.096$; $p = 0.135$; Table 11), 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; $r^2 = 0.002$; $p = 0.83$; Table 12). Species composition for the catch of fall and spring gillnets has remained relatively stable since 1988 (Table 13).

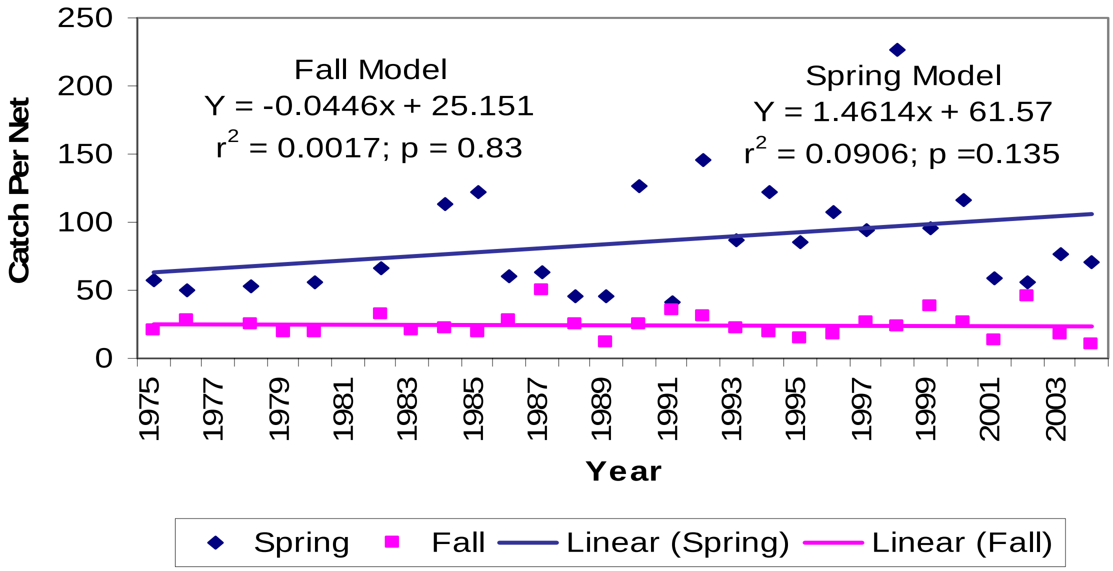

Figure 45. Catch per net (all species combined) in fall floating and spring sinking gillnets and associated trend lines in Libby Reservoir, 1975 through 2004.

Table 11. 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 2004.

	YEAR														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Surface Temperature	16	15	13.8	13.8	16.6	15.8	15.5	17.2				19			
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
Number of Floating Nets	54	28	28	28	28	28	28	28	28	28	28	14	14	14	14
Reservoir Elevation	2456	2448	2421	2441	2446	2454	2450	2448	2439	2453	2434	2433	2441	2435	2445
	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
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
RB X WCT∠	0.3	0.2	0.2	0	0	0	0	0	<0.1	0	0	0	0	<0.1	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
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
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
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
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
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
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
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
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

*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 12. 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 2004.

	YEAR														
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Surface Temperature	11.7	9.8	16.7	14.4	13.3	13.5	8.9								
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
Number of Sinking Nets	27	28	28	28	28	28	28	28	27	28	14	14	14	14	14
Reservoir Elevation	2358	2330	2333	2352	2405	2386	2365	2350	2417	2352	2371	2392	2384	2417	2419
	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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

*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 13. Percent composition of major fish species* caught in fall floating and spring sinking gillnets in Libby Reservoir, 1988 through 2003. Blank entries in table indicate either no fish were captured or that they occurred in very small proportions.

	1988		1989		1990		1991		1992		1993		1994		1995		1996	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RB	3.0		0.1		0.7		1.0		0.3		1.8		0.9		4.4		1.4	
WCT	0.5		0.3		0.7		1.0		1.7		3.8		0.7		0.8		1.2	
HB	1.0		0.3		1.1		0.5		0.7		0.2		0.0		0.3		0.2	
ONC	4.5	0.7	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
MWF	0.5	1.6	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
CRC	39.4	63.8	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
NPM	2.9	7.7	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
RSS	0.8	0.2	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
FSU	0.0	2.3	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
CSU	0.0	12.7	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
KOK	47.3	1.7	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
YP		5.5		9.4		3.7		5.2		1.2		1.1		0.9		2.9		3.4
BT		2.4		1.4		1.0		1.1		1.7		1.1		2.5		2.8		3.3

	1997		1998		1999		2000		2001		2002		2003		2004		Average	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RB	1.7	0.2	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	0.3
WCT	0.6	0.4	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	0.9	0.1
HB	0	0	2.3	0	0	0	0	0	0	0	0	0	0.4	0.0	0.0	0.0	0.4	0.0
ONC	2.3	0	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	2.4	0.4
MWF	2.4	1.9	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	1.1	1.0
CRC	56.0	33.8	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	46.7	50.3
NPM	18.0	20.0	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	11.7	9.7
RSS	3.5	0.2	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	0.7	0.2
FSU	0	7.2	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	3.7
CSU	3.38	20.8	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	1.4	11.8
KOK	14.4	2.2	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	22.5	1.7
YP	0	7.4	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	0.1	3.1
BT	0.1	5.1	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	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). Since 1997, *Cyclops* and *Daphnia* have been the first and second most abundant genera of zooplankton present in the reservoir (Figure 46). Other lesser abundant genera in decreasing order of abundance include *Diaptomus, Bosmina, Diaphanosoma, Epichura and Leptodora* (Figure 46). Zooplankton abundance within the reservoir varies by season (Table 14; 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 2004 for the most abundant 7 species of zooplankton (Table 14). 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 8 years, *Diaptomus* has peaked during October during 5 of the last 8 years, and Cyclops has peaked in June during 4 of the last 8 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 2004 (Table 14). For the 7 most abundant species of zooplankton in the reservoir at the three sites, we only found significant differences (by species) for 7 out of the possible 21 comparisons. In each of these seven instances when significant differences occurred between sampling locations, it was usually the Canada strata that had a lower abundance when compared to the two lower strata. For example, subsequent multiple comparisons indicated that *Daphnia Bosmina*, and *Cyclops* densities were significantly higher at the Rexford and Tenmile starta than the Canada stratum This only exception to this trend was in the case of Leptodora, where the Canada stratum had a significantly higher abundance than the Tenmile stratum. The month and area interaction term was significant for *Bosmina*, *Diaptomas*, *Cyclops*, and *Epischura* in 2004 (Table 14).

The trends in Daphnia abundance (Figure 45) and size (Figures 48 and 49) in Koocanusa 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 = 0.053; Figure 48), with the majority of the remainder in the size class 1.0 – 1.499 (mean annual proportion = 0.335, and standard deviation = 0.035). *Daphnia* larger than 1.5 mm have on average comprised less than 5% of the total since 1993 (Figure 48).

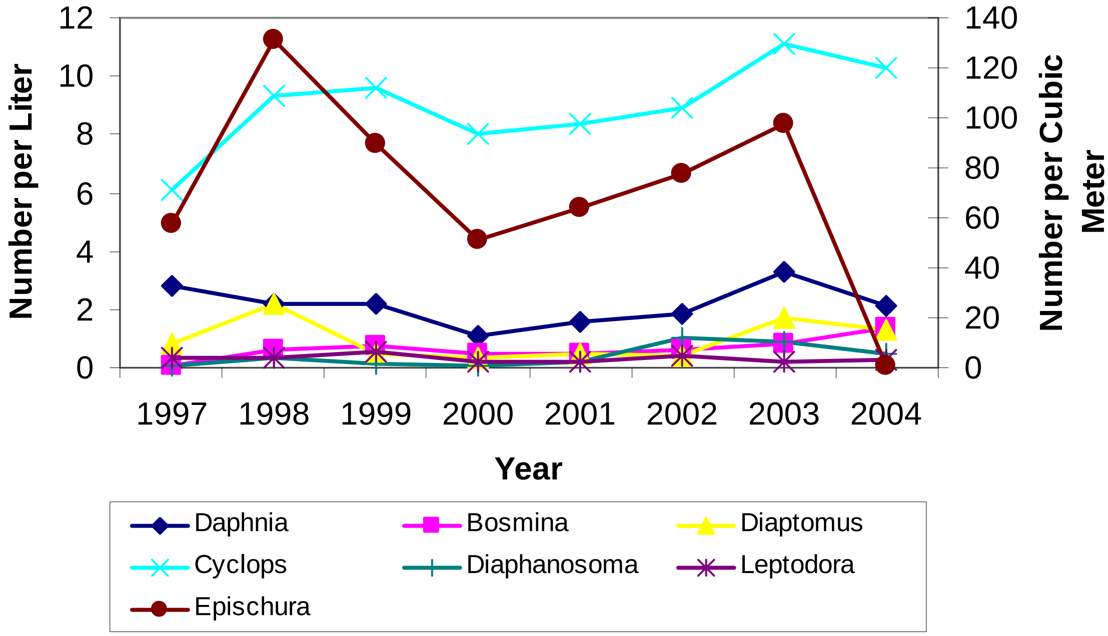

Figure 46. Annual zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2004. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter. The data utilized for this figure are presented in Appendix Table A9.

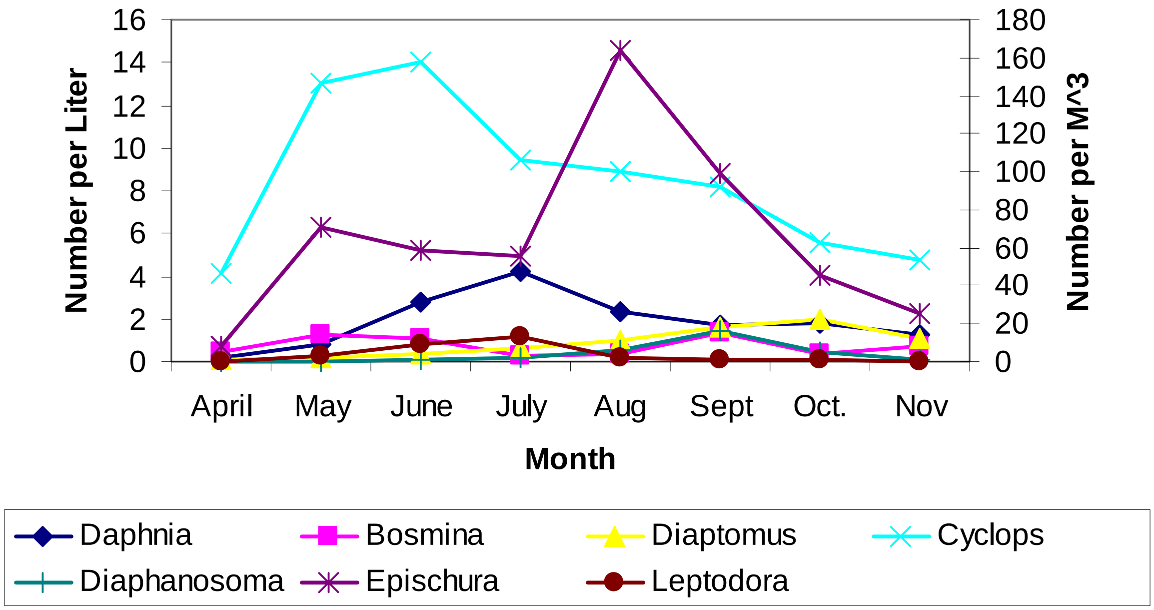

Figure 47. Mean monthly zooplankton abundance estimates for seven genera observed in Libby Reservoir from 1997-2004. Abundance for *Epischura* and *Leptodora* are expressed in number per cubic meter. All other densities are expressed as number per liter.

Table 14. 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 2004.			
Genus	**Month**	**Area**	**Month X Area Interaction**
Daphnia	5.32*10-5	0.002	0.053
Bosmina	7.73*10-10	0.011	0.011
Diaptomas	5.07*10-6	0.167	0.002
Cyclops	2.44*10-5	0.025	0.030
Leptodora	1.19*10-6	0.096	0.284
Epischura	3.16*10-7	0.883	0.0003
Diaphanosoma	0.002	0.541	0.755

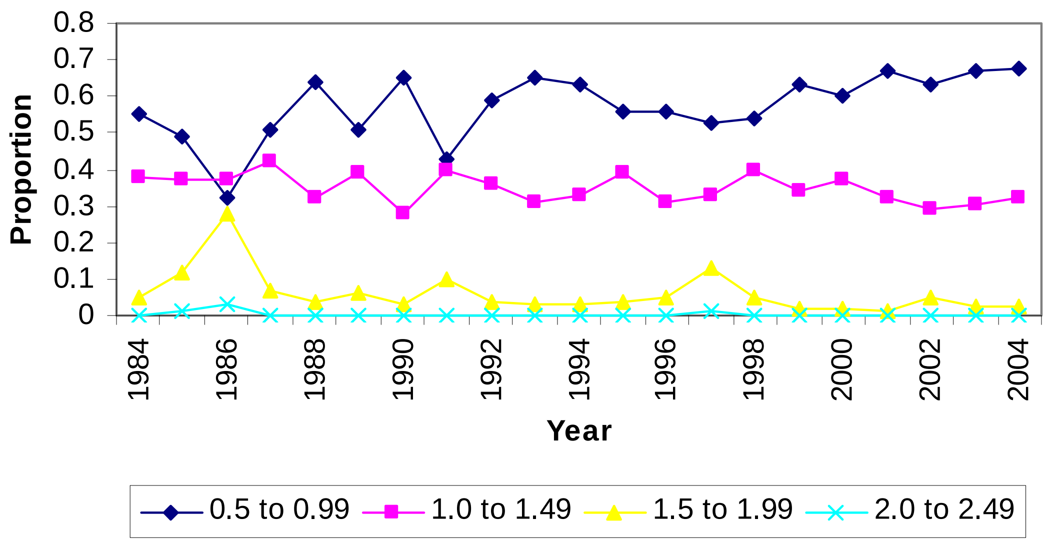

Figure 48. *Daphnia* species size composition in Libby Reservoir, 1984 through 2004.

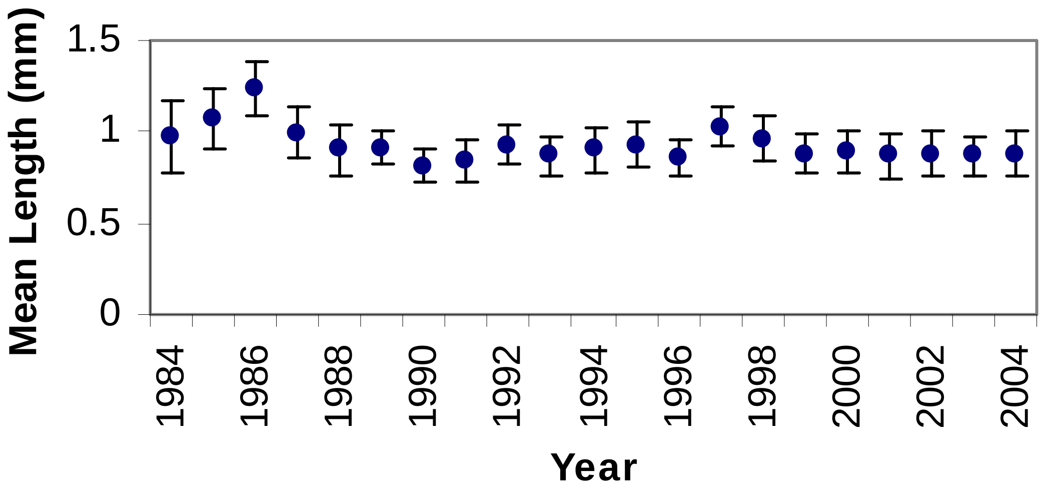

Figure 49. Mean length of *Daphnia* species in Libby Reservoir, 1984 through 2004, with whisker bars representing plus and minus one standard deviation from the mean.

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 that we monitor below Libby Dam have not increased in proportion to the increases we have observed in redd counts in bull trout spawning tributaries located upstream of Libby Dam over the past 10 years. We are however, confident that we have identified the important core spawning tributaries below Libby Dam within the Montana portion of the basin. Yet, our estimates of adult bull trout abundance throughout 2004 ranged from 906 to 1,068, which is widely disparate between the numbers of redds we counted in the bull trout spawning tributaries below Libby Dam. This observation is consistent with a previously stated hypothesis (Dunnigan et al. 2004) that bull trout abundance below Libby Dam is strongly correlated to entrainment through Libby Dam. Research to resolve this issue will remain a priority for the Libby Mitigation Project.

MFWP opened a recreational fishery on bull trout in Koocanusa 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 USFWS. The fishery allowed limited harvest of bull trout within the United States portion of Koocanusa Reservoir from June 1, 2004 to February 28, 2005. 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 analysis is still in progress, but MFWP staff at the Libby Area Office anticipates that the final harvest estimate of bull trout will range between 300-500 bull trout. Based on the spring gillnetting information for 2005 (see above), we did not detect a reduction in bull trout abundance within Koocanusa Reservoir attributable to the fishery. It is not clear whether or not we were able to detect any substantial reduction in the number of bull trout redds within the tributaries upstream of Libby Dam. Bull trout redd counts in both the Wigwam River and Skookumchuck Creek increased from 2003 to 2004, and exhibit a significant positive trend through time (see above). However, bull trout redds decreased in Grave Creek and the White River. The decrease was sharpest for Grave Creek, where we observed a 48% reduction in the number of redds from the previous year. However, the total number of redds observed in 2004 (141 redds) was within the range of variability observed during the past several years. However, the decrease in redd counts in Grave Creek may be attributable to harvest that occurred near the Tobacco River confluence during the period when bull trout destined for Grave Creek congregated prior to spawning. We will continue to monitor the bull trout fishery in Koocanusa Reservoir to evaluate the potential impact on the Grave Creek bull trout population.

Catch rates of burbot in our baited hoopnets in the Kootenai River directly below Libby Dam have precipitously and significantly decreased in recent years, with the a mean seasonal catch for the last three years of 0.014 fish per trap day. In comparison, our catch rates for our first and second year of burbot monitoring using similar gear and techniques in Libby Reservoir during the same period was approximately 5 times higher. Catch rates from the 2003/2004 and 2004/2005 burbot trapping season in Libby Reservoir were similar between years and between sites within the reservoir. However, the interval between setting the trap and pulling the trap (set duration) differed between seasons in our study, and was significantly longer for the

2004/2005 season than the prior season (mean set durations 6.3 and 4.8 days respectively; $p < 0.05$). Bernard et al. (1991) concluded that baited hoop traps fished in Alaskan lakes baited with chopped herring lost their efficacy after two days, but that in rivers, moving the traps daily was more effective than rebaiting them. Therefore, if future burbot trapping in Libby Reservoir continues, it may be worthwhile to decrease the set duration to maximize catch, or directly investigate the optimal set durations in Libby Reservoir using chopped kokanee for bait.

On average, we captured significantly longer and heavier burbot during the 2004/2005 season than the 2003/2004 season. Although, the burbot we captured during both seasons had similar condition factors. We also saw a difference in the minimum size of burbot that we captured in the hoop traps between years. During the 2003/2004 trapping season the minimum size of burbot that began to recruit to the baited hoop traps was 350 mm, which was 103 mm smaller than the minimum size burbot we caught in 2004/2005. Nevertheless, our burbot trapping data from both seasons suggest that burbot in Libby Reservoir do not fully recruit to the baited hoop traps until the fish are approximately 600 mm total length. MFWP conducted an age and growth study on burbot from Libby Reservoir from fish collected in the early 1980s and early 1990s (unpublished data), and assuming that burbot growth rates were comparable between those periods and recent samples, burbot are not fully recruiting to our hoop traps until they are approximately 7-9 years old. However, the burbot we captured during the 2003/2004 trapping season may have begun recruiting to the hoop traps at ages 4-6, and the burbot captured during the 2004/2005 trapping season may not have begun recruiting until ages 5-7.

The concept of home range as it applies to ecology, has its beginnings rooted in mammalian and avian studies. Gerky (1953) was one of the first investigators to apply the concept of home range to fish ecology. Gerky defined home range as “the area over which an animal normally travels”. Since Gerky’s early investigations many authors have employed the concept of home range to describe the movement and distribution of fish in both lentic and lotic environments. Minns (1995) performed a literature review and found forty-six home range estimates for fish from 21 lakes and 25 rivers. These individual studies provided estimates of home ranges for 24 different species of fish including several warm water species and trout, but estimates for burbot were not included. Minns (1995) found that fish body size was related to home range and that home ranges in lakes were larger then those in rivers. Our estimates of burbot home range in Koocanusa Reservoir were several orders of magnitude larger than the home range estimates that Minns (1995) reported from his literature search that included 11 fish species in lentic environments, all of which were less than 1 km^2. Of the 21 published estimates of home range from lake environments, American eels (LaBar and Facey 1983) had the largest home range (0.28 km^2), followed by white crappie (0.16 km^2; Guy et al. 1994), and largemouth bass (0.13 km^2; Colle et al. 1989). Each of these estimates were derived using the minimum convex polygon method of estimating home range.

Few studies have investigated burbot home range or movement patterns. In the lower Kootenai River, Paragamian and Hoyle (2003) used sonic and radio telemetry to track burbot movements during the winter of 2002/2003. Due to low population numbers, this study had difficulty marking enough fish to infer movement patterns. However, fish were generally sedentary, but moved up to 50 km during the spawning period, but distance moved during the spawning period was generally 10-15 km. Hudd and Lehtonen (1987) found that burbot off the coast of Finland homed after displacement and occasionally migrated further than 20 km. Breeser et al. (1988) studied burbot in an Alaskan glacial river and found that burbot moved during all seasons, but that movements were longest during the spawning season. The maximum distance Bresser et al. (1988) observed burbot moving was 125 km. They also noted that while most fish tended to move frequently, some tagged fish remained sedentary for long periods (>10 weeks) and then moved. Most of the tagged fish in this study returned to the general vicinity of the original capture and release site by March or April. The maximum total distance we observed any single fish moving in Koocanusa Reservoir was approximately half this distance (64.3 km). Several other authors have noted rather sedentary burbot behavior during parts of the year. Bergersen et al. (1993) observed little movement of tagged burbot in a Wyoming reservoir during winter and early spring. We found little evidence to suggest that burbot in Libby Reservoir moved long distances to spawn, and that home range sizes were similar between seasons. However, we acknowledge that our ability to detect a difference in the home range size between seasons was low. Carl (1995) monitored the diel movement of burbot in a lake in Ontario to determine habitat use and patterns of activity. Burbot were active mostly during nighttime hours. Burbot in this study were less active and occupied deeper water during the summertime compared to the spring. Carl (1995) concluded that burbot in his study used an area-restricted search pattern, in which individual burbot exhibited fidelity to activity sites from year to year, presumably due to previous foraging success. Libby Reservoir burbot exhibited strong fidelity to a particular side of the reservoir during the duration of our tracking. This may suggest that mixing of adult burbot may be limited to populations on the right and left reservoir banks. We were also able to determine that many of the tagged burbot extensively utilized the old Kootenai River channel and floodplain during daylight hours, which often represented the maximum depth available within the reservoir for that given time of year. This observation was consistent with Carl (1995) who reported that burbot selected deep cool water habitat for daytime resting.

Our results indicate that biological 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 Fish and Wildlife Program (MFWP,CSKT and KTOI 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. In 2003, MFWP implemented several projects to mitigate for a portion of the losses attributable to the construction and operation of Libby Dam. We identified Libby, Grave and Young creeks as high priority streams for restoration activities based on habitat quality, fish community composition, and native fish abundance. The monitoring program for each of these projects includes pre- and post-construction monitoring that allows comparisons to describe changes in the physical environment and biological responses resulting from these restoration actions. We adopted a phased approach for restoring Libby and Grave creeks. MFWP partnered with the Kootenai River Network during the fall of 2002 to restore 4,300 feet of lower Grave Creek, within a section named the Grave Creek Phase I Restoration Project. This project represents a phased approach by the cooperators to restore the lower 3 miles of Grave Creek. The Grave Creek Phase I Restoration Project 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 Monitoring summarized in this report was designed to determine if these parameters changed recently. We found no evidence that the stream channel dimensions changed significantly at any of our survey locations. However, pool width, depth and length did decrease within the project area from 2003 to 2004, but these changes were generally small and averaged between 10-15%. We also continued monitoring the first Libby Creek Demonstration Project MFWP completed on Libby Creek during fall 2001. The stream channel dimensions and quality and quantity of pool habitat within the project area did not change substantially since construction, although erosion rates substantially decreased within the project area. However, channel erosion rates and channel instability above and below the project area remain high. MFWP completed the Young Creek State Lands Restoration Project during fall 2003, which changed the stream channel dimensions within this area. The monitoring results presented in this document evaluate whether these physical changes were maintained after the first spring freshet. Stream channel dimensions within the riffles of this section of Young Creek changed only slightly, with an overall decrease in cross sectional area and bankfull width, and an increase in overall bankfull depth. Pool volume and area within the project reach remained essentially unchanged between years.

Introduction

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

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

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

Large daily fluctuations in river discharge and stage (4-6 feet per day) strand large numbers of sessile aquatic insects in the varial zone (Hauer and Stanford 1996). 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 1996). 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 (1996) 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; Marotz 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, CSKT and KTOI 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, CSKT and KTOI 1998) and the Kootenai Subbasin Plan (KTOI and MFWP 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. 2004). 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. (2004). 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. 2004). We continued to monitor the physical stream dimensions, pattern and profile during 2004 to determine if the newly constructed 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 for 2002, 2003, and 2004. Although we did not present any of those photographs within this document, they have been digitally archived within our project files. In 2004, we re-surveyed the same six permanent cross-sections that were originally surveyed in 1999 (pre project), 2002 (post-construction) and 2003 (after the first spring freshet), to determine if the channel had changed between 2003 and 2004. 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 a paired t-test between years. We found no evidence that the stream channel dimensions changed between 2003 and 2004 at the six permanently located transects (Table 1). Although, the variance of our estimates of mean bankfull width, depth, width to depth ratio, cross sectional area, and maximum bankfull depth all lowered substantially from 2003 to 2004.

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. 2003 and 2004). 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 mean width, length and maximum bankfull depth of the 27 pools constructed in the project area in 2003 and 2004. 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. Total pool area had the highest relative change between years (23.2%; Table 2). Both total length and mean pool length decreased by 11.8% from 2003 to 2004 (Table 2). Although we did not measure mean bankfull depth of the 27 pools, it is likely that it also decreased between years, and therefore, total pool volume within the restoration area likely also decreased from 2003 to 2004.

In addition to a complete census of all pools within the project area, we also surveyed seven riffles within the project area to evaluate changes in riffle slope through time. In 2003 we measured the stream channel dimensions at the each riffle between the seven meanders sections throughout the project area. We established the cross section at the longitudinal mid-point of each riffle. We repeated these cross sectional surveys after the spring freshet in 2004. Our cross-sectional surveys indicated that our riffles responded differently than the pools within the project. Mean bankfull width increased by 6.5% from 49.4 feet in 2003 to 51.7 feet in 2004 (Table 3). Maximum and mean bankfull depths within the riffles also increased from 2003 to 2004 by 3.0 and 4.6%, respectively. However none of these differences were statistically significant (Table 3). Our survey results also suggest that mean riffle slope decreased from 1.06% in 2003 to 0.86% in 2004 which represented an 18.3% decrease, although this decrease was no significant. This trend was similar to the one we observed for the previous year within the project site (see Dunnigan et al. 2004).

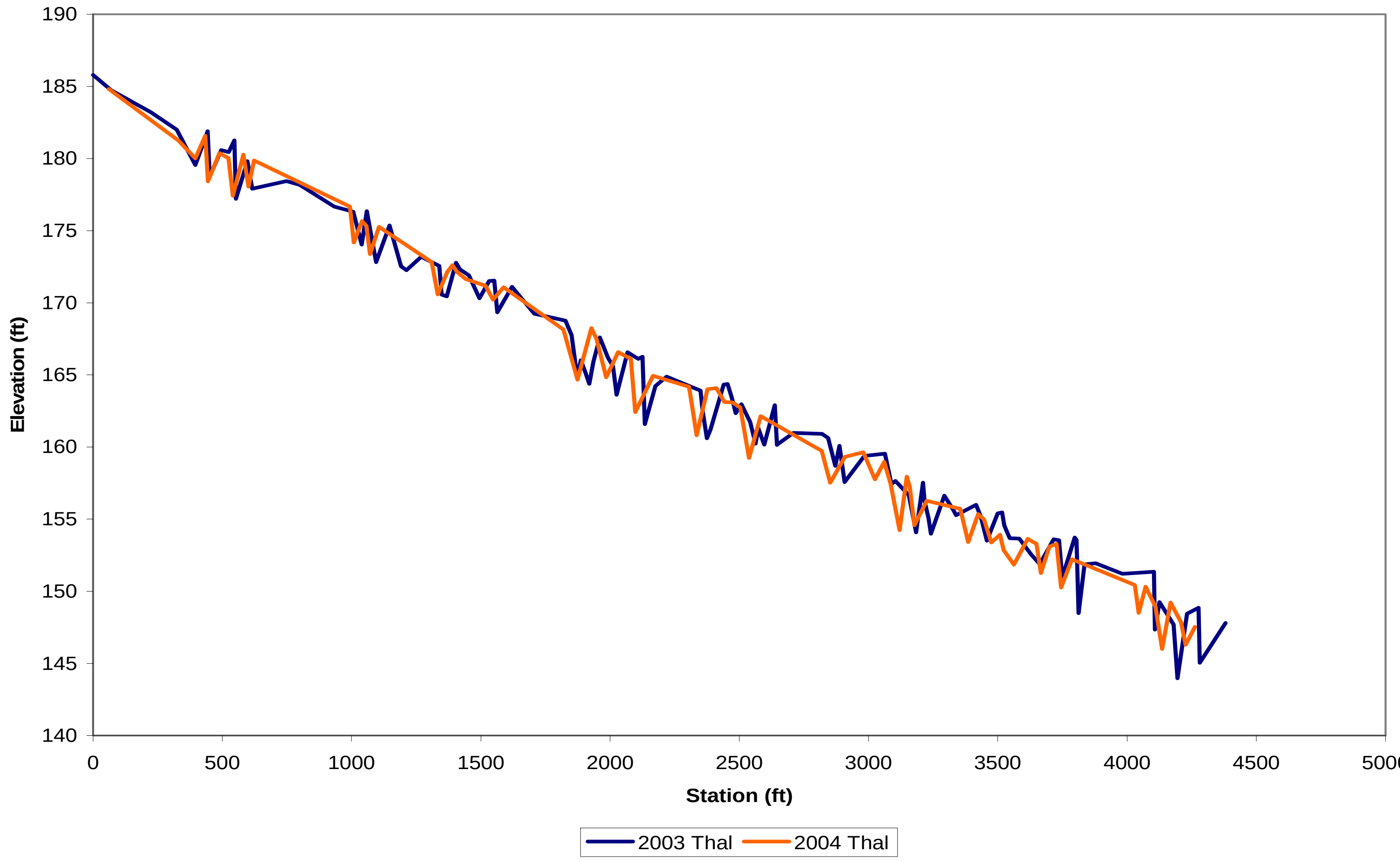


Figure 1. The longitudinal profile for the Grave Creek Phase I Restoration Project. The survey was completed in 2003 and 2004. The station (longitudinal location measured at the channel thalweg) begins at the upstream boundary of the project.

Table 1. Mean bankfull width, depth, width to depth ratio, cross sectional area, and maximum depth for 6 permanent cross sectional surveys in 2003 and 2004. Variance estimates for annual mean values are presented in parentheses. A paired t-test was preformed for each parameter, and the P value for a two sided test is presented.

	Mean Bankfull Width (ft)	**Mean Bankfull Depth (ft)**	**Width to Depth Ratio**	**Cross Sectional Area (Square ft.)**	**Maximum Bankfull Depth (ft)**
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 (5.44)	128.2 (219.0)	4.58 (1.0)
Percent Change	4.1%	3.0%	0.9%	2.6%	3.2%
Paired t-Test Results (P-value)	0.128	0.447	0.897	0.401	0.660

Table 2. Mean bankfull width, maximum bankfull depth, and length measured from 27 pools in 2003 and 2004. Variance estimates for annual mean values are presented in parentheses. A statistical comparison of annual mean values was not performed because the 27 pools represented all pools within the project area, and therefore represents a complete census. The percent change for each parameter from 2003 to 2004 is also presented.

	Mean Bankfull Width (ft)	**Maximum Bankfull Depth (ft)**	**Mean Length (ft.)**	**Total Length (ft.)**	**Total Area (ft^2)**
2003	54.0 (46.4)	5.6 (1.9)	74.8 (842.3)	1944	4,039.9 (3067888)
2004	49.5 (63.6)	4.9 (1.0)	66.9 (341.6)	1739	3,278.4 (9718666)
Percent Change	-9.2%	-14.3%	-11.8%	-11.8%	-23.2%

Table 3. Mean bankfull width, maximum bankfull depth, and length measured from the 7 riffles located between each stream channel meander in the Grave Creek Phase I Restoration Project in 2003 and 2004. Variance estimates for annual mean values are presented in parentheses. A paired t-test was preformed for each parameter, and the P value for a two sided test is presented.

	Mean Bankfull Width (ft)	Maximum Bankfull Depth (ft)	Mean Bankfull Depth (ft.)	Cross Sectional Area (sq. ft.)	Width to Depth Ratio	Riffle Slope (%)
2003	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	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)
Percent Change	6.5%	3.0%	4.6%	8.2%	0.7%	-18.3%
P-value	0.547	0.286	0.366	0.176	0.942	0.406

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 region. We selected this project because Young Creek one of the most potentially productive tributaries to Libby Reservoir. Although bull trout do not routinely spawn in Young Creek, juvenile bull trout commonly enter Young Creek from the reservoir and rear for extended periods. This stream also provides water for agriculture, and other riparian-dependent resources. 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. The degraded condition of this section of Young Creek has contributed to the stream's inability to adequately transport stream flow and bedload supply and still maintain a stable channel. 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 intent of the project is 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 natural stream system; and 4) improve fish habitat, particularly for westslope cutthroat trout, and improve the function and aesthetics of the stream and adjacent riparian ecosystem.

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. 2004). 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 in 2004 were a 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 2003 and 2004 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) project construction (Table 4). We established the transect location at each riffle at the longitudinal mid-point of each riffle. Mean cross sectional area, width to depth ratio, mean bankfull width, and maximum bankfull depth all decreased from 2003 to 2004, listed in descending order (Table 4). Cross sectional area within the riffles showed the sharpest relative annual decrease from 2003 to 2003 (-14.9%; Table 4). Mean bankfull width in the riffles within this section of Young Creek increased slightly (3.5%) from 1.24 ft. in 2003 to 1.28 in 2004. 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 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. 2004). 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 2004. 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, 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 2003 and 2004. Cross sectional area, mean bankfull width, and width to depth ratio all decreased, in descending order from 2003 to 2004, with decreases generally less than 15% (Table 5). Maximum bankfull depth and total length of pools within this reach increased by 12.1 and 15.2%, respectively (Table 5). The overall annual change in pool surface area and volume was less than a net increase of 1% from 2003 to 2004. 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 (Figure 2). Total stream length within this section of Young Creek was similar from 2003 to 2004 (Figure 2). Overall stream gradient was also similar between years, increasing slightly from 1.08% in 2003 to 1.15% in 2004.

Table 4. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for 4 riffles in the existing stream channel and 10 and 11 riffles in the stream channel in 2003 (as built), and 2004, respectively for the Young Creek State Lands Stream Restoration Project. Variance estimates for annual mean values are presented in parentheses. The percent change for each parameter between 2003 and 2004 is also presented.

Riffle Cross Sections	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Width to Depth Ratio**
2002 (Existing)	16.75 (1.58)	27.88 (22.73)	0.60 (0.008)	1.05 (0.017)	48.3 (239.6)
2003 (As Built)	21.99 (10.07)	16.3 (9.18)	1.24 (0.05)	1.99 (0.09)	13.7 (21.2)
2004	18.71 (6.25)	14.83 (3.63)	1.28 (0.07)	1.85 (0.13)	12.29 (17.30)
Percent Change 2003/2004	-14.9%	-9.0%	3.5%	-6.6%	-10.3%

Table 5. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio and total length measured for 2 pools in the existing stream channel and 8 and 14 pools in 2003 (as built) and 2004, respectively for the Young Creek State Lands Stream Restoration Project. Variance estimates for annual mean values are presented in parentheses. The percent change between 2003 and 2004 for each parameter between treatments is also presented.

Pool Cross Sections	**Cross Sectional Area (ft^2)**	**Mean Bankfull Width (ft)**	**Mean Bankfull Depth (ft)**	**Maximum Bankfull Depth (ft)**	**Width to Depth Ratio**	**Total Length (ft)**
2002 (Existing)	19.25 (3.13)	23.5 (24.5)	0.79 (0.005)	2.35 (0.13)	30.14 (80.15)	85
2003 (As Built)	37.68 (65.09)	21.8 (18.0)	1.73 (0.084)	3.23 (0.42)	12.99 (12.78)	389
2004	31.81 (36.96)	19.16 (24.73)	1.73 (0.23)	3.63 (0.53)	12.44 (45.12)	448
Percent Change 2003/2004	-15.6%	-12.2%	0.0%	12.1%	-4.2%	15.2%

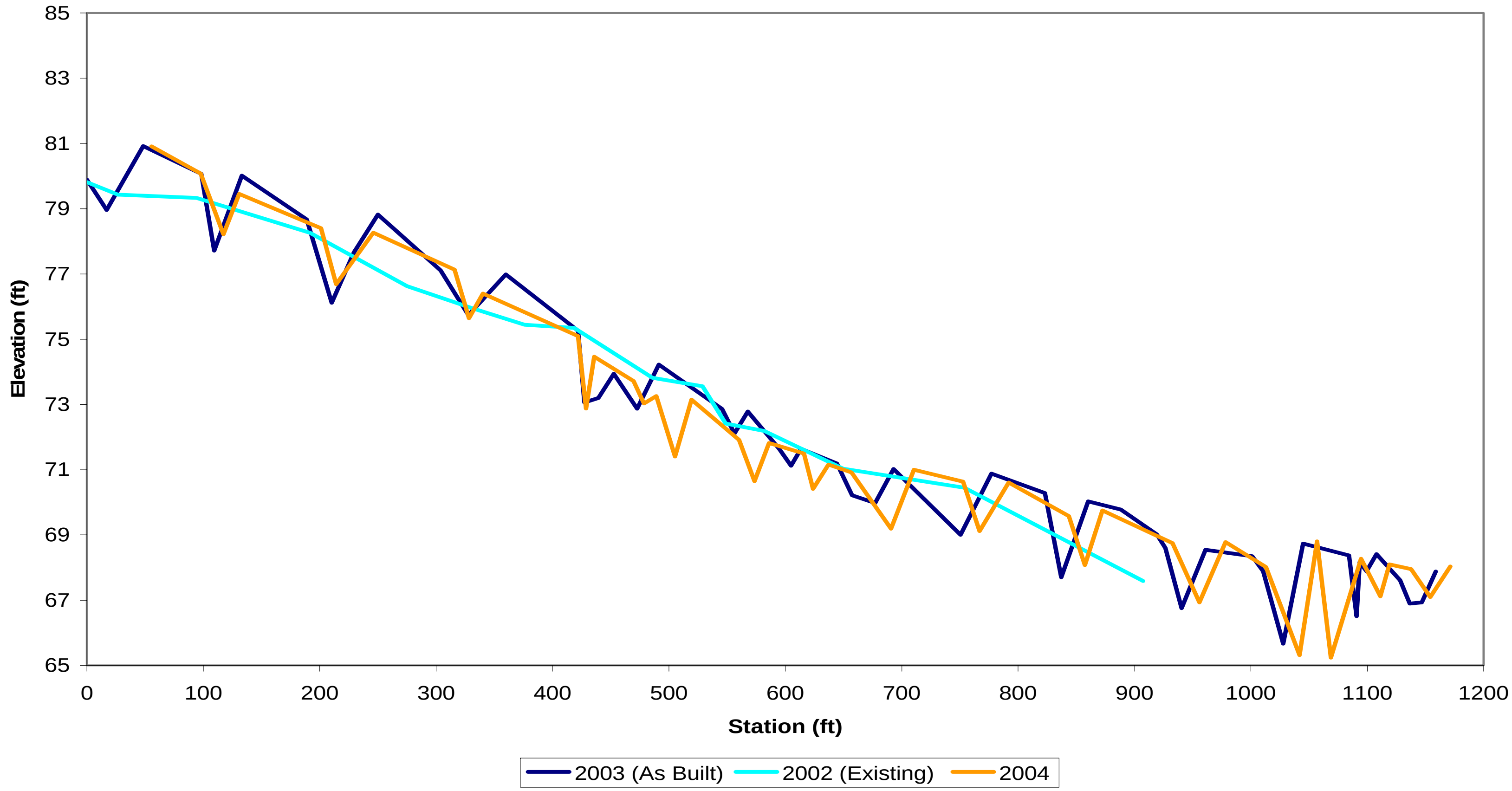


Figure 2. The longitudinal profile of the reach of Young Creek located within the State Lands Restoration Project. The survey was completed in (2002; existing), 2003 (as built) and 2004. The station (longitudinal location measured at the channel thalweg) begins at the upstream boundary of the project. The existing stream channel was approximately 250 feet shorter due to the less meander frequency that existed prior to the restoration activities.

Libby Creek Demonstration Project

One of the single largest point sediment sources within the Libby Creek Watershed existed above the confluence of Elliot Creek (RM 12.0). Two unstable and eroding banks in this area were contributing substantial amounts of course and fine sediment to Libby Creek each year. The largest eroding bank within the project site was over 700 feet long, averaged 80 feet high and was contributing an estimated average of 5,900 cubic yards of sediment annually to Libby Creek. A second large unstable bank in the lower section of the project area was also contributing substantial amounts of sediment to Libby Creek. This bank was approximately 340 feet long and averaged 12 feet high. The sediment resulting from these two banks increased sediment deposition; accelerated bank erosion; increased width/depth ratio and decreased meander width ratio in Libby Creek both within and downstream of the Demonstration Project area.

MFWP cooperated with the landowner, Plum Creek Timber Company, to complete the Libby Creek Demonstration Project within this area in the fall of 2001, which restored one meander length the Libby Creek stream channel (approximately 1,700 feet). All channel and structure construction was completed in the dry. The project restored this section of Libby Creek to a properly functioning stable stream channel capable of maintaining its course through the valley through the construction of 1,700 feet of stream channel installing 7 rock J-hook vanes, 7 rootwad and log complexes, and numerous channel plugs to fill the old stream channel.

The main objective of this project was to reduce sediment loads into Libby Creek and educate local private landowners and agency administrators about the benefits of constructing a properly functioning stream channel. The specific objectives of this project were to 1) Decrease coarse and fine sediment sources, 2) Decrease the stream's width depth ratio, and 3) Return the stream channel to a properly functioning configuration able to efficiently transport bed load sediment during high discharge events; and 4) Increase the quality and quantity of fisheries habitat within this reach of Libby Creek.

MFWP designed a long term monitoring program to evaluate the effectiveness of the stream restoration project. Our monitoring program for this project included 4 permanent cross sections within the project area, Wolman pebble counts (Wolman 1954) at each cross section, a longitudinal profile survey, and permanent photographic points. Dunnigan et al. (2003) reported that the restoration work significantly changed the stream channel dimensions, which ultimately resulted in a deeper and narrower channel, which translated into a significantly lower width/depth ratio after project implementation. The stream restoration work on lower Libby Creek also increased the quantity and quality of rearing habitat for native salmonids within the project reach. The total number of pools within the project reach increased by 25%, and maximum pool depth measured during summer base flow increased by 45.7% (Dunnigan et al. 2003). This project also reduced bank erosion within the project reach by limiting creek access to the two large eroding banks located within the project reach. Dunnigan et al. (2003) measured a minimum of 10,500 cubic yards of course and fine sediment would have entered Libby Creek during the winter of 2002/2003 had not been implemented. Modeling that Dunnigan et al. (2003) also performed showed a substantial decrease in erosion rates at this site as a result of the project. Therefore to ensure that this project continued to meet the project objectives through time, we continued monitoring this project area in 2004.

We re-surveyed the 5 existing cross sections within the project area in 2004 and compared those results with those from 2003. We found no evidence that the dimensions of the stream channel within the project area had significantly changed from 2003 to 2004 (Table 6; Figures 3 and 4). The relative change in bankfull width, depth, cross sectional area, maximum bankfull depth, and width to depth ratio within the project area ranged between 1.1 to 6.4% from 2003 to 2004. Bankfull width changed the least, while maximum bankfull depth saw the sharpest increase from 5.28 feet in 2003 to 5.62 feet in 2004 (Table 6).

In addition to the cross section surveys located within the project area, we also established 2 cross sections located upstream and 1 cross section located downstream of the project area in 2003 and added a second cross section located downstream of the project area in 2004. We resurveyed all cross sections annually once we had established them, with the exception of cross section 1A, R1, and 4, which were surveyed according to the schedule described in Table 7. Our intent was to have the cross sections located outside of the project area to serve as relative control sites to evaluate stream bank stability and erosion rates on lower Libby Creek in the near vicinity of the Libby Creek Demonstration Project and compare those results to our monitoring within the project area. The dimensions of the Libby Creek channel outside the Libby Creek Demonstration Project area were significantly different compared to the channel dimensions within the project area. The stream outside the project area was significantly wider, shallower and a higher width to depth ratio (Table 6). For example, the mean bankfull width was 64.5 and 68.1% as wide above and below the project area, and maximum bankfull depth within the project area was 37.3 and 71.3% deeper inside the project than outside the project area, in 2003 and 2004, respectively. These results were consistent for all stream channel dimension comparisons inside and outside the project area in 2003 and 2004, and although the comparisons were not statistically different for bankfull area comparisons in 2003 and mean bankfull depth comparisons in 2004, the differences were consistent and relatively large (Table 6).

We also measured bank erosion on the outside meander bends of each cross section during the 2004/2005 winter within and outside of the Libby Creek Demonstration Project reach. We measured erosion rates by surveying permanent cross sections across the stream channel. It should also be noted that most of the permanent cross sections are located in outside bends where bank erosion rates are highest. We also established a toe and bank pin in December 2004, in addition to the permanent cross section to measure and visually document erosion rates at the lower most cross section (5B). We used WinXPro software to analyze changes in cross sectional areas at each permanent cross section (Table 7). To measure bank erosion at the cross sections located on meanders, we compared changes in the near bank region of the outside bends, which is defined as the region from the channel thalweg to the top of bank along the cross section (Figures 3 and 4). In the riffle areas we compared the cross sectional area within the entire bankfull width of the cross section. Local conditions on Libby Creek in February 2005 created a high discharge event that accompanied by relatively large ice flows. We resurveyed cross sections 1-4 and 5B after the ice flow had occurred. We estimated that 11.9 square feet of bank eroded at cross section 5B (Figure 5) during the winter 2005 ice flow. The bank at this site is 236 feet long and averages 4.6 feet high. Erosion rates were similar along the entire length of the stream bank.

Given these conditions, we estimated that approximately 95 cubic yards of course and fine sediment eroded from this single site during the single high flow event over the 2004/2005 winter (Figure 5). The only other cross section that we surveyed that had a substantial increase in cross sectional area (erosion) was Cross Section #4 from 2003 to 2005. However, the erosion of material at this site was not associated with the near bank area, but rather in the mid-channel area within the cross vane, which meant that scour increased pool depth and volume (Figure 4).

Table 6. Mean cross sectional area, bankfull width, depth, maximum bankfull depth, and width to depth ratio measured for 5 permanent cross sections within the Libby Creek Demonstration Project area surveyed in 2003 and 2004, 3 permanent cross sections outside the project area surveyed in 2003 and 4 permanent cross sections outside the project area surveyed in 2004. Variance estimates for annual mean values are presented in parentheses. The P-value of paired t-tests for comparisons within the project area (between 2003 and 2004), and the P-values from student t-tests for comparisons within and outside the project area in 2003 and 2004 are also presented.					
Cross Section (year surveyed)	Bankfull Width(ft)	Bankfull Area (ft^2)	Mean Bankfull Depth (ft)	Max. Bankfull Depth (ft)	W/D Ratio
Project 2003	67.7 (51.7)	214.8 (809.7)	3.10 (0.15)	5.28 (0.29)	22.0 (12.5)
Project 2004	68.4 (61.3)	224.8 (728.7)	3.20 (0.21)	5.62 (0.72)	21.5 (24.5)
Outside 2003	111.3 (2276.3)	193.7 (758.3)	1.84 (0.22)	3.87 (0.56)	64.7 (1720.3)
Outside 2004	115.5 (816.7)	165.0 (348.0)	2.21 (2.42)	3.28 (0.743)	87.8 (1777.6)
P-Value Within Project 2003/2004	0.588	0.309	0.332	0.226	0.643
P-Value Within/Outside Project 2003	0.078	0.344	0.006	0.020	0.052
P-Value Within/Outside Project 2004	0.009	0.007	0.208	0.005	0.005

Table 7. Cross section summary information associated with the Libby Creek Demonstration Restoration Project. WinXPro software was used to analyze changes in cross sectional areas at each permanent cross section in the near bank region of the outside bends, which is defined as the region from the channel thalweg to the top of bank along the cross section.

Cross Section	Habitat Type	Location	Survey Dates	Cross Sectional Change From 2003-2004 (ft^2)*	Cross Sectional Change From 2004-2005 (ft^2)*	Cross Sectional Change From 2003-2005 (ft^2)*
1A	Riffle	Upstream of Project	9/03 & 12/04	-97.1	N/A	N/A
1	Pool	Within Project	9/03, 12/04 & 6/05	-7.2	2.1	-3.3
2	Pool	Within Project	9/03, 12/04 & 6/05	-8.9	0.8	-12.9
3	Pool	Within Project	9/03, 12/04 & 6/05	-19.2	7.4	-10.5
R1	Riffle	Within Project	9/03 & 12/04	-6.3	N/A	N/A
4	Pool	Within Project	9/03 & 5/05	N/A	N/A	19.3
5B	Riffle	Downstream of Project	12/04 & 3/05	N/A	11.9	N/A

* Negative value indicates cross sectional area lost (material deposited).

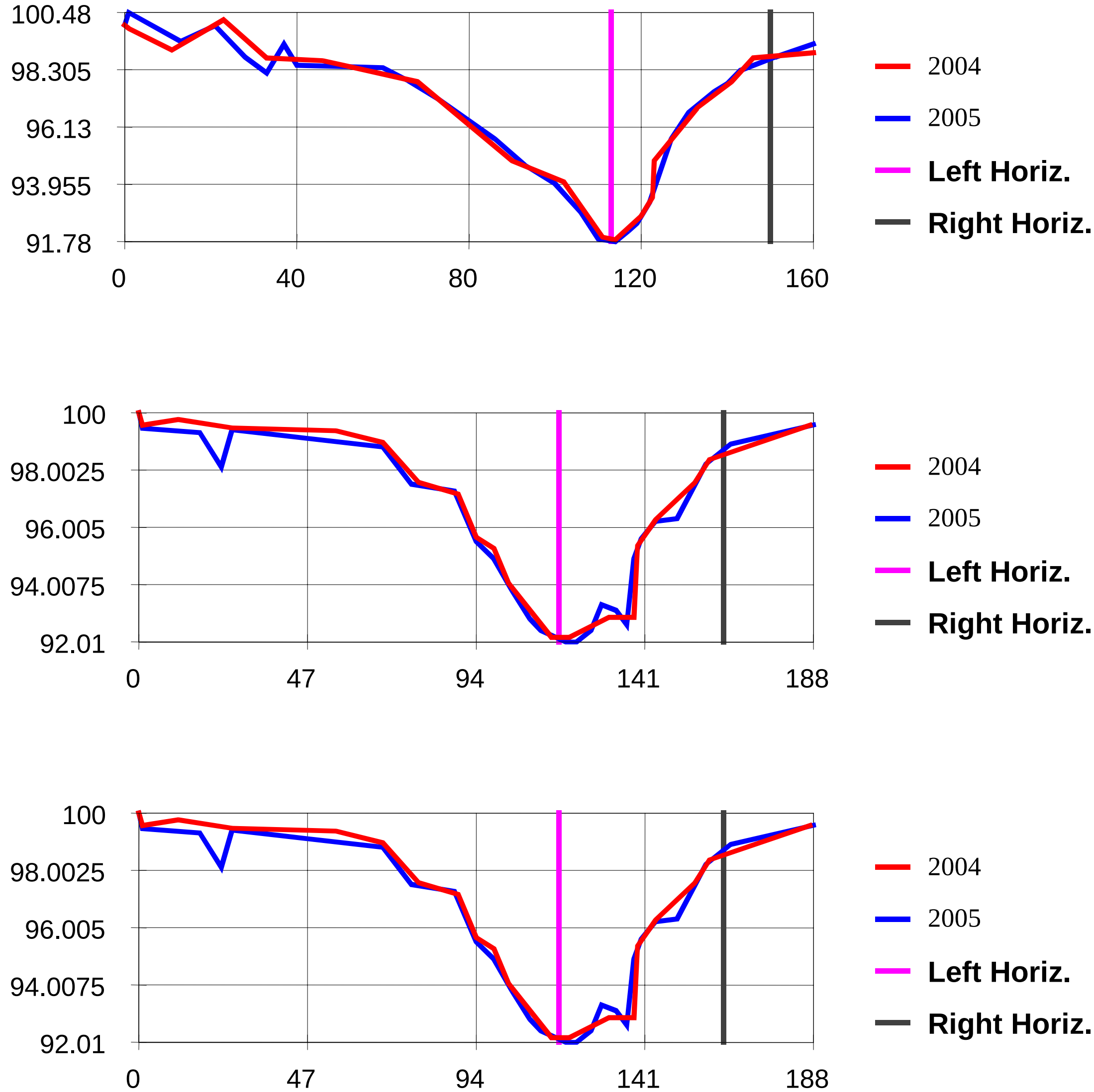
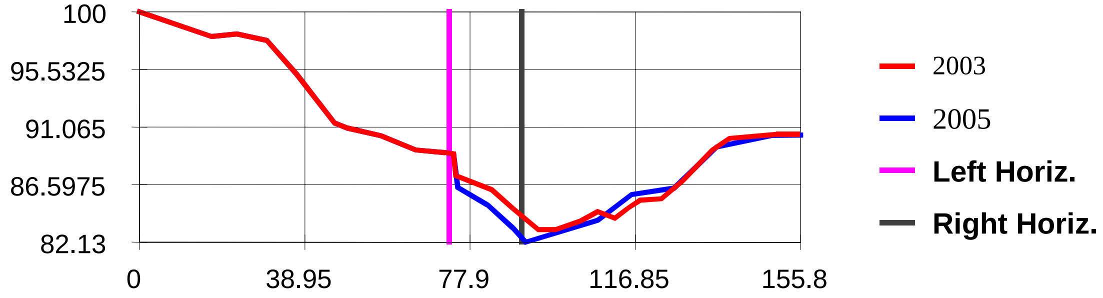


Figure 3. Cross sections 1-3 (top to bottom, respectively) on the Libby Creek Demonstration Project.



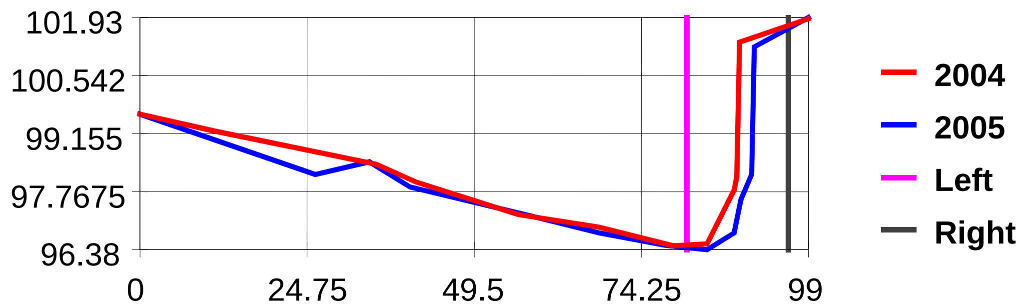


Figure 4. Cross sections 4 and 5B (top to bottom, respectively) on the Libby Creek Demonstration Project.

Figure 5. The upper photograph was taken on December 29, 2004 at Cross Section 5B located downstream from Libby Demonstration Project. Pictured in this photograph are the horizontal and vertical bank pins to measure bank erosion at this site. The lower photograph was taken on March 8, 2005 after an ice flow event on lower Libby Creek. Note in the lower photograph that the vertical bank pin has been scoured away as a result of the high flow event.

Discussion

The Grave Creek Phase I and Libby Creek Demonstration Restoration Projects maintained the designed channel dimensions since construction. Streams with C3 channel types should have width/depth ratios >12 and typically range from 10-37 (Rosgen 1996). Both the Libby and Grave Creek restoration projects were designed within this criterion and continued to meet it after the channel forming flows that occurred during the first spring freshet following project construction. The most substantial change in the physical dimensions within the Grave Creek Phase I Restoration Project was the overall flattening of riffles and the decrease of pool areas and volume as result of decreased length, width and depth. The stream channel dimensions measured at the cross- section surveys the Grave Creek Phase I Restoration Project did not significantly ($p > 0.05$) change since construction. Mean bankfull width, depth, maximum depth, width to depth ratio and cross sectional area all remained similar between years. Pool dimensions within both projects were similar between years. However, pool volume and area has decreased each year since construction as a result of loss of length, width and depth. Although it is important to keep in mind that pool depth, quantity and quality still exceeded conditions that existed prior to project construction. We believe the observed changes in pool-type habitat that occurred since construction has had relatively minor effects on the quantity and quality of juvenile salmonid rearing habitat, and that overall this section of Grave Creek exists at a state near dynamic equilibrium. In addition to the minor changes in pool depth, we have observed an overall decrease in riffle slope since project construction. However, the annual rate of change is slowing. The mean change the first year after construction was nearly 40% reduction in slope (Dunnigan et al. 2004), compared to the mean rate of change of 18% observed during the 2004 spring freshet. Therefore, we believe that these structures are nearing a point of equilibrium in terms of channel dimensions. We think that these particular structures can provide critical gradient control within a restoration project, but that design modification could improve their function. We believe that future designs for similar structures should utilize smaller diameter material and increasing the cross sectional area through these structures to approximately 1.25 to 1.5 times the mean bankfull riffle width. We further recommend the run width below the cobble gradient control structures be designed at 0.8 to 1.0 times the mean bankfull riffle width. The cobble gradient control structures were constructed with material that was between D90 to D100 sized substrate within each particular stream. We incorporated these design modifications into the Grave Creek Phase II Restoration Project constructed in the fall of 2005, and we will continue to monitor the performance of the cobble gradient control structures in projects in a continual effort to evaluate the performance of these particular structures.

The dimensions of Young Creek within the Young Creek State Lands Restoration Project changed little between 2003 and 2004, with changes generally less than 15%. Cross sectional area within the riffles showed the sharpest relative annual decrease from 2003 to 2003. These trends were generally true for both riffle and pool type habitats. Although we increased the total number of pools within the project area from 2003 to 2004, the net effect on pool volume and area was offset by an overall decrease in stream bankfull width within the pools. The number of pools increased at 2 locations. A pool was created at a cross log intended for gradient control, and an additional pool was formed from a change in the stream pattern that resulted when Young Creek migrated slightly down valley. Overall, we were pleased by the performance of the Young Creek project after the first spring freshet. However, the spring freshet that occurred in 2004 were moderated by a low snow pack and the Young Creek stream channel dimensions within the restoration area may continue to slightly adjust during the 2005 spring freshet. The vegetation at this project site also responded well to the stream treatment and we believe that it will further serve to protect the newly constructed stream banks until the stream channel bed becomes fully armored.

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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.

Year	1997	1998	1999	2000[B]	2001	2002	2003	2004
Section 1								
Rainbow Trout	123 (261)	130 (151)	82 (89)	-----	-----	-----	56 (57)	108 (111)
Brook Trout	41 (47)	49 (56)	60 (64)	-----	-----	-----	59 (66)	11 (13)
Bull Trout	0	0	0	-----	-----	-----	0	92 (95)
Total Population[A]	149 (214)	182 (207)	141 (149)	-----	-----	-----	115 (123)	200 (203)
Section 2								
Rainbow Trout	36 (41)	79 (82)	76 (83)	-----	93 (102)	-----	84 (n/a)	102 (107)
Brook Trout	56 (58)	125 (137)	72 (80)	-----	82 (87)	-----	58 (61)	24 (27)
Bull Trout	47 (49)	15 (16)	3	-----	2	-----	40 (42)	49 (53)
Total Population[A]	92 (96)	205 (217)	149 (163)	-----	180 (193)	-----		153 (160)
Section 3								
Rainbow Trout	54 (58)	164 (170)	177 (205)	-----		-----	99 (104)	112 (117)
Brook Trout	74 (77)	82 (88)	110 (117)	-----		-----	67 (72)	41 (45)
Bull Trout	0	0	0				10 (n/a)	3 (n/a)
Total Population[A]	66 (93)	248 (257)	284 (308)	-----		-----		155 (162)

A) Includes rainbow, rainbow x cutthroat hybrids, and brook trout. Bull trout were not included in the total population estimate.
B) Therriault Creek was not sampled during the 2000 or 2002 field seasons.

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
Westslope Cutthroat	4	18	3	13 (n/a)	4 (n/a)
Rainbow Trout	1	17	26	25 (29)	41 (45)
Brook Trout	1	10	5	9 (18)	1(n/a)
Bull Trout	9	33	5	41 (144)	63 (67)
Mountain Whitefish	54	3	33	21 (22)	70 (73)
Long Nose Dace	6	-----	-----	-----	-----
Water Temp. ^{0}C	-----	17	-----	-----	-----
Effort (minutes)	44	56.9	NA	NA	

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

B) Four bull trout ≥ 470 mm were likely lacustrine - adfluvial fish from Libby Reservoir moving into Grave Creek to spawn. 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 ≥ 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
Section 1 (Tooley)									
Westslope Cutthroat[B]	-----	3	36 (37)	139 (148)	-----	55 (64	88 (96)	Not sampled	68 (70)
Rainbow Trout[B]	-----	19 (23)	62 (70)	3 (n/a)	-----	2 (n/a)	14 (19)		8 (n/a)
Brook Trout	-----	11 (17)	120 (124)	102 (105)	-----	36 (39)	30 (31)		20 (n/a)
Mountain Whitefish	-----	-----	-----	-----	-----	-----	2 (n/a)		2 (n/a)
Total Population [A]	12 (13)	36 (40)	220 (228)	248 (258)	-----	96 (107)	148 (158)		96 (98)
Section 3 (303 A Rd.)									
Westslope Cutthroat	-----	234 (246)	416 (452)	314 (336)	-----	-----	-----	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)
Rainbow Trout	-----	-----	-----	-----	-----	-----	-----		-----
Brook Trout	-----	-----	-----	3 (n/a)	-----	6 (12)	4 (n/a)		10 (12)
Total Population [A]	155 (229)	100 (114)	439 (500)	358 (373)	-----	136 (148)	232 (249)		230 (241)
Section 5 (State)									
Westslope Cutthroat	-----	-----	216 (227)	256 (290)	126 (153)	153 (174)	268 (290)	178 (183)	115 (118)
Rainbow Trout	-----	-----	-----	-----	-----	-----	-----	-----	-----
Brook Trout	-----	-----	62 (71)	52 (65)	19 (22)	25 (27)	46 (49)	35 (n/a)	60 (63)
Bull Trout	-----	-----	-----	-----	-----	-----	2 (n/a)	0	3 (n/a)
Total Population [A]	-----	-----	280 (294)	314 (353)	113 (119)	176 (195)	315 (335)	213 (183)	230 (241)

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
Section 1 – below Hwy 2							
Rainbow Trout	81 (127)	26	125	46 (51.09)	117 (130)	84 (96)	113 (118)
Brook Trout	6 (8)	6	13	10 (12.33)	16 (24)	5	9 (15)
Bull Trout	-----	-----	-----	-----	3	0	1 (n/a)
Mountain Whitefish	-----	-----	-----	-----	3	1	
Total Population [B]	90 (116)	32	138	57 (63.79)	138 (153)		138 (144)
Water Temp. ^{0}C	9	-----	16	15	14	------	------
Section 2 –above Hwy 2							
Rainbow Trout	203 (225)	-----	-----	148 (193)	-----	100 (108)	120 (128)
Brook Trout	7	-----	-----	2	-----	2	30 (34)
Bull Trout	5 (6)	-----	-----	-----	-----	2.08	-----
Total Population [B]	208 (228)	-----	-----	160 (213)	-----		150 (160)
Water Temp. ^{0}C	5	-----	-----	20	-----	------	------
Section 3 – upper Cleveland							
Rainbow Trout	-----	-----	170 (194)	172 (182)	163 (183)	112.3 (127)	88 (104)
Brook Trout	-----	-----	-----	-----	-----	------	------
Bull Trout	-----	-----	3	8 (11)	7	11 (14)	2 (n/a)
Mountain Whitefish	-----	-----	-----	-----	1	-----	
Total Population [B]	-----	-----	170 (194)	172 (182)	163 (183)		88 (104)

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
Section 4 – below lower Cleveland							
Rainbow Trout							352 (365)
Brook Trout							------
Bull Trout							5 (n/a)
Total Population [B]							355 (368)
Section 5 –above lower Cleveland							
Rainbow Trout							172 (185)
Brook Trout							------
Bull Trout							6 (n/a)
Total Population [B]							172 (185)
Section 6 – lower Cleveland							
Rainbow Trout							218 (234)
Brook Trout							1 (n/a)
Bull Trout							------
Total Population [B]							219 (235)

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
Rainbow Trout	42 (46)	73 (85)	39 (43)	25 (27)
Brook Trout	-----	3	7 (8)	4 (n/a)
Bull Trout	-----	-----	------	------
Total Population [A]	42 (46)	73 (85)		27 (29)
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 2004. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.08	0.69	0.07	1.80	0.00	1.32	0.00
		0.00	0.58	0.00	3.40	0.00	5.23	0.00
May	(3)	0.54	5.52	1.18	35.00	0.71	30.18	0.10
		0.09	1.31	2.50	1,196.45	0.50	691.13	0.01
June	(3)	3.71	0.20	0.70	27.94	2.36	65.07	0.41
		8.27	0.02	0.35	37.29	0.67	6,219.63	0.11
July	(3)	3.20	0.07	1.86	11.99	7.07	54.23	0.40
		0.13	0.00	0.84	0.06	39.56	4,319.37	0.00
August	(3)	1.03	0.62	2.37	5.64	3.30	98.63	0.61
		0.08	0.13	0.09	0.38	8.67	1,019.39	0.01
September	(3)	1.04	7.51	3.50	3.62	2.60	370.63	1.15
		0.18	0.83	0.24	1.24	2.67	110,969.18	0.28
October	(3)	1.09	1.43	1.87	3.85	0.94	57.06	0.54
		0.25	1.20	1.16	2.64	0.66	3,955.20	0.05
November	(3)	1.03	0.66	0.59	7.42	0.00	18.96	0.12
		0.19	0.04	0.04	9.68	0.00	321.57	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 2004. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.38	1.99	0.20	11.93	0.00	0.00	0.01
		0.11	2.57	0.04	75.75	0.00	0.00	0.00
May	(3)	1.24	9.23	0.58	41.19	4.24	28.29	0.24
		0.18	14.95	0.26	691.43	4.52	2,401.54	0.02
June	(3)	2.09	0.06	0.32	17.95	2.83	202.76	0.06
		0.79	0.01	0.03	20.88	0.50	99,324.23	0.00
July	(3)	5.24	0.00	0.79	10.72	16.74	35.46	0.23
		3.18	0.00	0.12	57.86	85.22	981.99	0.01
August	(3)	1.21	0.16	2.59	8.70	0.47	350.80	1.49
		1.15	0.01	0.59	19.19	0.66	13,378.46	0.06
September	(3)	0.50	4.29	1.65	2.59	1.65	84.31	1.22
		0.01	1.56	0.01	0.42	1.17	534.13	0.00
October	(3)	1.13	0.86	1.28	4.59	0.84	32.82	0.51
		0.36	0.26	0.27	0.47	0.05	823.55	0.00
November	(3)	0.70	0.34	0.49	5.30	0.00	11.88	0.12
		0.13	0.15	0.05	18.80	0.00	148.23	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 2004. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.003	0.01	0.001	0.08	1.33	0.47	0.03
		0.00	0.00	0.00	0.00	0.02	0.66	0.00
May	(3)	0.10	0.57	0.03	1.40	2.20	15.72	0.03
		0.03	0.80	0.00	2.85	3.19	655.79	0.00
June	(3)	2.08	0.01	0.19	12.93	3.01	19.62	0.07
		1.38	0.00	0.01	18.01	2.85	1,154.44	0.00
July	(3)	6.89	0.00	0.19	8.96	14.30	11.95	0.26
		9.62	0.00	0.02	22.19	58.78	428.17	0.00
August	(3)	1.63	0.04	0.63	3.51	0.47	709.98	0.71
		0.13	0.01	0.26	4.85	0.66	129,751.03	0.41
September	(3)	5.07	4.39	3.41	6.56	3.32	17.45	2.44
		20.67	52.98	4.95	19.44	7.73	913.16	8.40
October	(3)	6.87	0.10	6.28	6.17	9.14	29.02	1.77
		19.94	0.01	14.57	9.05	127.46	2,525.90	7.87
November	(3)	3.51	0.33	2.40	6.33	3.88	34.91	0.13
		21.37	0.00	11.05	12.80	45.24	199.06	0.00

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

Year	(N)	*Daphnia*	*Bosmina*	*Diaptomus*	*Cyclops*	*Leptodora*	*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