Mitigation for the Construction and Operation of Libby Dam

Annual Report
2000

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Bonneville Power Administration
P.O. Box 3621
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MITIGATION FOR THE CONSTRUCTION AND OPERATION OF LIBBY DAM

ANNUAL REPORT
2000

By:

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Montana Fish, Wildlife and Parks
475 Fish Hatchery Road
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Funded by:
Bonneville Power Administration
Division of Fish and Wildlife
P.O. Box 3621
Portland, OR 97208
Ron Morinaka, COTR
Project Number 199500400
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September, 2002

EXECUTIVE SUMMARY

"Mitigation for the Construction and Operation of Libby Dam" is part of the Northwest Power Planning Council's resident fish and wildlife program. The program was mandated by the Northwest Planning Act of 1980, and is responsible for mitigating for 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.

ACKNOWLEDGEMENTS

We are thankful to the many people that substantially contributed to this project. Neil Benson, Monty Benner, Will Young, and Kimber Hrach helped with field data collection, data entry and proofing, and lab processing. Brian Marotz was the project leader of this project and provided thoughtful review of this report. Hatchery staff from Washoe Park State Fish Hatchery in Anaconda, Montana provided westslope cutthroat trout eggs for the remote site incubator studies in Young Creek, which made that research possible. Many of the aquatic habitat restoration projects that were accomplishments and summarized in this report were cooperative efforts between Montana Fish, Wildlife and Parks and other agencies and organizations. The Glen Lake Irrigation Diversion Project was accomplished by funding from several cooperating entities including the USFWS "Partners for Wildlife", Glen Lake Irrigation District, and the USFS. Lincoln County assisted with the design and construction of the Eureka Community Fishing pond, and funding and implementation of the Parmenter Creek restoration project. The City of Troy contributed to the Troy Water Works Project and the Troy Community fishing pond. This work was funded by the Bonneville Power Administration, and was administered by Ron Morinaka.

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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 redevelop fisheries and fisheries habitat in basin streams and lakes.

Libby Mitigation sponsored a study to determine habitat preference for juvenile white sturgeon in the lower Kootenai River (Young and Scarnecchia, in press). We funded a graduate project to assess the current and historic causes of instability in Libby Creek, and recommend stabilization priorities (Sato 2000). This project also funded conceptual plan development for Granite/Big Cherry Creeks and Grave Creek to stabilize stream banks and restore fisheries habitat.

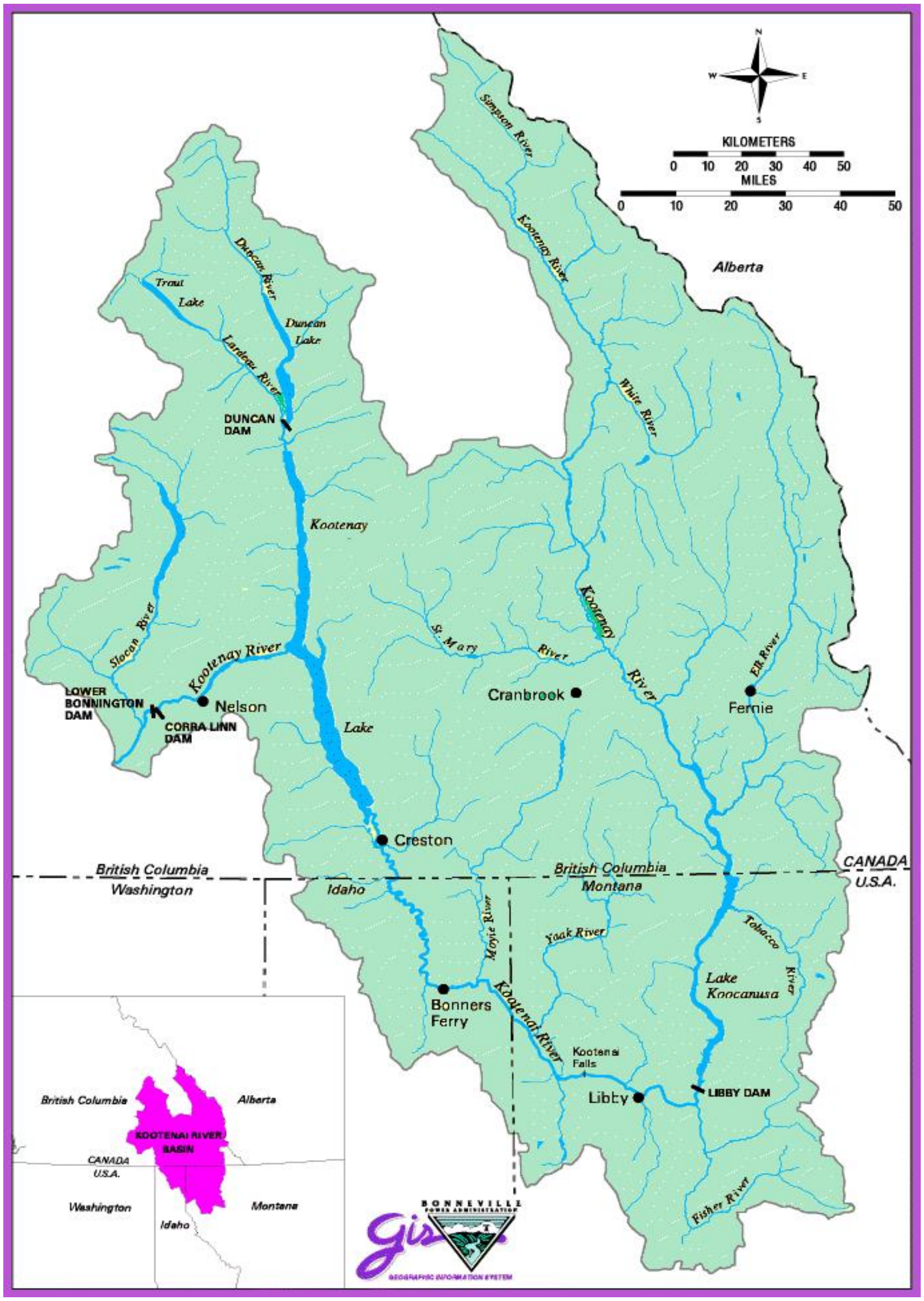

Figure 1. Kootenai River Basin (Montana, Idaho and British Columbia, Canada).

PROJECT HISTORY

Work on Libby Reservoir to assess the effects of operation on fish populations and lower trophic levels began in 1982. This project established relationship between reservoir operation and biological productivity, and incorporated the results in the computer 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 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 salmon/steelhead biological opinion, the strategy was adopted by the White Sturgeon Recovery Team in their Kootenai white sturgeon recovery plan (USFWS 1999).

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 similarly 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 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 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.

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

1997 - We 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 - We 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 - We developed an isolation facility for the conservation of redband rainbow 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.

1999 - We 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 - We 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 - We 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 - We were 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 - We 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 - We 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 headcut 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.

ASSOCIATIONS

The primary goals of our 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). This project creates new trout habitat by restoring degraded habitat to functional condition through stream rehabilitation 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. We are currently funding a graduate degree project through the University of Idaho to study habitat use by juvenile sturgeon in the lower Kootenai River and to determine changes in growth rates of sturgeon since dam completion. This project has also typed habitat in the lower river during previous IFIM field investigations.

The radio-telemetry work of this project will identify migration habits, habitat preferences and spatial distribution of species in the Kootenai system. Much of this information can be utilized by the IFIM project in the Flathead watershed (Project 199101903).

Project personnel are completing activities in the lower Kootenai River in Montana that will gather data to serve as 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 Koocanusa 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.

We have increased our involvement with the Kootenai River Network (KRN) during the past year. 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 will lead to improved 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 local citizens to collaborate in natural resource management in the basin and involves local individuals and groups, as well as two states, one province, two countries and affected tribal nations. Montana Fish, Wildlife and Parks is an active participant in KRN and will serve on the KRN Executive Board. Formal participation in the KRN helps Montana Fish, Wildlife and Parks achieve its goals and objectives toward watershed restoration activities in the Kootenai Basin.

PROJECT PERSONNEL

GREGORY C. HOFFMAN

FISHERIES and WATERSHED BIOLOGIST
Montana Department of Fish, Wildlife and Parks
475 Fish Hatchery Road
Libby, MT 59923

DEGREES EARNED

University of Wisconsin - Stevens Point; Stevens Point, WI
Master of Science *in* Fisheries, August, 1994

South Dakota State University; Brookings, SD
Bachelor of Science *in* Wildlife and Fisheries Sciences, June, 1990

University of Minnesota - Crookston; Crookston, MN
Associate of Applied Science *in* Natural Resources Conservation, June, 1986

CURRENT RESPONSIBILITIES

Develop and coordinate mitigation projects in the Kootenai River Drainage in northwest Montana, including stream rehabilitation, easement development, and lake reclamation. Supervise 3-5 technicians, write and manage budgets, produce annual and project reports and work plans, and develop and implement monitoring and research program for on-the-ground projects. Maintain and distribute computer simulation models for Koocanusa Reservoir and the Kootenai River, including IFIM and IRC, and coordinate research efforts in Montana for recovery of the endangered Kootenai River white sturgeon.

RECENT EMPLOYMENT

Montana Department of Fish, Wildlife and Parks
    Fisheries Research Biologist, 02/98 to 04/00
    Fisheries Research Specialist, 04/97 to 01/98
    Fisheries Research Technician, 04/96 to 04/97

EXPERTISE

- Well-versed in fisheries theories, principles, and methods of research, management, and conservation.
- Fisheries statistics and population dynamics analysis.
- Scientific and technical literature preparation and use.
- Fisheries and other environmental sampling methods and data analysis.
- Stream habitat enhancement.
- Personal computers and application programs, computer habitat simulation models, and GPS/GIS applications.

1994: BLM "Proper Functioning Condition" Workshop - Casper, Wyoming
1995: USFS "R1/R4 Stream Inventory Methodology" - Salmon, Idaho
1995: USFS "R1/R4 FBase Stream Inventory Data Analysis" - Challis, Idaho
1996: AFS Public Outreach Symposium - Bozeman, Montana
1996: SCUBA Certification - Kalispell, Montana
1996: Inter-Fluve, Inc. “Design of Natural Stream Channels” - Bozeman, MT

LARRY F. GARROW

FISHERIES FIELDWORKER III

Montana Department of Fish, Wildlife and Parks
475 Fish Hatchery Road
Libby, MT 59923

DEGREE EARNED

University of Montana - Missoula, MT
Bachelor of Science in Wildlife Biology with an emphasis in aquatic and fisheries management, December 1985

CURRENT RESPONSIBILITIES

Senior fisheries technician on the BPA funded Libby Reservoir Project supervising and scheduling, under the direction of the project biologist, one to three fisheries technicians. Primary duties include assisting project personnel in fisheries research, monitoring and enhancement of fish populations within the Kootenai Basin. Ensure that equipment is properly maintained and organized. Enter, proof and summarize data into statistical and graphical formats for completion of project reports. Locate, document and prioritize potential mitigation sites. Lead technician in the planning, coordination and implementation of stream and lake chemical treatments to remove undesirable fish species. (1.0 FTE)

RECENT EMPLOYMENT

Fisheries Fieldworker III; MFWP; Libby, MT; 02/92 to present
Interim Fisheries Biologist; MFWP; Libby, MT; 09/94 to 01/95
Fisheries Fieldworker II, I; MFWP; Libby, MT; 06/89 to 09/92
Fisheries Fieldworker I; MFWP; Superior, MT; 04/89 to 06/89
Fisheries Laborer I; MFWP; Fort Peck; MT; 04/88 to 07/88
Experimental Biology Aide I; Oregon Department of Fish and Wildlife; Charleston, OR; 10/87 to 01/88
Stream Surveyor; Oregon Department of Fish and Wildlife; Powers, OR; 07/87 to 09/87

EXPERTISE

Field sampling and data collection using backpack, mobile and boom electrofishing methods, gill nets, hoop traps, fyke nets, Idaho weir traps, beam trawls, Schindler traps, Wisconsin nets, setlines, and draft tube nets.
Scheduling and coordinating the logistics of field operations.
Licensed to apply aquatic piscicides.
Expert in the safe operation of jet and propeller driven motor boats.
1992: PADI SCUBA certified.
1999: Applied Fluvial Geomorphology - Wildland Hydrology; Pagosa Springs, Colorado

JAY A. DE SHAZER
FISHERIES FIELDWORKER III
Montana Fish, Wildlife and Parks
475 Fish Hatchery Road
Libby, MT 59923

DEGREE EARNED

Montana State University; Bozeman, MT
Bachelor of Science *in* Fish and Wildlife Management, June 1989

CURRENT RESPONSIBILITIES

Research, monitor and document the effects on fisheries caused by the construction and operation of Libby Dam. Identify and implement mitigation projects to enhance fisheries within the Kootenai River Basin. Survey, design and coordinate the implementation of habitat enhancement projects.

RECENT EMPLOYMENT

Biological Technician; USFS; Rexford Ranger District; Eureka, MT; 06/89 to 04/91

EXPERTISE

- Well-versed in fisheries theories, principles, and methods of research, management, and conservation.
- Scientific and technical literature preparation and use.
- Fisheries and other environmental sampling methods and data analysis.
- Surveying, mapping and designing stream habitat enhancement.
- Personal computers and application programs, computer habitat simulation models, and GPS/GIS applications.
- Boat maintenance and operation
- Heavy equipment operation

1996: AFS Public Outreach Symposium - Bozeman, Montana
1996: Inter-Fluve, Inc. "Design of Natural Stream Channels" - Bozeman, MT
1995: Physical Habitat Simulation system - Logan, UT
1992: SCUBA Certification - Kalispell, Montana
1998: Applied Fluvial Geomorphology - Wildland Hydrology; Pagosa Springs, Colorado
River Morphology & Application - Wildland Hydrology; Pagosa Springs, Colorado
1999: Natural Channel Design - Wildland Hydrology; Blackfoot River, Montana
2000: River Assessment - Wildland Hydrology; Pagosa Springs, Colorado

THOMAS E. OSTROWSKI

FISHERIES FIELDWORKER III

Montana Department of Fish, Wildlife and Parks
475 Fish Hatchery Road
Libby, MT 59923

DEGREE EARNED

Michigan State University - East Lansing, MI
Bachelor of Science in Forest Resource Management, May 1985

CURRENT RESPONSIBILITIES

Lead fisheries technician for BPA funded Fisheries Mitigation Project in the Kootenai River Basin. Under the direction of project biologist, responsible for supervising the collection of stream morphological and biological data used to develop and assess stream naturalization projects in the Kootenai Basin. Primary duties include locating, surveying and prioritizing potential mitigation sites, prepare site plans, obtaining permits, coordinating with landowners and agency personnel and contractors as required to implement mitigation projects. Aid project biologist in summarizing data used in progress reports.

RECENT EMPLOYMENT

Fisheries Technician for U.S. Forest Service
    Alsea District, Siuslaw National Forest; Philomath, OR; 5/91 - 9/91
    Cordova District, Chugach National Forest; Anchorage, AK; 4/90 - 11/90
    Elk City District, Nez Perce National Forest; Grangeville, ID 6/85 - 4/90

EXPERTISE

- Proficient background in the principles, methods of fish population and habitat surveys.
- Global Positioning Systems (GPS) and application computer programs used for mapping.
- Lead Projects SCUBA diver with advanced certification and experienced in adverse diving conditions.
- Experienced surveyor at the 3rd level of error using laser level and "Total Station" survey equipment.

1996: Advanced SCUBA (PADI) Certification - Kalispell, Montana
1997: Fish Mark and Recapture Symposium - Montana State University; Bozeman, Montana
1998: Applied Fluvial Geomorphology - Wildland Hydrology; Pagosa Springs, Colorado
River Morphology & Application - Wildland Hydrology; Pagosa Springs, Colorado
1999: Natural Channel Design - Wildland Hydrology; Blackfoot River, Montana
2000: River Assessment - Wildland Hydrology; Pagosa Springs, Colorado

MON TY R. BENNER
FISHERIES FIELDWORKER II

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

DEGREE EARNED

University of Montana; Missoula, MT
Bachelors of Science Degree in Wildlife Biology (Aquatic Option)

CURRENT RESPONSIBILITIES

- Radio telemetry monitoring of bull trout and rainbow trout.
- Stream surveying and implementation of stream restoration projects.
- Stream habitat surveying.
- Redd counts for bull trout and rainbow trout in streams and rivers in Canada and United States.
- Hoop net trapping in Kootenai River for burbot trend monitoring.
- Electrofishing (mobile, boat and backpack) for population estimates.
- Gill netting in area lakes to monitor population trends.
- Collect and prepare fish scales and otolith for aging and growth data.

RECENT EMPLOYMENT

Montana Fish, Wildlife and Parks, Libby, MT
Fish and Wildlife Technician I
Summer 1997
June 15, 1998 to present

EXPERTISE

- Surveying and sampling for stream restoration projects.
- Fisheries sampling methods and data analysis.
- Operation of boats (prop and jet drive) in a safe manner in lakes and rivers.
- Ability to communicate with the public in a clear and concise manner.
- First Aid and CPR certified.
- SCUBA certified.
- Well versed in general maintenance including carpentry, plumbing, and masonry.
- Ability to use various computer programs.
- Heavy equipment operation.

2000: Applied Fluvial Geomorphology (Dave Rosgen)- Lubrecht Experimental Forest, Montana
1999: SCUBA Certification (Bighorn Divers)- Kalispell, Montana
1999: Introduction to ArcView GIS – Helena, MT

NEIL J. BENSON

FISHERIES FIELDWORKER II

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

DEGREE EARNED

University of Montana; Missoula, MT
Bachelors of Science Degree in Wildlife Biology (Aquatic Option)

CURRENT RESPONSIBILITIES

- Ultrasonic and radio telemetry implantation and monitoring in burbot, bull and rainbow trout.
- Stream surveying for design and monitor Rosgen type stream rehabilitation.
- Stream habitat survey using modified Hankin and Reeves methodology.
- Redd counts for bull, and rainbow trout in streams and rivers in the Canada and United States.
- Year round SCUBA transects below Libby dam for burbot trend monitoring.
- Wild egg collection from redband rainbows.
- Hoop net trapping in Kootenai River and Lake Koocanusa for burbot trend monitoring.
- Electrofishing (mobile, boat and backpack) for population estimates.
- Gill netting in area lakes to monitor population trends.
- Microhabitat location and data collection using snorkeling and radio telemetry.
- Installation and monitoring of HOBO temperature probes.
- Prepare, mount and age scales, using acetate sheets, heated presses and microfiche readers.

RECENT EMPLOYMENT

Montana Fish, Wildlife and Parks, Libby, MT
Fish and Wildlife Technician I
Summers 1993-1998

EXPERTISE

- Ability to operate, and maintain, boats (prop and jet) in a safe manner in lakes and rivers.
- Ability to communicate with the public in a clear and concise manner.
- First Aid and CPR certified.
- SCUBA certified.
- Ability to use GPS.
- Ability to collect and fertilize wild fish eggs.
- Ability to produce educational videos.
- Well versed in general maintenance including carpentry, plumbing, and masonry.
- Ability to use various computer programs.

2000: Applied Fluvial Geomorphology – Lubrecht Experimental Forest
1999: Introduction to ArcView GIS – Helena, MT
1996: SCUBA Certification – Kalispell, MT

DESCRIPTION OF STUDY AREA

Subbasin Location

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. In terms of runoff volume, the Kootenai is the second largest Columbia River tributary. In terms of watershed area (36,000 km^2 or 8.96 million acres), it ranks third (Knudson 1994).

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.

Climate

The subbasin has a relatively moist climate, with annual precipitation even at low elevations generally exceeding 20 inches. Warm, wet air masses from the Pacific bring abundant rain and 1,000 to 7,500 mm (40 to 300 inches) of snowfall each year. In winter, Pacific air masses dominate and produce inland mountain climates that are not extremely cold, although subzero continental-polar air occasionally settles over the mountains of northern Idaho and vicinity.

The Continental Divide Range, with crest elevations of 10,000 to 11,500 feet along nearly 250 km (155 miles) of ridgeline, is a major water source for the river. The range receives 2,000 to 3,000 mm (80 to 120 inches) of precipitation annually (Bonde 1987). Some of the high elevation country in the Purcell Range around Mt. Findlay receives 2,000 mm (80 inches) of precipitation a year; but most of the range, and most of the Selkirk and Cabinets, get only 1,000 to 1,500 mm (40 to 60 inches) annually (Daley et al. 1981). In the inhabited valley bottoms, annual precipitation varies from just under 500 mm (20 inches) at Rexford, Montana (USACE 1974) and Creston, British Columbia (Daley et al. 1981) to just over 1,000 mm (40 inches) at Fernie, British Columbia (Oliver 1979).

Topography

The drainage basin is located within the Northern Rocky Mountain physiographic province, which is characterized by north to northwest trending mountain ranges separated by straight valleys that run parallel to the ranges.

The topography of the Kootenai River subbasin is dominated by steep, heavily forested mountain canyons and valleys. Consequently, nearly all of the major tributaries to the river, including the

Elk, Bull, White, Lussier, and Vernnillion Rivers have a very high channel gradient, particularly in their headwaters. In contrast, the mainstem of the Kootenai has a fairly low channel gradient after entering the Rocky Mountain Trench near Canal Flats. The river drops less than 1,000 feet (305 meters) in elevation from Canal Flats to Kootenay Lake, a distance of over 300 miles (480 km). However, even along the river's slow meandering course, valley-bottom widths are generally less than two miles and are characterized by tree-covered rolling hills with few grassland openings. The only exceptions to this topography are the slightly wider valley bottoms in the Bonners Ferry-to-Creston area and the Tobacco Plains, located between Eureka, Montana and Grasmere, British Columbia.

Synder and Minshall (l996) identified three different geomorphic reaches of the Kootenai River between Libby Dam and Kootenay Lake. The first reach (Canyon) extends from Libby Dam to the Moyie River (92 km). It flows through a canyon in places, but otherwise has a limited flood plain due to the closeness of the mountains. The substrate consists of large cobble and gravel. The second reach (Braided) extends from the Moyie River to the town of Bonners Ferry (7.5 km). It is extensively braided with depths that are typically less than 9 m, and substrates that consist mostly of gravels. The river has an average gradient of 0.6 m/km, and velocities higher than 0.8 m/s. The third reach (Meander) extends from just below the town of Bonners Ferry to the confluence of the Kootenay Lake (82.5 km). Here, the river slows to an average gradient of 0.02 m/km, deepens, and meanders through the Kootenai Valley back into British Columbia and into the southern arm of Kootenay Lake. The meandering section through the Kootenai Valley is characterized by water depths of up to 12 meters in runs and up to 30 meters in pools (Snyder and Minshall 1994). This reach has been extensively diked and channelized, which has had profound effects on ecosystem processes.

Geology

Mountains in the subbasin are composed of folded, faulted, and metamorphosed blocks of Precambrian sedimentary rocks of the Belt Series and minor basaltic intrusions (Ferreira et al. 1992). Primary rock types are meta-sedimentary argillites, sitlites, and quartzites, which are hard and resistant to erosion. Where exposed, they form steep canyon walls and confined stream reaches. The porous nature of the rock and glaciation and have profoundly influenced basin and channel morphology (Hauer et al. 1997).

The river character changes dramatically from a bedrock-controlled regime in Montana to a silt/clay regime near the town of Bonners Ferry, Idaho. During the Pleistocene, continental glaciation overrode most of the Purcell Range north of the river, leaving a mosaic of glacially scoured mountainsides, glacial till, and lake deposits. Late in the glacial period, an ice dam blocked the outlet at West Arm of Kootenay Lake. The dam formed glacial Kootenay Lake, the waters of which backed all the way to present-day Libby, Montana. Glacial Kootenay Lake filled the valley with lacustrine sediments, which included fine silts and glacial gravels and boulders. The Kootenai River and lower tributary reaches in Idaho are actively reworking these lacustrine sediments today. A terrace of lacustrine sediments on the east side of the valley is approximately 150 feet above the current floodplain and is a remnant of the ancestral valley floor. Tributary streams working through remnant deposits to meet the present base level of the mainstem and from the mainstem reworking existing floodplain and streambank deposits continue to be a source of fine sediments. An extensive network of marshes, tributary side channels, and sloughs were formed by lowering of the lake level, flooding, and the river reworking its floodplain. Some of these wetlands continued to be supported by groundwater recharge, springtime flooding, and channel meandering. Much of this riverine topography however, has been eliminated by diking and agricultural development, especially in the reach downstream of Bonners Ferry, Idaho.

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. Streamflow in unregulated tributaries generally peaks in May and 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 fish-migration barrier, 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 Kootenai River has an average annual discharge of 868 m^3/s (30,650 cfs).

Soils

Soils formed from residual and colluvial materials eroded from Belt rocks or in materials deposited by glaciers, lakes, streams, and wind. Wind deposits include volcanic ash from Cascade Range volcanoes in Washington and Oregon. In many areas, soils formed in glacial till and are generally loamy and with moderate to high quantities of boulders, cobbles, and gravels. Although soils within the mountainous regions vary widely in character, most mountain and foothill soils are on steep slopes and well drained, with large amounts of broken rock. Rock outcrops are common.

Soils deposited by glaciers or flowing water are, for the most part, deep, well-drained, and productive soils. Most of forest soils in the subbasin are somewhat resistant to erosion by water. In most of the valleys, soils are deep, relatively productive, and gently sloping.

Ustolls, Ochrepts, and Ustalfs are the dominant soils in valleys and on lower mountain slopes. Ochrepts, Borolls, and Orthents are dominant on upper mountain slopes and crests. Orthents and areas of rock outcrop are extensive on steep mountain slopes, and Fluvents and Aquolls are in valleys (NRCS 2000).

Land Use

The Kootenay Basin remains relatively remote and sparsely populated. Fewer than 100,000 people live within the basin upstream from Kootenay Lake, an area larger than the states of Maryland and Delaware combined. The largest municipal center is Cranbrook/Kimberley, which has a population of about 25,000. Only a handful of other communities have populations larger than 2,000. They include Libby, Montana, Bonners Ferry, Idaho, and Fernie, Sparwood, Elkford, and Creston, British Columbia.

The forest products industry remains the most dominant employment and most extensive development activity in the subbasin. Roughly 90 percent of the drainage is forested. Logging and associated road building has occurred in nearly all of the lower elevation valleys and on many higher elevation ridges. Roadless areas larger than 5,000 acres are uncommon. Nine roadless areas totaling 139,600 acres exist in the Idaho portion of the subbasin (IPNF 1991). In the Montana portion, nine roadless areas totaling 241,500 acres are present, including approximately 60,000 acres of upper Libby and Lake creeks within the Cabinet Mountains Wilderness Area (USDA 1987). The largest contiguous block of land without logging roads in the British Columbia portion of the Kootenay Basin is the 390,000-acre Kootenay/Mt. Assiniboine National and Provincial Parks (Rocchini 1981). Approximately 150,000 acres of the headwaters of the St. Mary River and Findlay Creek northwest of Cranbrook/Kimberley are within the Purcell Wilderness Conservancy. The total surface area of undeveloped areas amounts to about 10 percent of the Kootenai Subbasin above Kootenay Lake.

Coal and hard rock mining are prominent activities in the subbasin, particularly along the Elk and St. Mary rivers and in the northern Cabinet Mountains. Large-scale, open-pit coal mining began in the Elk River watershed in the early 1970s. Since the late 1930s, the Sullivan Mine at Kimberley, B.C. has been the largest metal producer in the basin. In 1981 it was one of the two largest lead-zinc mines in the world (Daley et al. 1981). From 1981 to the present, a large copper and silver mine and chemical floatation mill has operated in the Lake Creek watershed south of Troy, MT.

About two percent of the subbasin is agricultural land, much of it used for pasture and forage production (Bonde and Bush 1982). Agricultural development is confined primarily to narrow valley bottoms. Though it utilizes a relatively small area, it has had a large impact on habitats of the mainstem river and tributary mouths because most of the activity occurs in the floodplain. The largest contiguous block of agricultural land is within the Purcell Trench, which extends roughly from Bonners Ferry, Idaho to the river's entry into Kootenay Lake. Production of oats, wheat and barley account for 62 percent of the agricultural output in the Bonners Ferry/Creston area, with livestock production accounting for 20 percent. Hay and grass seed production and livestock grazing are the most common agricultural activities in the rest of the subbasin.

The two largest industrial operations and point-source discharges to the Kootenay River are the Crestbrook Forest Industries' pulp mill in Skookumchuck, B.C. and the Cominco mining, milling, and fertilizer plant in Kimberley, B.C. (Daley et al. 1981).

Another industrial operation in the basin was the mining and processing of vermiculite by the W.R. Grace Company northeast of Libby, Montana on Rainy Creek.

Fish Species

Eighteen species of fish are present in Koocanusa 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” rainbow trout fishery, and the state record fish was harvested there in 1997 (over 38 pounds). Bull trout *Salvelinus confluentus* are captured “incidentally”, and 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
White sturgeon	*Acipenser transmontanus*	R	D[Î]	Y[Ï]
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

[Î] Five white sturgeon were relocated from below Libby Dam to the reservoir. At least one of these fish moved upriver out of the reservoir while two have been accounted for from angler reports and one verified mortality.

[Ï] An abundance of anecdotal reports exist of white sturgeon above Kootenai Falls although research to date has failed to validate any reports.

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 at Libby Dam to allow for withdrawal of water from the reservoir's upper stratum.

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 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). 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. A barren varial zone has been created by daily changes in water-flow and stage. Power operations cause rapid fluctuations in dam discharges (as great as 400 percent change in daily discharge), which are inconsistent with the normative river concept (ISAB 1997; ISAB 1997b). Flow fluctuations widen the riverine varial zone, which becomes 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 erosional impacts and destabilizing 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 streamflow, 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 subterranean because of the deltas (Paragamian V., IDFG, pers. com. 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.

Bull Trout Habitat

Forestry practices are the dominant land use in all bull trout core areas and represent the highest risk to bull trout in the middle Kootenai (Libby Dam to Kootenai Falls). This risk to the bull trout population in the middle Kootenai is elevated due to the low number of spawning streams (Quartz, Pipe, O’Brien and Libby Creek drainages) available; a direct result of habitat fragmentation caused by Libby Dam. The Fisher River drainage is also being considered for designation as a core area. The middle Kootenai is a nodal habitat containing critical over-wintering areas, migratory corridors, and habitat required for reproduction and early rearing.

Dam operations are considered a very high risk to the continued existence of the Kootenai drainage population of bull trout (Montana Bull Trout Scientific Group 1996a). Dam operations represent a direct threat to bull trout in the middle Kootenai because of the biological affects associated with unnatural flow fluctuations and potential gas supersaturation problems arising from spilling water. The dam is a fish barrier, restricting this migratory population to 29 miles of river. Habitat fragmentation caused by Libby Dam increases the likelihood that localized effects become a higher risk to the confined population.

In the upper Kootenai (above Libby Dam), the threats to bull trout habitat include illegal fish introduction, introduced fish species, rural residential development, and forestry. Additional risks come from mining, agriculture, water diversions, and illegal harvest (Montana Bull Trout Scientific Group 1996b). Critical spawning streams include the Grave Creek drainage in the U.S.

and the Wigwam drainage in British Columbia. Transboundary research is ongoing in Canadian tributaries known to be used by spawning bull trout: Elk River, St. Mary River, Skookumchuck Creek, White River, Palliser River, and the Kootenay River upstream (Baxter and Oliver 1997). Nodal habitats for this population are provided by Libby Reservoir, Tobacco River, and the Kootenay River in Canada.

Bull trout are found below Kootenai Falls in O'Brien Creek and in Bull Lake, the latter a disjunct population. Montana Fish, Wildlife & Parks (MFWP), in cooperation with Idaho Department of Fish and Game, are monitoring movement patterns of fish tagged after spawning in O'Brien Creek. These fish inhabit areas in the lower Kootenai River and Kootenay Lake during most of the year.

White Sturgeon Habitat

Alteration of the annual hydrograph in the Kootenai River caused by the operation of Libby Dam is considered a primary reason for declines in the Kootenai River white sturgeon population (USFWS 1999 and 2000). Very few young sturgeon have recruited to the population since Libby Dam began impounding the river. Research suggests that the spring freshet is required by white sturgeon for reproduction and early life survival. Historically, white sturgeon spawning corresponded with the May to July runoff period when suitable temperature, water velocity, and photoperiod conditions would normally exist. Prior to the initiation of experimental flow augmentation to restore normative conditions in 1992, Libby Dam had effectively eliminated the naturally high spring runoff event. In addition, cessation of periodic channel maintenance or "flushing" flows has allowed fine sediments to build up in Kootenai River bottom substrates. This sediment fills the spaces between riverbed cobbles, reducing fish egg survival, larval and juvenile fish security cover, and insect production. Biological production was diminished as a result.

Since 1992, experimental flow augmentation during the spawning period appears to have improved conditions for spawning, as evidenced by the collection of more sturgeon eggs (Paragamian et al. 2001). Although spawning has been documented during each year of the flow augmentation tests, few wild juvenile white sturgeon have been captured. Recruitment of juveniles to the Kootenai River white sturgeon population has been insufficient to recover the population and remains a serious concern.

Kootenai River white sturgeon spawn within an 18-km river reach downstream of Bonners Ferry, Idaho (river kilometers (rkm) 228-246). Acoustic Doppler profiles of the Kootenai River bottom have revealed large sand dunes located in the spawning reaches (IDFG/USGS unpublished data). The shifting sand substrate may contribute to egg suffocation and/or prolonged contact with contaminated sediments, contributing to the declining recruitment of young white sturgeon. Sand substrate is thought to be poor habitat for survival of eggs and larva when compared to spawning habitat in unimbedded cobble in the Columbia River (Parsley and Beckman 1994; Paragamian et al. 2001). More suitable substrates of cobble and gravel occur upstream of Bonners Ferry (Apperson 1992, Paragamian et al. 2001).

Researchers have postulated that it may be possible to entice sturgeon to spawn further upstream over unembedded cobble substrates. It is possible that the decline of white sturgeon recruitment may be related to changes in the operation of Kootenay Lake in British Columbia. Concomitant to Libby Dam construction, the springtime maximum surface elevation of Kootenay Lake was lowered 2 m. Higher lake elevations create a backwater effect in the spawning reach. Evidence suggests that as the lake elevation rose during any given spawning season, sturgeon spawned progressively further upstream (Paragamian et al. 2001). Fifty-nine percent of the variation in spawning location was attributable to Kootenay Lake elevation. A linear regression model indicated higher lake elevations might promote spawning further upstream over cobble substrate.

As a consequence of altered flow patterns, average water temperatures in the Kootenai River are typically warmer (by 3 degrees Celsius) during the winter and colder (by 1 - 2 degrees Celsius) during the summer than prior to impoundment at Libby Dam (Partridge 1983). However, during large water releases at Libby Dam in the spring, water temperatures in the Kootenai River may be colder than under normal spring flow conditions.

Much of the Kootenai River has been channelized, diked and stabilized from Bonners Ferry downstream to Kootenay Lake, resulting in reduced aquatic habitat diversity, altered flow conditions at potential spawning and nursery areas, and altered substrates in incubation and rearing habitats necessary for survival (Partridge 1983, Apperson and Anders 1991). Side-channel slough habitats in the Kootenai River flood plain were eliminated by diking and bank stabilization in the Creston Valley Wildlife Management Area in British Columbia and Kootenai National Wildlife Refuge in Idaho.

The overall biological productivity of the Kootenai River downstream of Libby Dam has also been altered. Libby Dam blocks the open exchange of water, organisms, nutrients, and coarser organic matter between the upper and lower Kootenai River. Snyder and Minshall (1996) stated that a significant decrease in concentration of all nutrients examined was apparent in the downstream reaches of the Kootenai River after Libby Dam became operational in 1972. Libby Dam and the impounded Lake Koocanusa reduced downstream transport of phosphorus and nitrogen by up to 63 and 25 percent respectively (Woods 1982), with sediment-trapping efficiencies exceeding 95 percent (Snyder and Minshall 1996). The Kootenai River, like other large river-floodplain ecosystems, was historically characterized by seasonal flooding that promoted the exchange of nutrients and organisms among a mosaic of habitats (Junk et al. 1989; Bayley 1995). As a result of channel alterations, the Kootenai River has a lowered nutrient and carbon-retention capacity. Wetland drainage, diking and subsequent flood control has eliminated the “flood pulse” of the river and retention and inflow of nutrients. Removal of riparian and floodplain forests has eliminated sources of wood to the channel and potential retention structures.

In relation to reduced productivity, potential threats to Kootenai River white sturgeon include decreased prey availability for some life stages, and a possible reduction in the carrying capacity in the Kootenai River and Kootenay Lake to sustain populations of white sturgeon and other native fishes. A limited food supply for young of the year could contribute to increased mortality rates, either through starvation or through increased predation mortality, because young of the year would spend more time feeding, thereby exposing themselves to higher predation risk. The reduction in native kokanee in the South Arm of Kootenay Lake may have also reduced nutrient contributions (deteriorating carcasses from spawners) from tributaries in Northern Idaho and British Columbia flowing into the Kootenai River. Kokanee were also considered an important food source for adult sturgeon to build reserves for the winter and help in final gonad maturation. Growth rates of sturgeon have declined and relative weights in the Kootenai River/Lake population are the lowest in reported sturgeon populations in the Northwest.

Releases from Libby Dam effect water retention time, and thus biological productivity in Kootenay Lake, British Columbia (USFWS 1999). The warm, sunlit epilimnion contains the highest density of photosynthetic phytoplankton, as well as zooplankton. As inflow to the lake increases, more water must flow through the outlet or be stored in the pool. If the pool elevation is stable or declining, inflowing waters displace a commensurate volume that passes through the outlet. The physical configuration of Kootenay Lake, including a shallow sill at the outlet to the West Arm and a downstream control called Grohman Narrows at the outlet to Corra Linn Dam, result in an epilimnetic release of water from the lake. Decreased water retention in the lake's epilimnion results in greater downstream loss (entrainment) of organisms through the turbines. This effect, caused by high summer discharges from Libby Dam is exacerbated during the summer when thermal stratification in Kootenay Lake is well established. Downstream loss of free nutrients and biomass reduces food availability within Kootenay Lake which is inhabited by white sturgeon. Concerns over nutrient levels in the lake are evident by past investigations of nutrient loading (Daley et al. 1981) and ongoing lake fertilization experiments being conducted by Ashley and Thompson (1996).

The Adaptive Environmental Assessment modeling performed for the Kootenai River system in 1997 identified predation on eggs and larvae as a potential threat to successful white sturgeon recruitment. For broadcast spawners like white sturgeon, the mortality rate on eggs and larvae will increase with: 1) an increase in the number of predators; 2) an increase in the vulnerability of eggs or larvae to predation associated with changes in habitat or foraging behavior; and 3) a decrease in the volume or area of water that the eggs/larvae are dispersing into or over (as volume or area decreases, prey concentration to predators in increases). In post-impoundment years, Kootenai River springtime flows have been reduced substantially and vulnerability has increased due to an increase in water clarity and reduced food supply, as well as loss of unimbedded habitat in the spawning reach (Korman and Walters 1999).

Georgi (1993) noted that the chronic effects on wild sturgeon spawning in "chemically polluted" water and rearing over contaminated sediments, in combination with bioaccumulation of contaminants in the food chain, is possibly reducing the successful reproduction and early-age recruitment to the Kootenai River white sturgeon population. Results from a contaminant study performed in 1998 and 1999 showed that water concentrations of total iron, zinc, and manganese, and the PCB Arochlor 1260 exceeded suggested environmental background levels (Kruse 2000). Zinc and PCB levels exceeded EPA freshwater quality criteria. Several metals, organochlorine pesticides, and the PCB Arochlor 1260 were found above laboratory detection limits in ova from adult female white sturgeon in the Kootenai River. Plasma steroid levels in adult female sturgeon showed a significant positive correlation with ovarian tissue concentrations of the PCB Arochlor 1260, zinc, DDT, and all organochlorine compounds combined, suggesting potential disruption of reproductive processes. In an experiment designed to assess the effects of aquatic contaminants on sturgeon embryos, results suggest that contact with river-bottom sediment increases the exposure of incubating embryos to metal and organochlorine compounds (Kruse 2000). Increased exposure to copper and Arochlor 1260 significantly decreased survival and incubation time of white sturgeon embryos and could be a potentially significant additional stressor to the white sturgeon population.

Burbot Habitat

The timing of the collapse of the burbot fisheries in Idaho and British Columbia coincide with the operation of Libby Dam and associated changes in discharge volumes and water temperature. McPhail (1995) stated, "although burbot populations often increase after impoundment, the downstream effects of impoundment can be detrimental." Burbot are plentiful in Lake

Koocanusa, Montana (Skaar, D. MFWP, pers. com. 2000) and make up a portion of the fish entrained through Libby Dam (Skaar et al. 1996). The population downstream of Libby Dam has declined, however.

Winter hydropower operations produce higher flows and wider flow fluctuations than occurred naturally prior to Libby Dam. Burbot are winter spawners, known to spawn at temperatures from 1 to 4 ^{o}C (McPhail and Paragamian 2000). The Kootenai River is now 4^{o}C warmer during winter than prior to impoundment. Unnaturally high flows or altered temperatures during winter may have altered the spawning behavior of fluvial and adfluvial burbot in the Kootenai River, disrupted their spawning synchrony [burbot are considered highly ordered in their spawning (Becker 1983)], or affected their physiological fitness or spawning readiness. Burbot can move extensive distances during the winter to spawn. Burbot are weak swimmers and have a low endurance for extended periods of increased flow (critical velocity of about 24 cm/s) (Jones et al. 1974). In the Kootenai River, traditional spawning tributaries in Idaho are 50 to 120 km upstream from Kootenay Lake. Current velocities in the lower Kootenai River are subject to change daily due to operations at Libby Dam, and water velocity is a function of river discharge and Kootenay Lake surface elevation. Flows in the Kootenai River at Copeland, Idaho greater than 255 m^3/s produce average current velocities higher than the critical velocity (>24cm/s) for burbot (Paragamian 2000). Flow near the Idaho/B.C. border can often be as high as 510 m^3/s during normal winter dam operations. Tagging and telemetry studies in the river have shown that burbot move freely between the lake and the river in Idaho, providing flow velocities are low. Paragamian (2000) provided telemetry data that indicated high flows during the winter inhibit spawning migrations of burbot in the Kootenai River. In addition, biopsies of post-spawn female and male burbot indicated that some burbot do not spawn and are reabsorbing gonadal products (Paragamian 1994; Paragamian and Whitman 1996).

Westslope Cutthroat Trout and Interior Redband Trout Habitat

Libby Dam has affected westslope cutthroat trout and interior redband trout in many of the same ways as it has affected bull trout. Alterations of the hydrograph have resulted in a loss of mainstem salmonid spawning and rearing habitat. Fluctuating discharges from Libby Dam force juvenile salmonids to frequently seek new habitat, increasing the risk of predation. In addition, the widely fluctuating flows prevent colonization of the varial zone by periphyton and macroinvertebrates, reducing the efficiency with which energy is transferred from one trophic level to another. Abundance and diversity of important aquatic invertebrates has declined since construction of Libby Dam (Hauer et al. 1997), further reducing food abundance for trout. All of these factors combined have likely resulted in reduced trout abundance in the Kootenai River.

Kokanee Habitat

Kootenai River kokanee are spawning populations from Kootenay Lake and the numbers of spawners in the river within Idaho and Montana are affected by habitat conditions altered by lake and river regulation. The construction of Duncan Dam on the Duncan River in 1967 and Libby Dam on the Kootenai River in 1972 resulted in reduced nutrient loading (primarily nitrogen and phosphorus) to Kootenay Lake followed by a decline in phytoplankton, zooplankton, and ultimately kokanee abundance (Ashley and Thompson 1993 and 1996). Kokanee populations continued to decline throughout the 1980s, and by 1990 the South Arm stocks of kokanee had become virtually extinct (Richards 1996). The presence of *Mysis relicta* in Kootenay Lake and their potential to compete with juvenile kokanee for zooplankton makes it difficult to quantify the affect of the reduced phosphorus loading on kokanee numbers. Dike construction and channelization in the lower river and grazing activity in key spawning tributaries in Idaho may also have influenced the decline of kokanee.

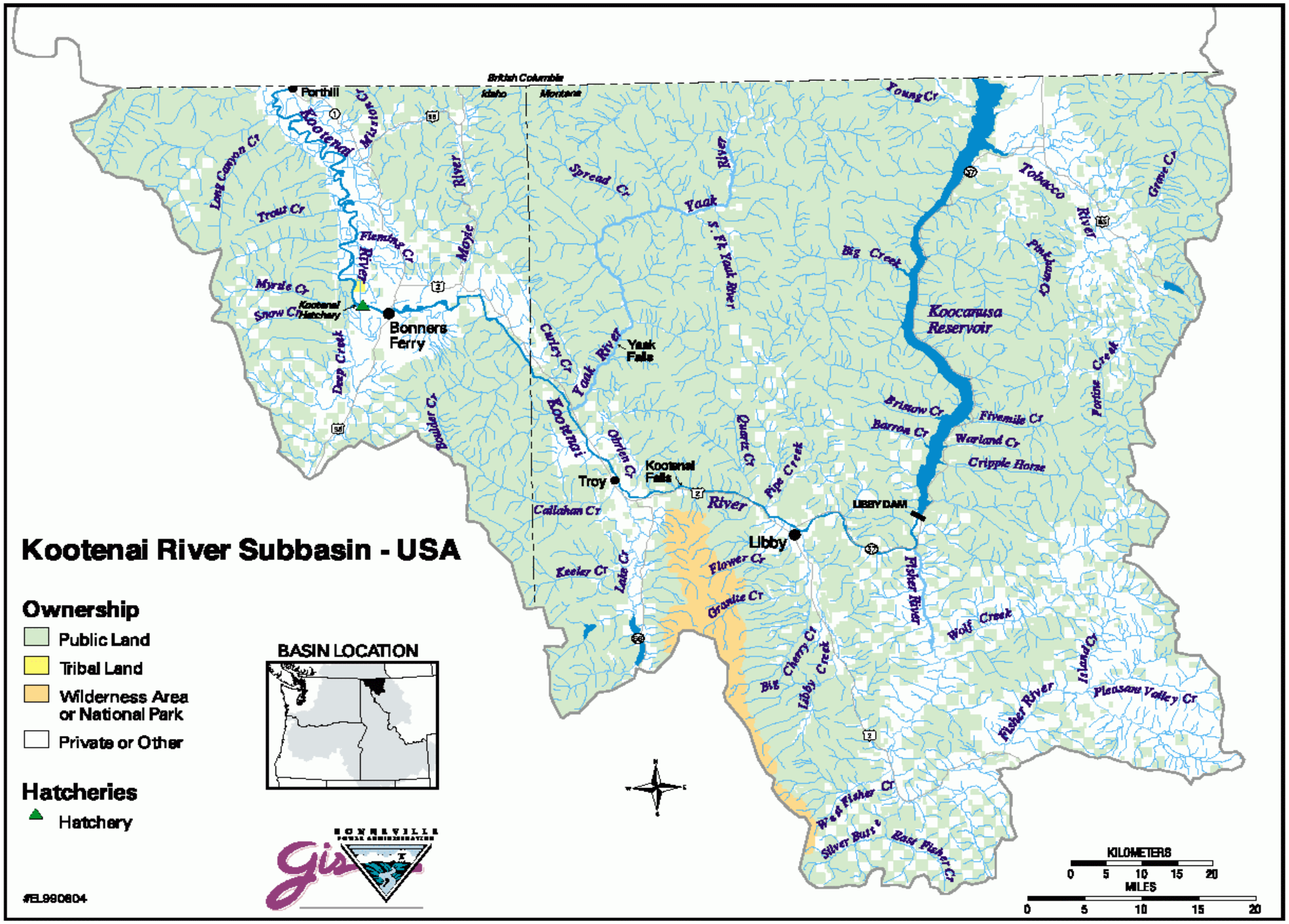

Figure 2. Kootenai River Basin, Montana.

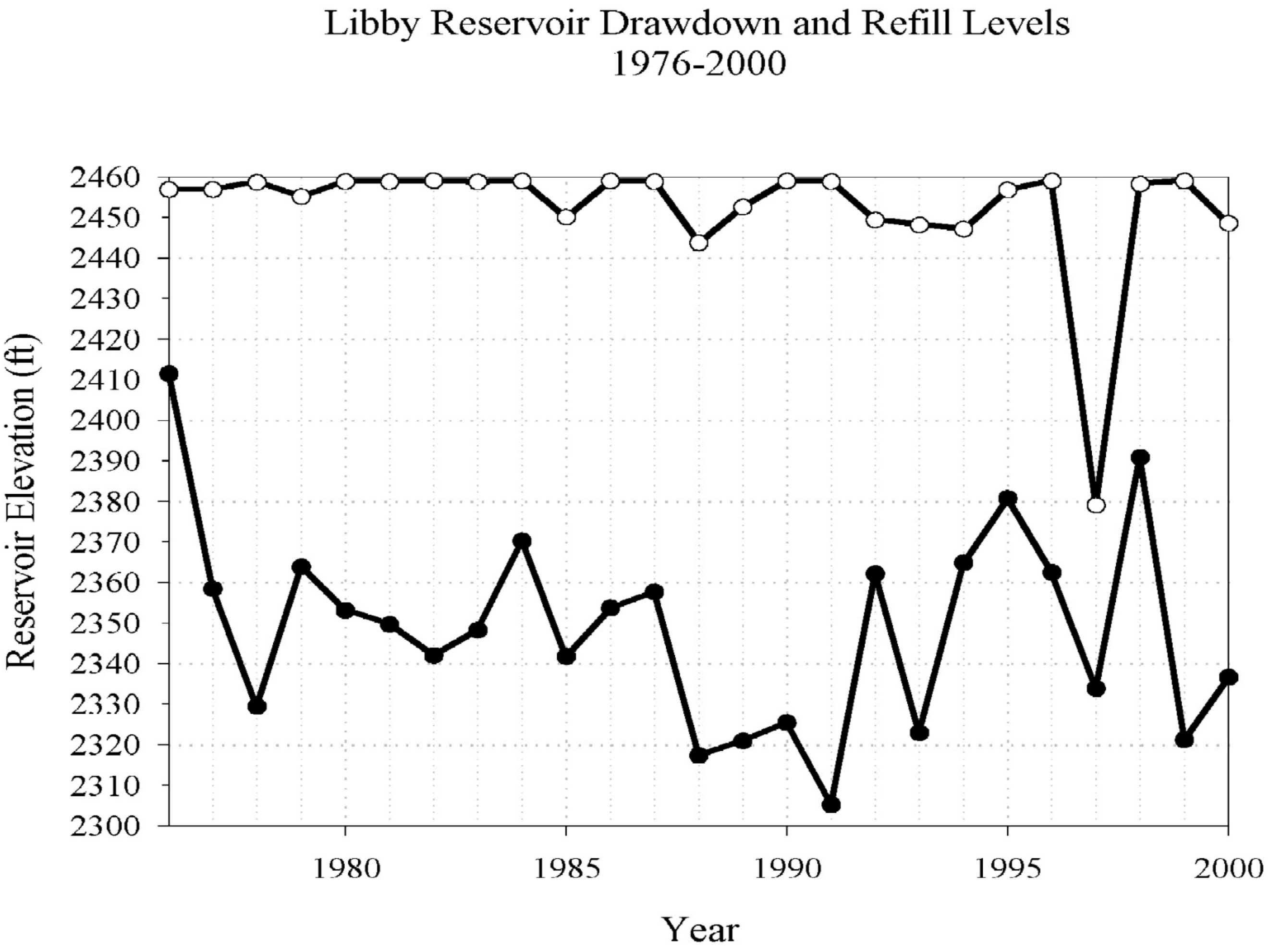

Figure 3. Libby Reservoir elevations (minimum, maximum), 1976 through 2000.

BULL TROUT REDD COUNTS

MFWP began counting bull trout redds in the Kootenai River drainage in 1983 (Grave Creek). Quartz, West Fork of Quartz, and Pipe Creeks were added to the list of surveyed streams in 1984. Due to added concern over diminishing bull trout populations throughout Montana, we began surveying other streams in the Kootenai basin in 1991. A total of 165 miles in 45 streams have been surveyed for bull trout redds to date. Streams were eliminated from the monitoring list if they lacked suitable spawning habitat and if there was no evidence of adult bull trout use.

Special restrictive fishing regulations were adopted in the early 1990's in response to increasing concern over declining bull trout populations across their range, including Montana. The Kootenai drainage (Quartz Creek) was closed to all fishing from July 15 to the third Saturday in May in 1992. A statewide closure (except the Swan drainage) was imposed for all bull trout fishing in 1993. No angling has been allowed within 100-yard radius of the mouths of O'Brien and Quartz Creek from 1 June through 30 August since 1996.

Methods

Redd surveys were conducted in the fall, (usually October) after bull trout spawned. MFWP and U.S. Forest Service (USFS) personnel walked streams, counting "positive" and "possible" redds. "Possible" redds were those that did not have fully developed pits and gravel berms. 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.

Results and Discussion

The Montana Bull Trout Scientific Group divided the Kootenai River into three separate core areas; Upper Kootenai River (upstream of Libby Dam), Middle Kootenai River (Kootenai Falls to Libby Dam) and the Lower Kootenai River (downstream of Kootenai Falls). We found the highest concentration of redds in the Middle Kootenai core area in Quartz and West Fork (W.F.) Quartz Creeks. In the Lower Kootenai core area, the highest concentration of redds was in O'Brien Creek. The Grave Creek drainage had the highest concentration of adfluvial bull trout redds in the United States tributaries of the Upper Kootenai River core area. The Wigwam River Basin in British Columbia had the highest concentration of redds for the Canadian tributaries of the Upper Kootenai core area population. Keeler Creek, a tributary of Lake Creek, supports a run of adfluvial bull trout isolated from the Lower Kootenai River. Redd counts in Keeler Creek were initiated in 1996.

Bear Creek, Pipe Creek and East Fork (E.F.) Fisher River are used sparingly by spawning bull trout. Other tributaries of the Kootenai River have little or no spawning habitat for bull trout. Due to the lack of historic data on most streams, it is difficult to know if these streams once supported runs of adfluvial or fluvial bull trout.

Upper Kootenai River

- ***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 2000. Grave Creek was surveyed from its confluence with the Tobacco River upstream to near the mouth of Lewis Creek (~13 mi.), where it becomes intermittent. Most redds in Grave Creek were located upstream from the mouth of Clarence Creek to the confluence with Lewis Creek. Surveyors found 10 redds between the confluence with the Tobacco River and one mile below Clarence Creek in 1983 (Table 3). We did not find redds in this reach during the most recent surveys (1993 through 2000).

Clarence and Blue Sky Creeks were surveyed in conjunction with Grave Creek. Redd locations in Clarence Creek were similar during each survey, except for 10 redds found above the bridge on road number 7036 in 1983. No redds were found in this reach during later surveys (1993 through 1996). Surveyors found few redds in Blue Sky Creek, which has scattered patches of quality gravel. No redds were found in Lewis, Williams, or Stahl Creeks, which were surveyed in 1983 and 1993, though juvenile bull trout were present in each of the streams.

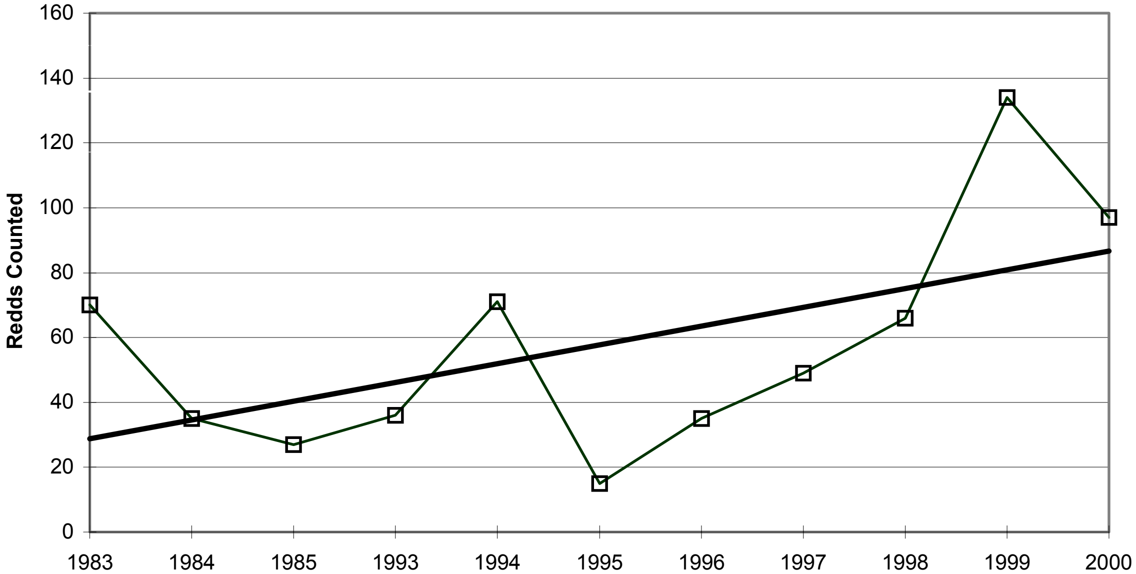

Figure 4. Bull trout redd counts in Grave Creek, Montana, and trend line.

Table 3. Bull trout redd survey summary for all index tributaries in the Kootenai River Basin above Libby Dam.

Stream	Year Surveyed	No. of Redds	Miles Surveyed
Grave[a]	1983	70	17
	1984	35	17
	1985	27	9
	1991	27	15
	1993	36	17.1
	1994	71	11.5
	1995	15	9
	1996	35	17
	1997	49	9
	1998	66	9
	1999	134	9
	2000	97	9
Wigwam (B.C. & U.S.)	1996	524	22
	1997	615	22
	1998	691	22
	1999	889	22
	2000	1204	22

a. Includes Blue Sky and Clarence Creeks

Table 4. Bull trout redd survey summary for all index tributaries in the Kootenai River Basin below Libby Dam.

Stream	Year Surveyed	No. of Redds	Miles Surveyed
Quartz[b]	1990	76	9
	1991	77	10
	1992	17	10
	1993	89	10.8
	1994	64	12.5
	1995	66	12.5
	1996	47	12.0
	1997	69	12.0
	1998	105	8.5
	1999	102	8.5
	2000	91	8.5
O'Brien	1991	25	13.25
	1992	24	8.0
	1993	6	8.0
	1994	7	6.5
	1995	22	4.5
	1996	12	4.0
	1997	36	4.3
	1998	47	4.3
	1999	37	4.3
	2000	34	4.3
Pipe	1990	6	10
	1991	5	10.5
	1992	11	11.5
	1993	6	13.5
	1994	7	9.8
	1995	5	10
	1996	17	12.0
	1997	26	8.0
	1998	34	8.0
	1999	36	8.0
	2000	30	8.0
Bear	1995	6	3.0
	1996	10	4.5
	1997	13	4.25
	1998	22	4.25
	1999	36	4.25
	2000	23	4.25
Keeler[c]	1996	74	9.3
	1997	59	8.9
	1998	92	8.9
	1999	99	8.9
	2000	90	8.9

b. Includes West Fork Quartz Creek
c. Includes West, South and North Forks of Keeler Creek

- ***Wigwam Drainage***

Redd counts in the Wigwam drainage in Canada continue to increase (Figure 5). This is probably due to several factors, including restrictive angling in Canadian waters, and closure of angling for bull trout in the U.S.

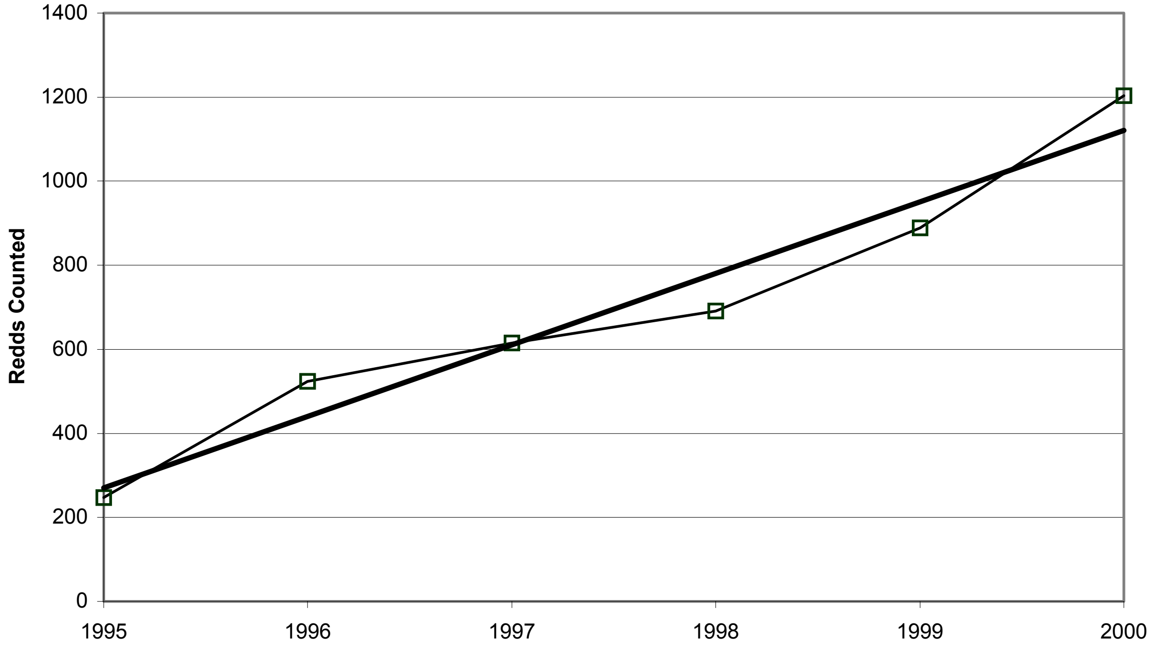

Figure 5. Bull trout redd counts in the Wigwam River, Montana and British Columbia, and trend line.

Middle Kootenai River

- ***Quartz Creek***

Although redd numbers have remained stable (Table 4), distribution of redds in Quartz and W. F. Quartz Creeks have varied. Counts in Quartz Creek upstream from the confluence with the W.F. have declined. Overall, the trend is upward (Figure 6).

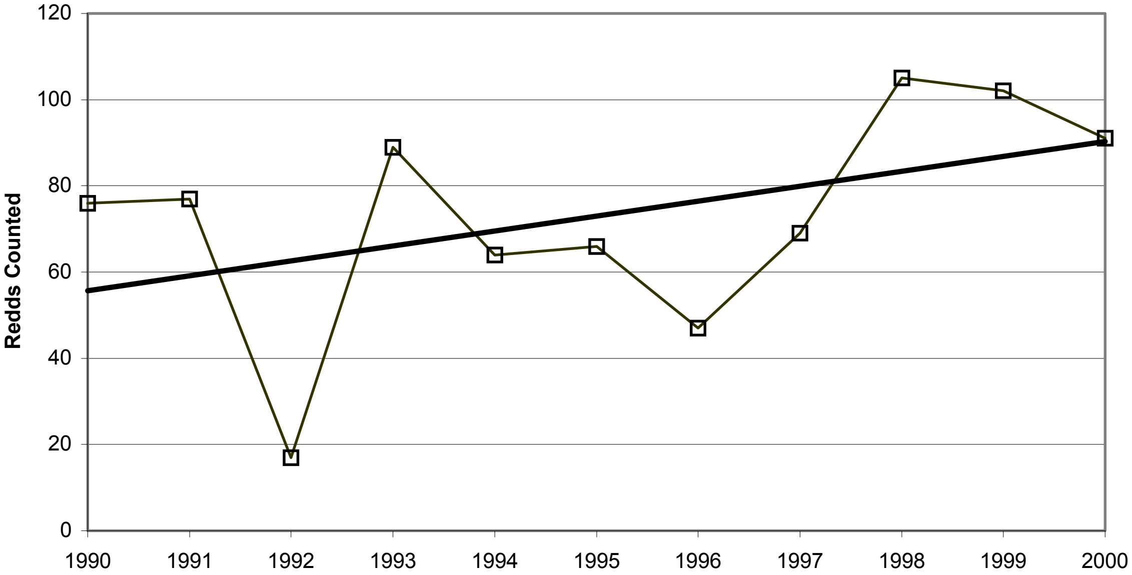

Figure 6. Bull trout redd counts in Quartz Creek, Montana, and trend line.

- ***Pipe Creek***

Pipe Creek has been surveyed for bull trout redds since 1991. Only 7 miles of the original 13.5 miles surveyed appear to have adequate bull trout spawning habitat; those portions of the stream are the only areas presently surveyed. No suitable spawning gravels exist in the lower 5 miles of Pipe Creek. There are brook trout present in Pipe Creek. The general trend of bull trout redds in Pipe Creek is generally increasing in recent years (Figure 7).

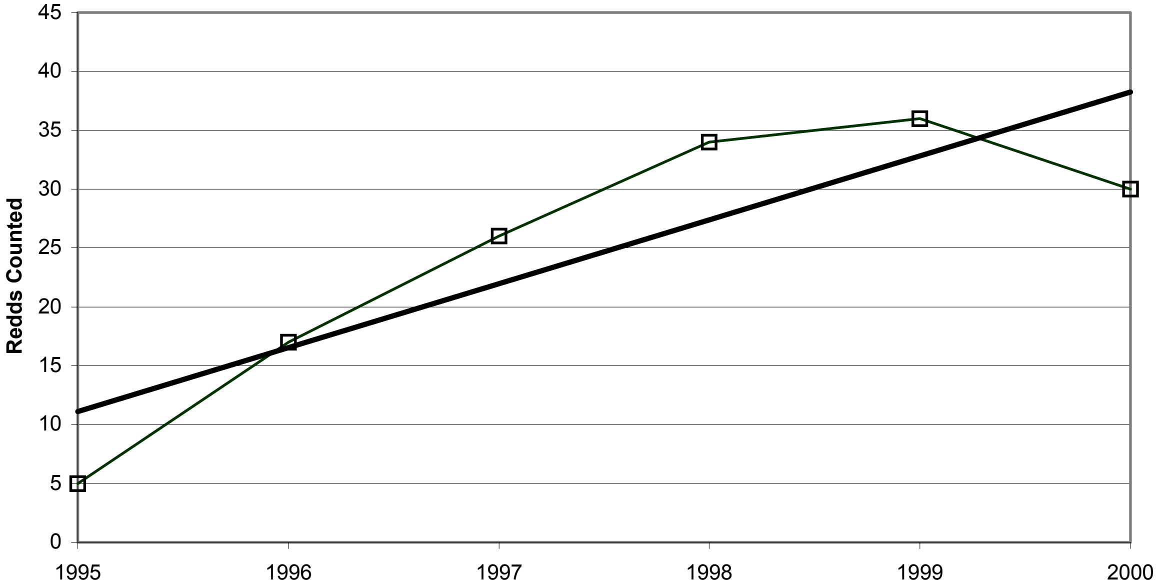

Figure 7. Bull trout redd counts in Pipe Creek, Montana, and trend line.

Libby Creek

Migrating adult bull trout were trapped in Libby Creek during the summer of 1996; the trap captured only two adult bull trout. In spite of the small number of bull trout captured, ten bull trout redds were counted in Bear Creek (Table 4), which is the only tributary to Libby Creek above the trap where bull trout redds have been found during all redd surveys. It is possible that the trap was set up after most bull trout had moved upstream. Libby Creek has a very unstable channel with little spawning habitat, and a lack of woody debris and overhead cover, which are important rearing habitat components (Baxter and McPhail 1996; Thomas and McPhail 1992). Trapping in subsequent years was ineffective. In 1998, three bull trout were observed below the trap between October 30 and November 2. Two of these fish were passed through the trap to continue upstream, and the third bull trout remained downstream of the trap. No bull trout were observed during the 1999 trapping season. We counted a total of 22 and 36 redds respectively in 1998 and 1999 in Bear Creek, a tributary to Libby Creek.

Lower Kootenai River

- ***O'Brien Creek***

Bull trout in the Kootenai River were isolated from O'Brien Creek by a log dam constructed in the 1930's for sawmill operations. Electrofishing data from the 1960's indicate bull trout migrated above the dam. It is uncertain to what level the dam impeded migration of fluvial bull trout due to its deteriorating condition in the 1950's and 1960's. The dam was removed in 1977, allowing unrestricted access for fish to upper O'Brien Creek. The general trend of bull trout redds in O'Brien Creek is generally increasing in recent years (Figure 8).

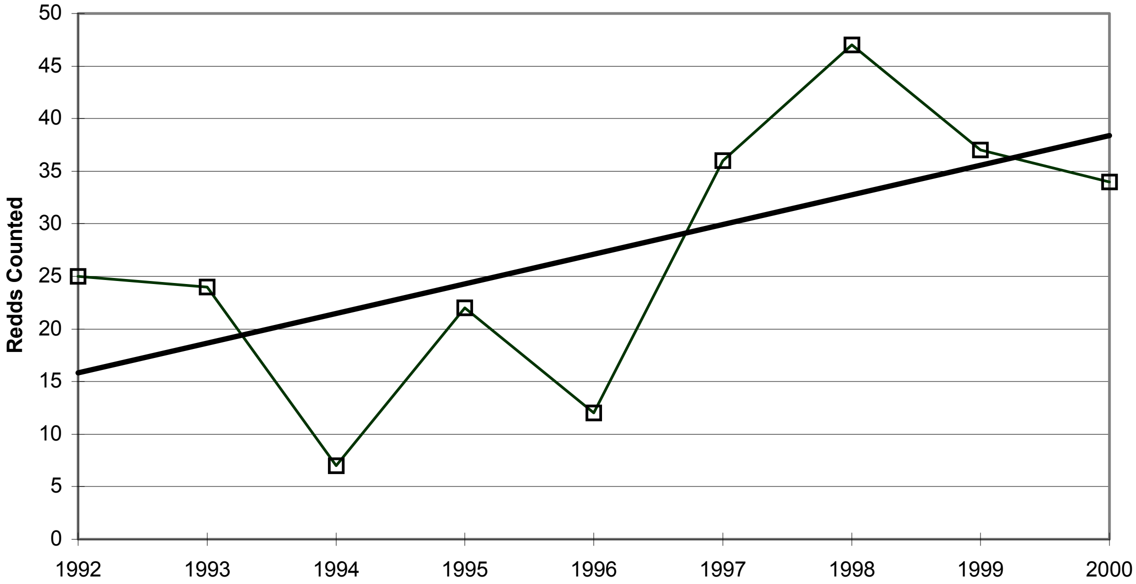

Figure 8. Bull trout redd counts in O'Brien Creek, Montana, and trend line.

- ***Keeler Creek***

Bull trout in Keeler Creek (including the North, South and West Forks), a tributary to Lake Creek, are adfluvial, migrating 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 Restoration Team 1996a). 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. The number of bull trout redds in Keeler Creek in 1998-2000 increased from those observed in 1996 and 1997, for a general increasing trend in recent years (Figure 9).

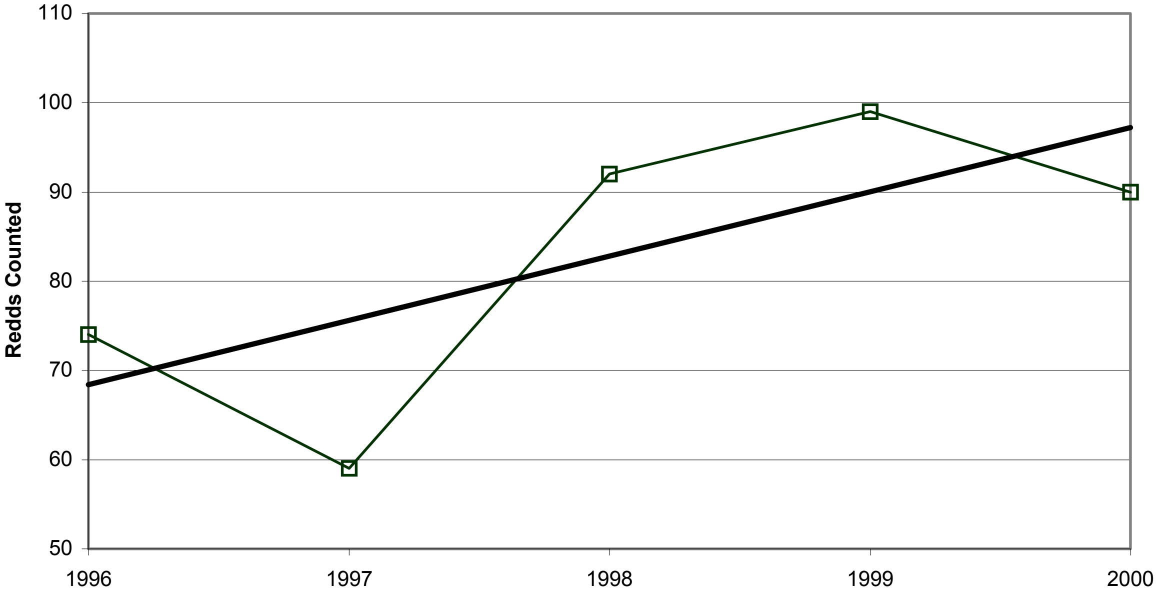

Figure 9. Bull trout redd counts in Keeler Creek, Montana, and trend line.

Discussion

Long-term monitoring of bull trout redd numbers are important in monitoring bull trout population trends (Rieman & McIntyre 1993). Trends in most streams show increases in abundance of bull trout; recent low water years may be associated with slight declines in counts. Index streams such as Quartz, Grave, O'Brien, Wigwam, Keeler and Bear Creeks will continue to be surveyed yearly. Annual monitoring of these index streams allows management agencies to evaluate the success or failure of recovery efforts. Streams with potential to provide bull trout spawning will be monitored semi-annually to determine bull trout use and changes in land use status. Habitat enhancement efforts by MFWP will target stream reaches identified as bull trout core areas, with the goal of increasing total miles of stream in the Kootenai Basin used by bull trout. We will continue to assist in monitoring British Columbia tributaries to Libby Reservoir to quantify bull trout spawning and determine contribution of these streams to Montana waters.

BULL TROUT RADIO TELEMETRY

FWP personnel have surgically implanted sixty-five low frequency transmitters (48 and 49 mhz) into bull trout 400-823 mm since January, 1998 (Figure 10). Nine of these fish were captured in Quartz Creek (above Kootenai Falls), one was captured in Callahan Creek (below Kootenai Falls), three were captured in Lake Koocanusa (released below the dam), and fifty-two were captured between Libby Dam and Alexander Creek (one from below the dam was released in Lake Koocanusa).

Figure 10. Implanting radio tag in a bull trout in the Kootenai River, Montana.

We tracked the radio-tagged bull trout from a jet boat using a Lotek SRX_400 receiver and hand held loop antenna. The fish that were not located were then tracked using a plane with loop antennas mounted to the wings and a Lotek receiver. The fish were tracked weekly through the spring and summer months and once a month during the winter due to a lack of fish migration.

Of the sixty-five radioed fish, eight of them have not been located since they were tagged and released. These included the fish tagged in Callahan Creek, one from above the dam, one from Quartz Creek and four from below Libby Dam. Eighteen of the fish were tracked through 1998 and 1999, but were not located in 2000 because of battery life or possible transmitter failure. The remaining fish were tracked and locations were documented throughout 2000 (Figures 11, 12).

Forty of the fish remained above Kootenai Falls and twenty fish migrated to below the falls after radio tags were implanted, traveling up to 84 miles. The fish that have remained above the falls show little movement during the winter months. There does, however, seem to be movements that correlate with changes in flows in the spring and for spawning migrations in fall. Of the nineteen remaining fish below Kootenai Falls, one migrated back up over the falls during a spawning migration in September of 2000. This is the first recorded instance of a fish migrating upstream over the falls; therefore, the falls is not a barrier to all upstream fish migration, though it does serve as a migration impediment. A majority of the fish below the falls displayed similar movement patterns as those above the falls.

We plan to continue monitoring the movements of the bull trout throughout the remainder of the battery life of the transmitters. We hope to capture several fish in Bear Creek, a tributary to Libby Creek, to determine if the spawning population there is adfluvial from the Kootenai River, fluvial from Libby Creek, or resident to Bear Creek. We will also capture five fish below the dam and place them above the dam to determine if they will migrate to the upper Kootenai to spawn.

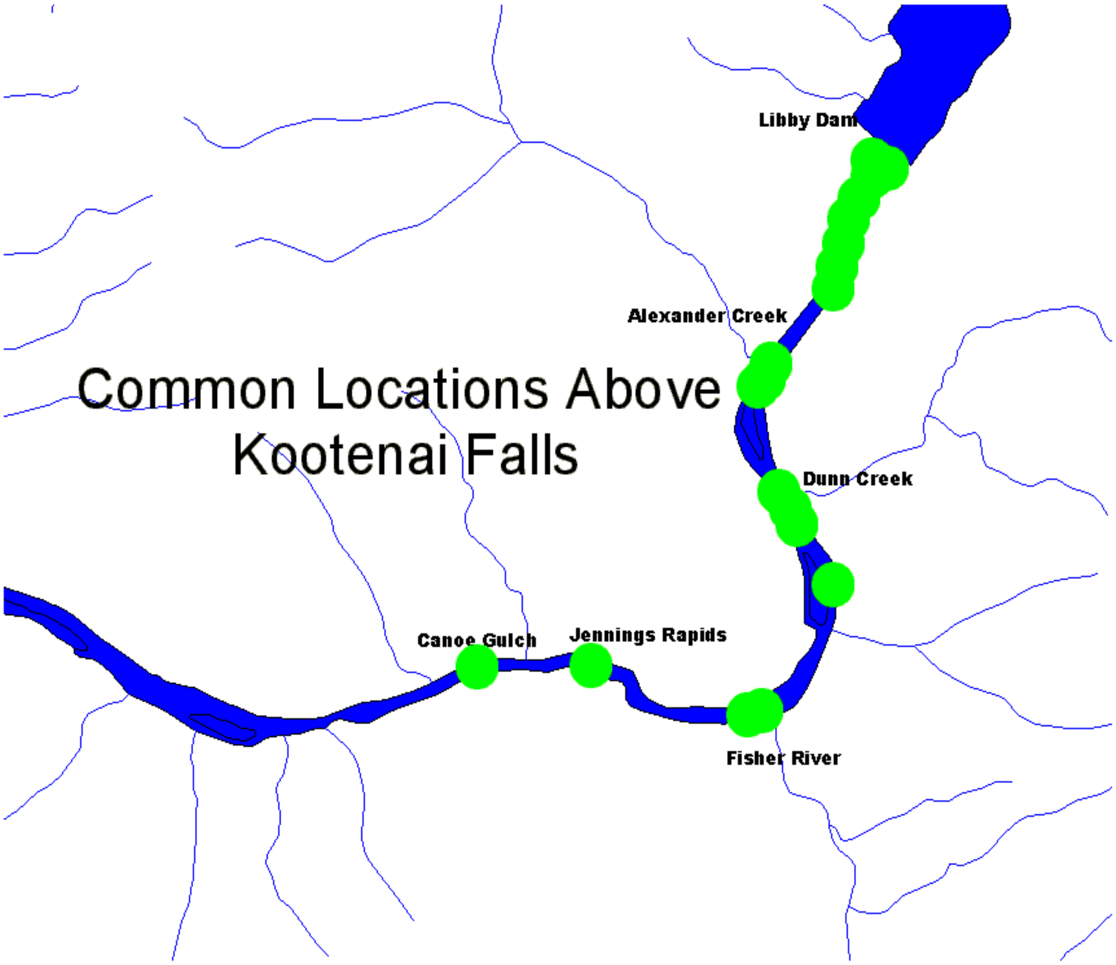

Figure 11. Location identification (green) of radio tagged bull trout in the Kootenai River upstream of Kootenai Falls, 2000.

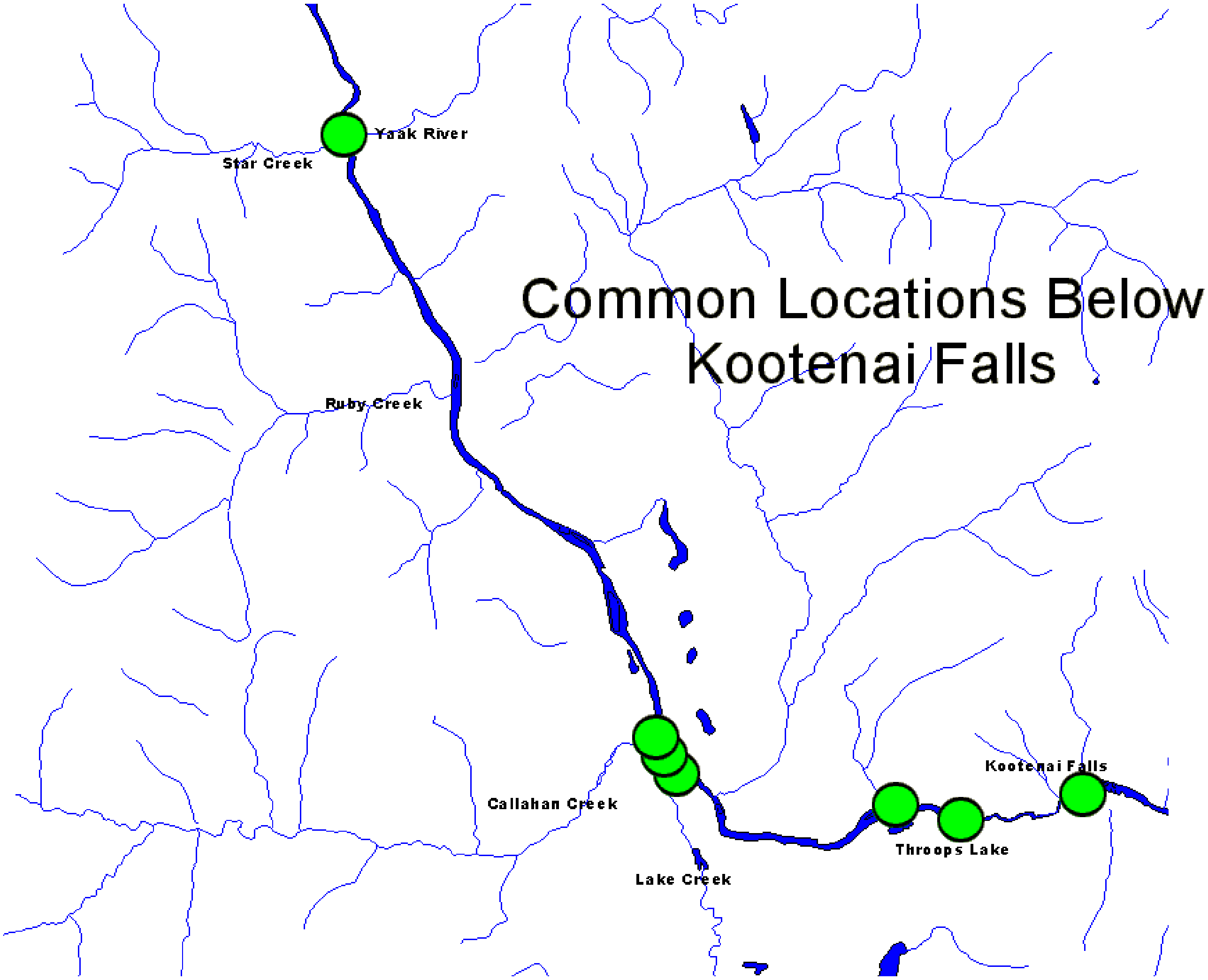

Figure 12. Location identification (green) of radio tagged bull trout in the Kootenai River downstream of Kootenai Falls, 2000.

BURBOT

We have monitored burbot densities in the stilling basin below Libby Dam and below Kootenai Falls since 1994. We use baited hoop traps during December and February to capture burbot in or near spawning condition. We pit tag all fish captured and scan for recaptures. This allows us to estimate spawning population density and movement.

We have observed spawning activity during SCUBA transects of the stilling basin (Figure 13), but have not documented successful spawning there. We placed experimental spawning boxes (Figure 14) in the stilling basin during the winter of 1999 to see if presence of various –sized gravels would induce successful spawning. We have yet to observe burbot using these boxes.

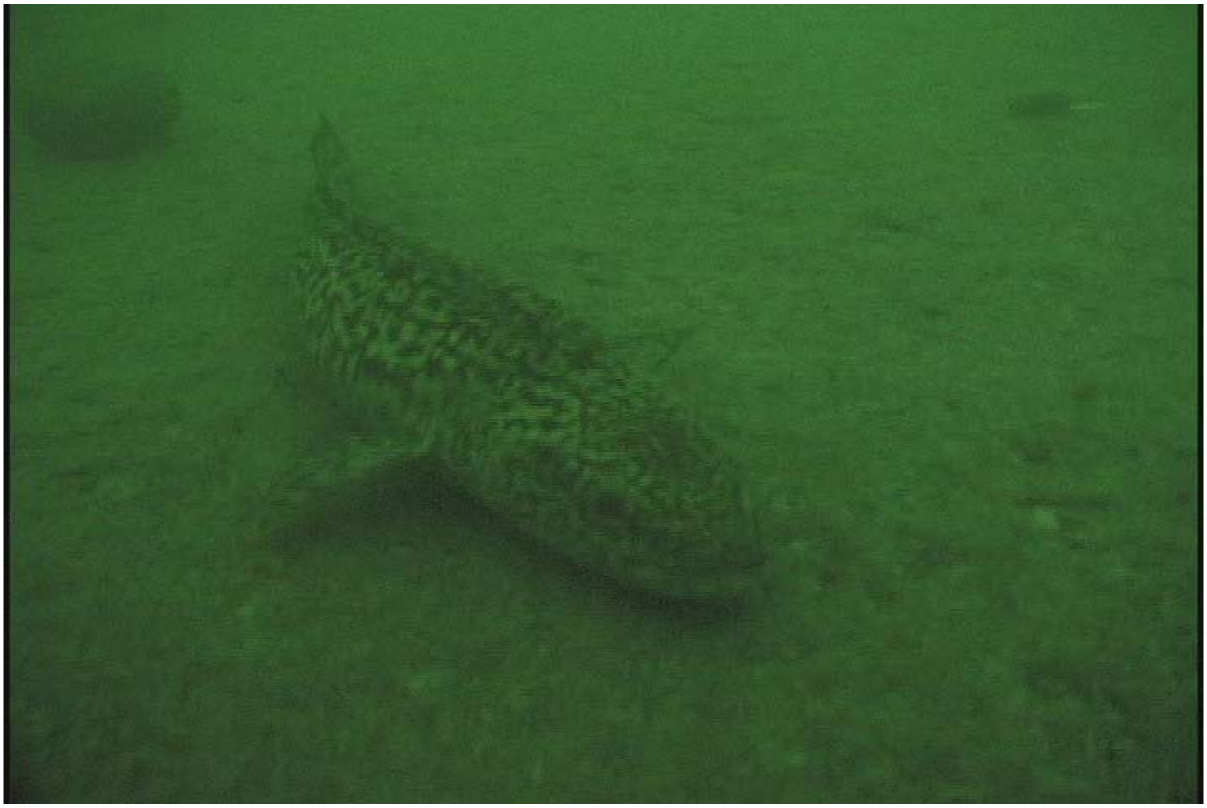

Figure 13. Burbot observed during SCUBA transects below Libby Dam on the Kootenai River, Montana.

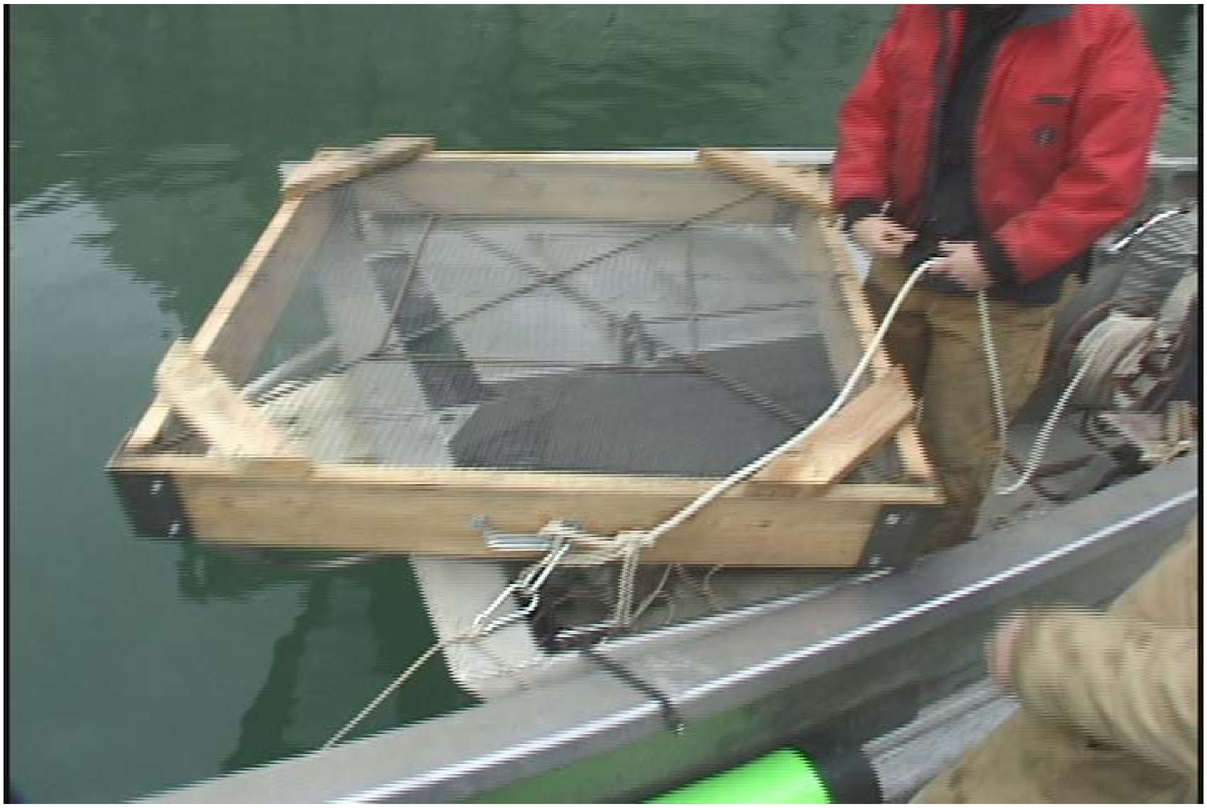

Figure 14. Experimental spawning box placed for burbot below Libby Dam on the Kootenai River, Montana.

The density of burbot captured in our hoop traps below the stilling basin has declined precipitously since 1996–97 (Figure 15). 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, which may correlate with lower water temperatures, something believed to be crucial for burbot reproduction.

We set hoop nets below Kootenai Falls in an attempt to capture burbot that may have migrated from Libby Dam downstream. Very few burbot have been captured below Kootenai Falls (Figure 16).

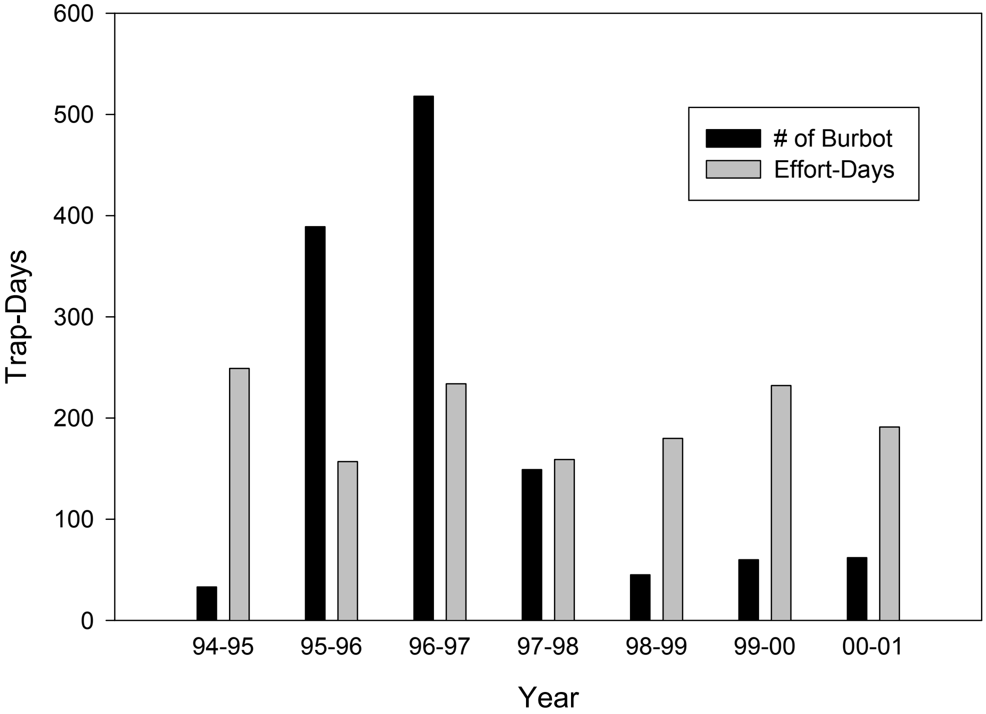

Figure 15. Capture of burbot below Libby Dam during winter months (December and February), 1994 through 2000.

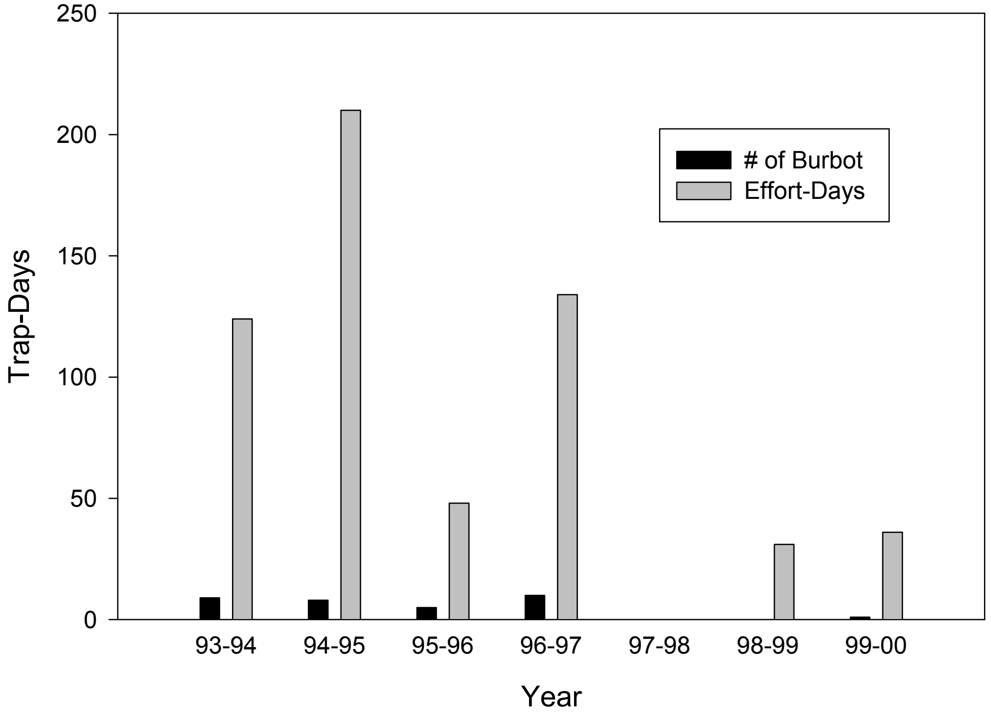

Figure 16. Capture of burbot below Kootenai Falls during winter months (December and February), 1994 through 2000.

KOOTENAI RIVER TEMPERATURE MONITORING

Temperatures in the Kootenai River below Libby Dam are monitored to help assure that proper temperatures are being attained through selective withdrawal gates in Libby Dam. We also monitor temperatures to observe if drastic changes induce behavior in bull trout, such as sudden migrations or movements, and to track the influence of tributaries on the Kootenai River mainstem temperatures. All temperatures presented in this section were collected using a Stowaway model temperature recorder manufactured by the Onset Corporation.

Water temperature in the stilling basin directly below Libby Dam has low diel variation when water is passed through the turbines from various depths in Libby Reservoir. The most variation in diel temperature within the stilling basin generally occurred between May 2 and October 27, 2000, with a mean difference between daily mean and maximum temperatures averaging 0.48 degrees F (Figure 17). The mean difference between daily mean and maximum temperatures between January 1 and May 1 was only 0.16 degrees F. The maximum mean daily and maximum temperature were 58.6 and 58.8 degrees F respectively, both occurring on August 17, 2000. The minimum mean daily and minimum temperatures were 36.34 and 36.41 degrees F respectively, these temperatures also both occurred on the same day, February 18, 2000. Water temperatures may be more variable occasionally when the spillway or sluice gate are operated.

Water temperature in the Kootenai River above and below the confluence of Libby Creek was monitored throughout in 2000 (Figure 18). The temperature recorder was located approximately 0.6 miles below the confluence of Libby Creek, on the opposite side of the river to ensure that thorough mixing had occurred. We split the annual temperature plot comparing upstream and downstream temperature data into 5 strata based on visual examination of the data. We identified periods when consistent patterns of difference between upstream and downstream temperatures existed. These five periods were January 1 – February 25, February 26 – May 15, May 16 – June 19, June 20 – August 14, and August 15 – December 31 (Figure 18). Five separate paired t-tests of the upstream and downstream temperature data confirmed significant differences in the visual observations during the five strata. Mean daily water temperatures in the Kootenai River during the January 1 – February 25, May 16 – June 19, and August 15 – December 31 strata were consistently cooler downstream of the confluence of Libby Creek by 0.32, 1.18 and 0.59 degrees F respectively, suggesting that Libby Creek may have been slightly decreasing the temperature of the Kootenai River during these periods in 2000. However, during the February 26 – May 15, and June 20 – August 14 strata, the Kootenai River downstream of the confluence of Libby Creek was warmer than upstream, suggesting a warming influence on the Kootenai River by Libby Creek.

Water temperature on the Kootenai River was monitored below the confluence of Quartz Creek approximately in 2000. We split the annual temperature plot of daily mean and daily maximum temperature data into 2 strata based on visual examination of the data (Figure 19). We identified periods when the difference between the daily mean and daily maximum temperatures was relatively large and relatively small. Diel variation in water temperature of the Kootenai River below Quartz Creek was lowest during the winter months (November – December and January –February), and highest during the non-winter months (March – October). The mean difference between mean daily and daily maximum during the winter and non-winter months was 0.38 and 1.73 degrees F, respectively. The highest diel variation (3.68 degrees) occurred on September 29. The maximum mean daily and maximum daily temperature recorded (60.53 and 63.03, respectively) both occurred on August 17, 2000.

Water temperature in the Kootenai River above and below the confluence of the Yaak River was monitored throughout in 2000 (Figure 20). The temperature recorder was located approximately 0.8 miles below the confluence of the Yaak River, on the opposite side of the river to ensure that thorough mixing had occurred. We split the annual temperature plot of upstream and downstream temperature data into 4 strata based on visual examination of the data. We identified periods when consistent patterns of difference between upstream and downstream temperatures existed. These four periods were January 1 – April 14, April 15 – April 30, May 1 – July 6, and July 7 – December 31 (Figure 20). Four separate paired t-tests of the upstream and downstream temperature data confirmed significant differences in the visual observations during the five strata. Mean daily water temperatures in the Kootenai River during the April 15 – April 30 and July 7 – December 31 strata were consistently cooler downstream of the confluence of the Yaak River by an average of 1.42 and 0.34 degrees F respectively, suggesting that the Yaak River may have been slightly decreasing the temperature of the Kootenai River during these periods in 2000. However, during the January 1 – April 14 and May 1 – July 6 strata, the Kootenai River downstream of the confluence of the Yaak River was an average of 0.83 and 0.56 degrees F warmer than upstream, suggesting a warming influence on the Kootenai River by the Yaak River.

Figure 17. Mean daily and maximum water temperature in the stilling basin below Libby Dam, Montana, 2000.

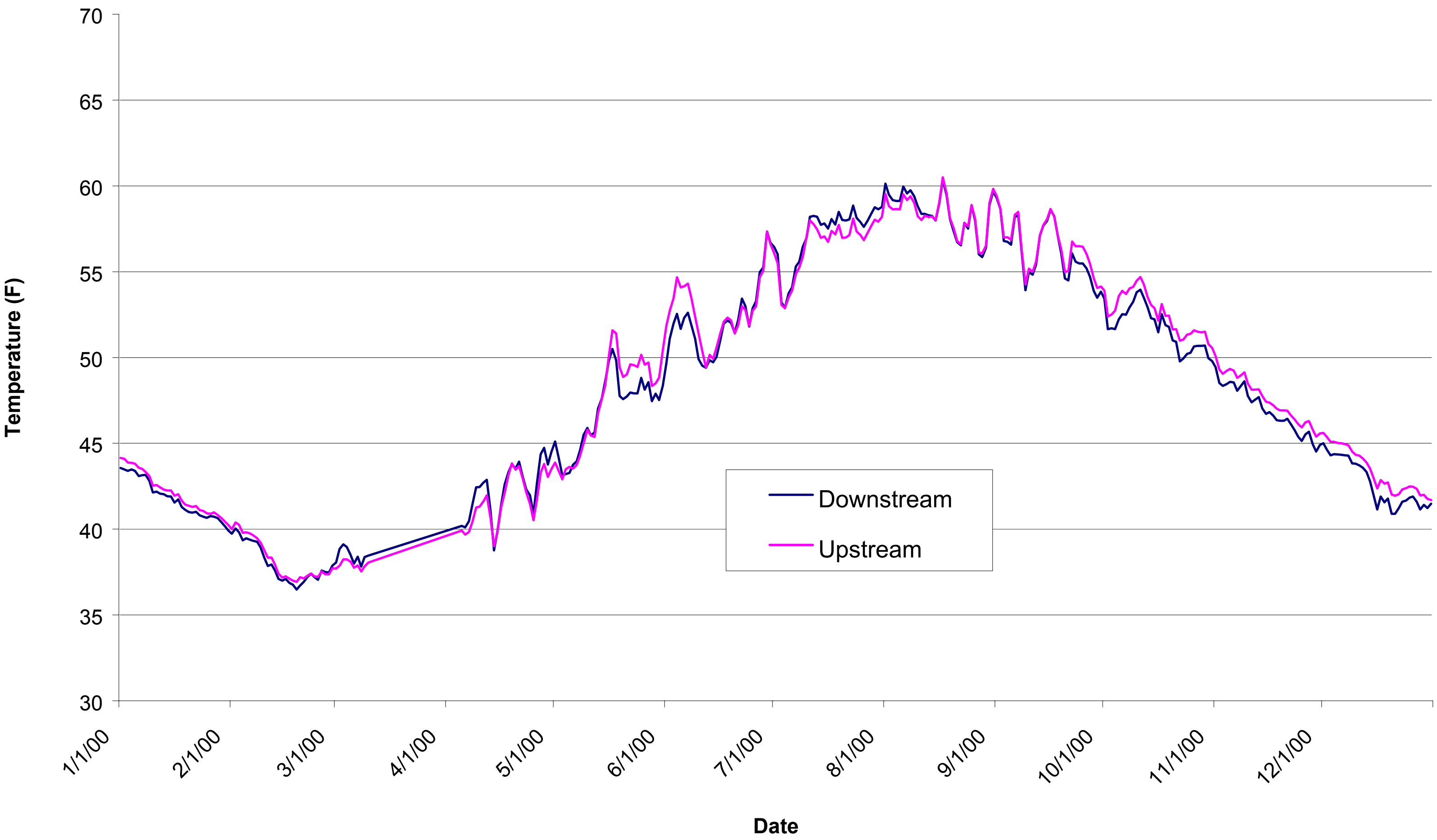

Figure 18. Mean daily water temperature above and below Libby Creek in the Kootenai River, Montana, 2000.

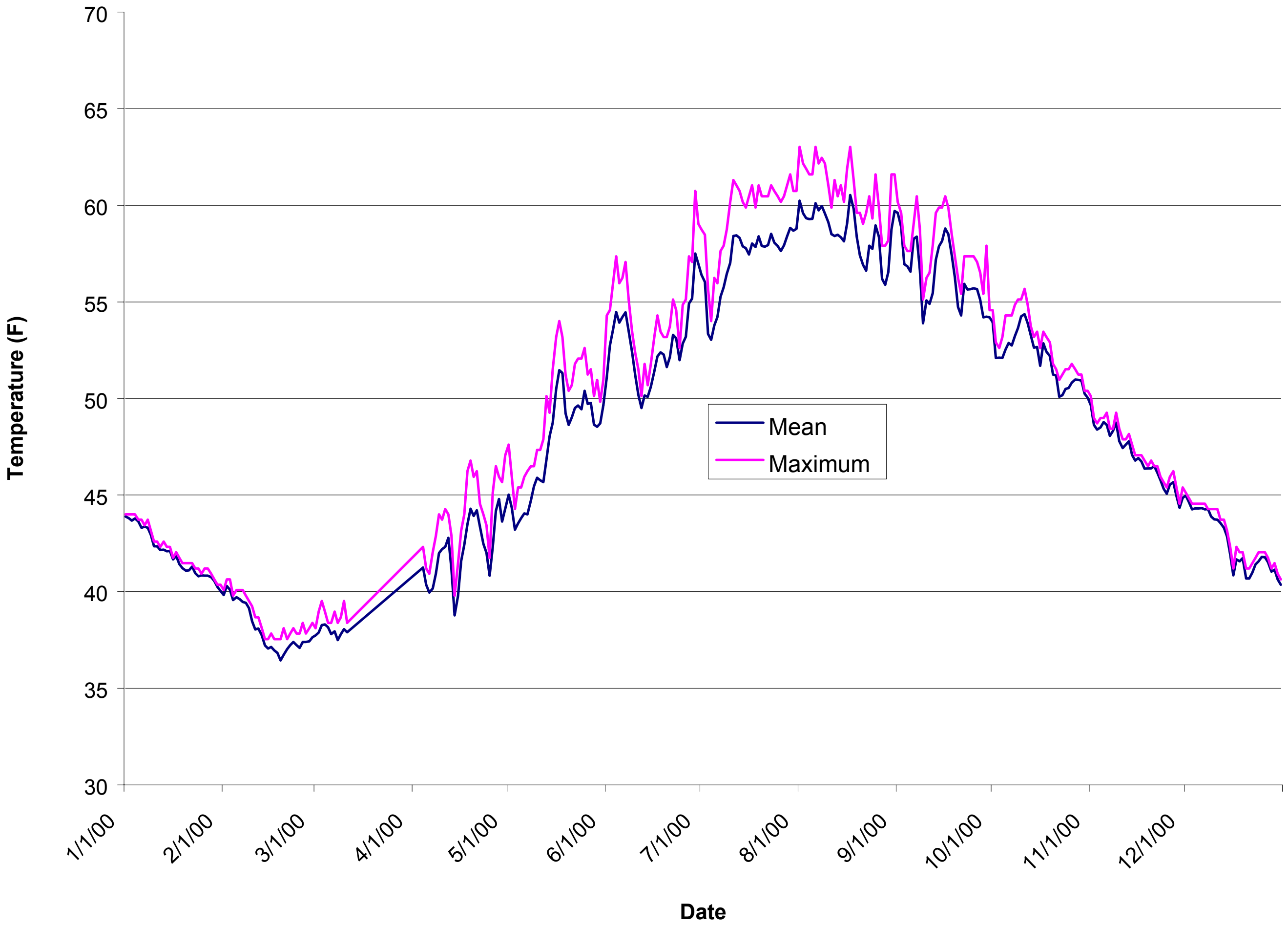

Figure 19. Mean daily and maximum water temperature below Quartz Creek in the Kootenai River, Montana, 2000.

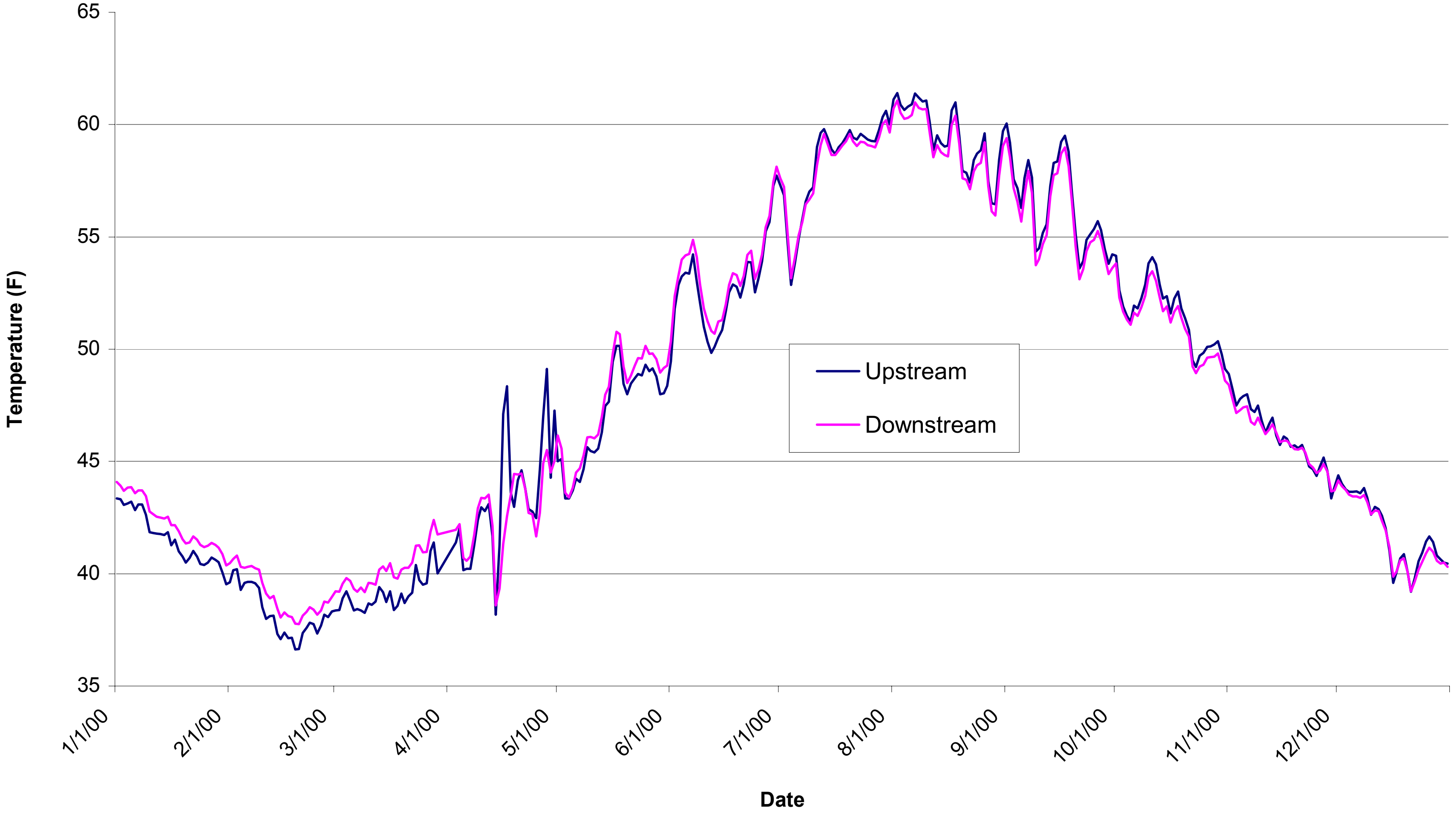

Figure 20. Mean daily water temperature above and below the Yaak River in the Kootenai River, Montana, 2000.

STREAM MACROINVERTEBRATE MONITORING

We collected macroinvertebrates during the summer of 2000 (21 June through 21 September) using Surber samplers and kick-nets within stream restoration project areas and below bank stabilization projects. We sampled Young Creek within the State section and upstream of the State section, Therriault Creek below a sediment source on the Vredenburg property, Sinclair Creek below the sediment source on the Purdy property, Libby Creek below the sediment source downstream from U.S. Highway 2 and upper Libby Creek in the Cleveland property project area, and the spring creek at Libby Field Station following treatment with antimycin. The sampling effort at these locations is intended to serve as an indicator of aquatic health and to provide a baseline for comparison through time.

We sampled three consecutive riffles representative of the available microhabitats at each site that contained gravel substrates or larger, sample depths less than one foot, and stream velocities of at least 1 fps, but not exceeding 3fps. Each riffle sample consisted of 3 Surber samples pooled together. For the first riffle, a diagonal transect was measured from the top right corner of the riffle to the bottom left corner (looking downstream); 1 Surber sample was taken at the top right stream margin, 1 midway between the top right and the center of the diagonal (at 1/4 the length of the diagonal), and 1 midway between the center of the diagonal and the bottom left corner of the riffle (at 3/4 the length of the diagonal). For the second riffle, a diagonal was measured from the bottom right corner of the riffle to the top left corner (looking downstream) and 1 Surber sample was taken at the bottom right stream margin, 1 midway between the bottom right and the center of the diagonal (at 1/4 the length of the diagonal), and 1 midway between the center of the diagonal and the top left corner of the riffle (at 3/4 the length of the diagonal). In the third riffle, a transect perpendicular to flow was measured; a single Surber sample was taken at the left margin, mid-stream, and midway between the center of the transect and the right margin.

We sampled microhabitats between the first and second riffles using a kick-net utilizing the "20 jab" method. The approximate proportions of productive macroinvertebrate habitats in the chosen reach were recorded using the following habitat types: riffles, snags, aquatic vegetation, and bank margins. The 20 jabs were collected proportionally among the habitats. A 1 m traveling kick, or a 1 m sweep if the current was too swift, was used to sample riffle habitats. We sampled with a 1 m sweep through and around snags. We scrubbed macroinvertebrates from coarser snags by hand. We sampled aquatic vegetation using a 1meter sweep, and bank margins with a combination of the techniques described above.

We stored samples in 95% ethanol; those with excessive organic detritus were decanted and refreshed with preservative in the lab. All samples were sorted as soon as possible to minimize decomposition. An independent contractor identified all aquatic invertebrates to the level of genus, and calculated several indices and metrics for comparison. However, for this report, we chose only to present species richness, EPT (Ephemeroptera, Plecoptera and Trichoptera) richness, and the Montana Biotic Index developed by the Montana Department of Environmental Quality (Bukantis 1998). We chose these particular measures due to their sensitivity to detect change due to perturbation, and for consistency with other similar efforts in the region and the state of Montana. Measures for the three riffles sampled at each site were pooled using the arithmetic mean. Results using the 20 jab methodology are presented separately for each site (Table 5). Species richness ranged from a high of 41.67 on the Young Creek site above the State lands section (riffle samples), and a low of 22.00 at the Libby Field Station Spring Creek (20 jab methodology; Table 5). The EPT richness was also lowest at the Libby Field Station Spring Creek site using the riffle sampling methodology (4.00), but highest at the Cleveland Property on Libby Creek (25.33; Table 5). The highest and lowest values for the Montana Biotic Index both occurred at the Cleveland Property on upper Libby Creek, ranging from 1.80 to 4.62 for the riffle and 20 jab methodologies, respectively (Table 5).

Table 5. Measures of species richness, Ephemeroptera, Plecoptera, and Tricoptera (EPT) richness, and the Montana Biotic Index for 8 stream reaches sampled in 2000.

Site and Sample Method	Species Richness	EPT Richness	MT Biotic Index
Sinclair Crk. Below Purdy Property: Riffle Surveys	34.67	22.00	3.13
Sinclair Crk. Below Purdy Property: 20 Jab Survey	41.00	18.00	3.32
Therriault Crk. Below Vredenburg Property: Riffle Surveys	34.67	17.67	3.42
Therriault Crk. Below Vredenburg Property: 20 Jab Survey	25.00	8.00	3.94
Spring Crk. Above Channel Reconstruction: Riffle Surveys	34.33	13.33	4.06
Spring Crk. Above Channel Reconstruction: 20 Jab Surveys	35.00	17.00	3.20
Spring Crk. Below Channel Reconstruction: Riffle Surveys	22.00	4.00	4.29
Spring Crk. Below Channel Reconstruction: 20 Jab Surveys	31.00	13.00	3.58
Young Creek Above State Lands Section: Riffle Surveys	41.67	24.67	3.11
Young Creek Above State Lands Section: 20 Jab Surveys	48.00	32.00	2.13
Young Creek State Lands Section: Riffle Surveys	38.67	23.33	2.80
Young Creek State Lands Section: 20 Jab Surveys	34.00	23.00	2.52
Libby Crk. Below Channel Reconstruction: Riffle Surveys	28.67	18.33	2.50
Libby Crk. Below Channel Reconstruction: 20 Jab Surveys	42.00	18.00	3.82
Libby Crk. Cleveland Property: Riffle Surveys	33.00	25.33	1.80
Libby Crk. Cleveland Property: 20 Jab	35.00	18.00	4.62

Surveys			

RESERVOIR ZOOPLANKTON MONITORING

Collection Methods

Three vertical zooplankton tows using a 0.3 m, 153µ Wisconsin net were performed monthly in each of three reservoir areas (Tenmile, Rexford and Canada) from 1983 to the present. Thirty-meter tows were done unless water column depth was less than 30 m, in which case the entire water column was sampled. After 1989, we sampled only when depths greater than 9 m were available. From 1983 through 1989, one sample was taken from a permanent station and two samples were taken randomly in each area. All samples were chosen randomly after 1989. Orientation (east, west and middle [>100 m from either shore]) for each site was also chosen randomly. All samples were pulled at a rate of 1 m/sec 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 or less) 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. *Daphnia*, *Diaptomus*, *Epischura* and *Diaphanosoma* were measured; 33-34 of each was measured from a randomly chosen subsample, with additional measurements taken from following subsamples if needed.

The purpose of monitoring zooplankton populations in Libby Reservoir is to relate changes in density and structure of the community to parameters of other aquatic communities, as well as to collect data indicative of reservoir processes, including aging and the effects of reservoir operation. Extensive analysis of data collected from 1988 through 1996 revealed possibilities for reducing zooplankton sampling effort. Eighty-six percent of the samples collected were obtained during April through November. Analysis of density and size structure throughout the year revealed no points that would be overlooked by sampling only April through November.

In an effort to further standardize sampling regimes, we experimented with the effects of sample depth on the resulting analysis. When we excluded samples of greater than 20 m, the resulting analysis revealed statistically (Kruskal-Wallis, P=0.05) similar results with regards to total zooplankton, *Daphnia*, and *Diaptomus* densities as analyses including depths to 30 m. These findings corroborate with the results of Schindler trap sampling in the reservoir, which revealed that 89.9% of all zooplankton captured were from depths of 20 m or less. From 1988 through 1996, 625 vertical zooplankton tows were taken from Libby Reservoir. Of these, 17 that were less than 10 m were excluded from analysis. Most sub-10 m samples were from the shallower Canada area, and because zooplankton densities are highest in the top 10 meters of the water column, a sampling bias towards higher zooplankton densities in the Canada area would have been likely. The remaining 608 samples were collected from 10 to 30 m.

Results and Discussion

Data are summarized for 1988 through 2000 and are discussed in this section; data for 1984 through 1987 are reported in Chisholm et al. (1989). For trend analysis, most tables and figures presented here include data collected during all years of the study (1984-2000).

In addition to the 11 species of zooplankton identified by Irving (1987) in Libby Reservoir (Table 6), *Diaphanosoma leuchtenbergainum* and *Ceriodaphnia* spp were found in small numbers. *Ceriodaphnia* remained uncommon, while *Diaphanosoma*, which were first noted in April, 1988, peaked in August, 1988 (4.60/l). After 1989, peak densities declined to less than 1.00/liter and always occurred during August or September (Appendix A, Tables A1 – A13).

We used linear regression to determine which biotic and abiotic factors are correlated to zooplankton size and abundance through time. Although Daphnia spp. mean length appears to be somewhat cyclic (Figure 21 and 22), the overall trend has been a significant decrease ($p = 0.014$; $r^2= 0.324$) in mean length since 1984 (Figure 21). Mean length of Daphnia spp. in Lake Koocanusa is also significantly positively correlated to mean length of kokanee salmon captured in fall gillnets and significantly negatively correlated to the mean length of Columbia River Chub (*Mylocheilus caurinus*) captured during spring gillnet sets ($p = 0.00082$; $r^2= 0.725$). The abundance of kokanee salmon may also influence the overall abundance of Daphnia in the reservoir. We found that kokanee salmon abundance (fish per net) from our fall gillnet sets was correlated to Daphnia abundance ($p = 0.0228$; $r^2= 0.362$). Chisholm et al. (1989) also presented evidence to suggest that kokanee were influencing the size structure of the Daphnia population in Lake Koocanusa.

Although biotic factors are likely influencing the population dynamics of zooplankton in the reservoir, it is likely that abiotic factors, namely reservoir operation likely have a greater influence on zooplankton population in the reservoir. The abundance of Daphnia spp. in the reservoir is correlated to reservoir operations. The abundance (numbers/l) of Daphnia spp. estimated from annual zooplankton sampling is significantly positively correlated to annual mean pool elevation ($p = 0.00419$; $r^2= 0.410$). A multiple linear regression using both annual pool elevation and the mean catch of kokanee per net from the fall gillnet sets did significantly improve the model fit (overall $p = 0.0092$; $r^2= 0.5740$), but the covariate fall kokanee abundance was no longer significant ($p = 0.1545$) when included with mean pool elevation ($p = 0.03929$). We attribute this situation to colinearity between the covariates ($p = 0.0768$; $r^2= 0.238$).

Table 6. Zooplankton identified in samples collected from Libby Reservoir, Montana, 1977 and 1988 (From Irving 1987).

Genera Species
Alona spp
Bosmina longirostris
Canthocamptus robertcokeri
Chydorus spaericus
Cyclops bicuspidatus thomasi
Epischura nevadensis
Daphnia
schlodleri
galeata mendotae
thorata
Diaptomus tyrelli
Leptodora kindtii

Additional zooplankton identified from samples collected from Libby Reservoir, Montana, 1988 through 1996.

Genera Species
Diaphanosoma leuchtenbergainum
Ceriodaphnia spp

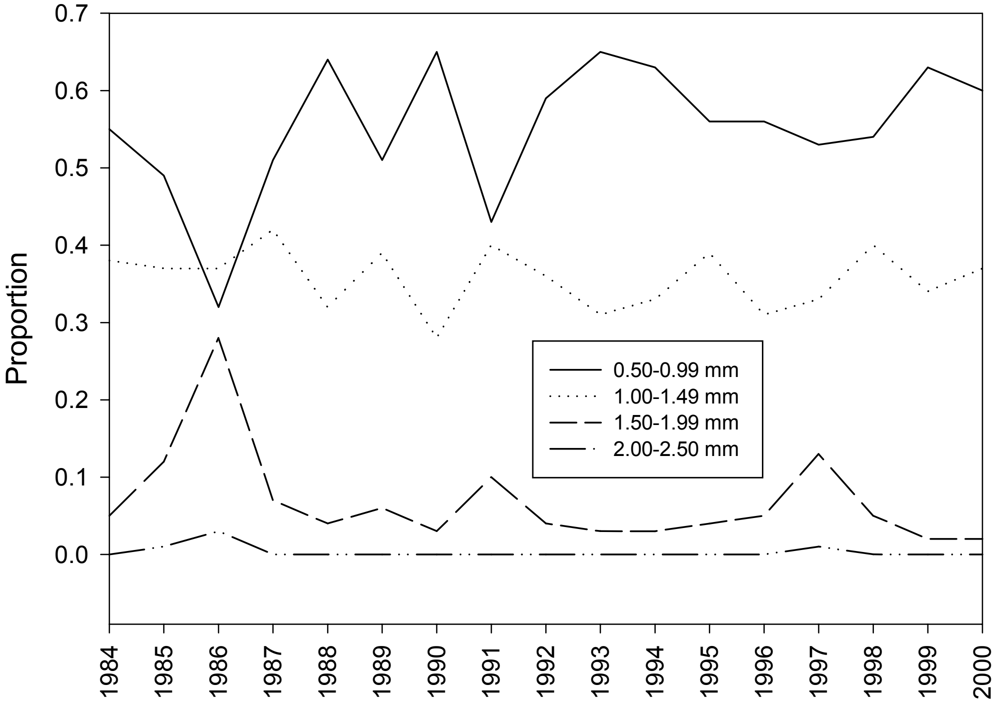

Figure 21. *Daphnia* spp size composition in Libby Reservoir, 1984 through 2000.

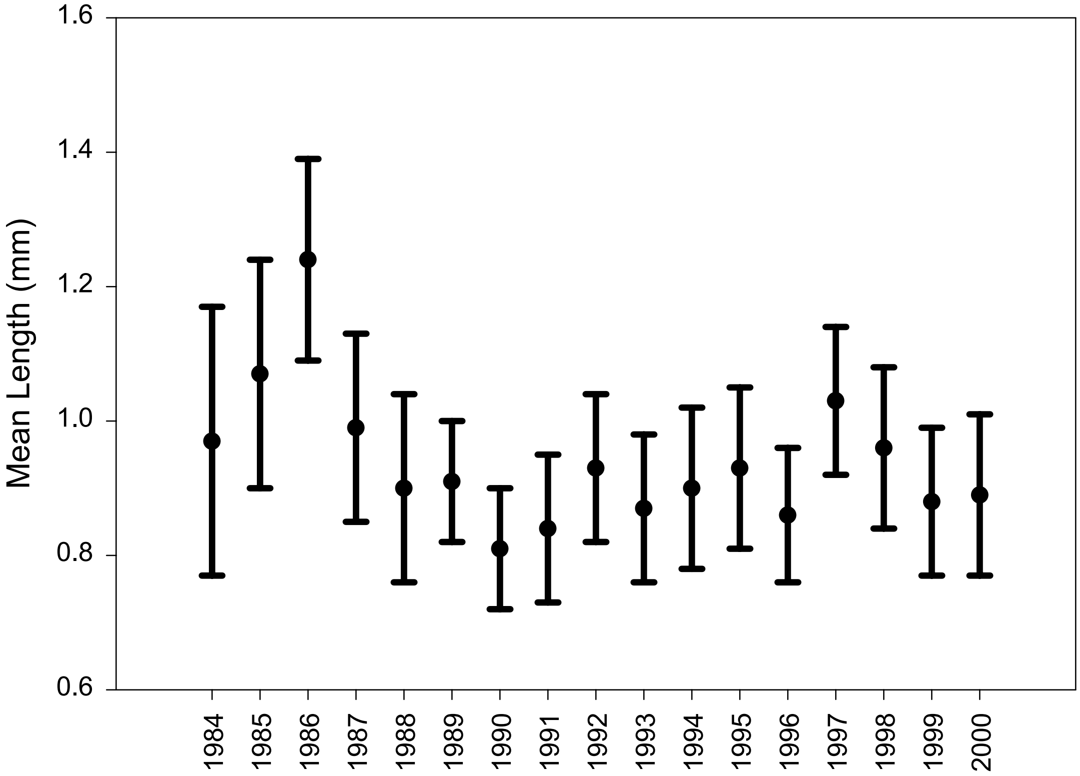

Figure 22. Mean length of *Daphnia* spp in Libby Reservoir, 1984 through 2000, with standard deviations.

KOOCANUSA RESERVOIR FISH ABUNDANCE

Methods

Gillnets have been used by MFWP 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). Data presented in this report focus on the period 1988 through 2000, but in several instances the entire database (1975 through 2000) is presented to show long-term catch trends.

Netting methods remained similar to those reported in Chisholm et al. (1989). Netting effort was reduced from 128 ganged (coupled) nets in 1975, to 56 in 1988, and 14 ganged floating and 28 single sinking nets in 1991 (Tables 7 and 8). 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 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 are also marked (tetracycline) prior to release into the reservoir which allows 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 (DV), 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 dropped to 13 - 17^{o}C.

Table 7. Average catch per net in floating gillnets set during the fall in the Tenmile and Rexford areas of Libby Reservoir, 1975 through 2000 Î.

	YEAR										
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Surface Temperature	16	15	13.8	13.8	16.6	15.8	15.5	17.2			
Date	9/25	10/2	9/25	10/5	9/27	10/10	9/23	9/22	9/21	9/14	9/12
Number of Floating Nets	54	28	28	28	28	28	28	28	28	28	28
Reservoir Elevation	2456	2448	2421	2441	2446	2454	2450	2448	2439	2453	2434
Average number of fish caught per net for individual fish species Ï											
RB	0.2	0.4	0.1	0.4	0.2	0.6	0.3	0.3	0.2	0.2	0.6
WCT	0.2	0.4	0.5	0.9	0.1	0.1	0.2	0.1	0.1	0.1	0.1
RB X WCTÐ	0.3	0.2	0.2	0	0	0	0	0	<0.1	0	0
SUB-TOTAL	0.7	1	0.8	1.3	0.3	0.7	0.5	0.4	0.3	0.3	0.7
MWF	0.2	0.5	0.2	0.3	0.4	0.3	0.3	0.5	0.4	0.1	0.1
CRC	18.2	18.4	23.3	17.1	10.4	1.2	11.7	17.8	14.4	24.3	12.9
NPM	1.8	2.1	1.8	2.2	3.4	2.7	1.8	4.0	4.9	6.4	3.9
RSS	0	0.1	0	0	0.3	0.2	0.1	1.0	0.3	0.3	<0.1
DV	0	0	0.1	0.3	0	1.2	<0.1	0	<0.1	<0.1	0.2
CSU	0.1	0.1	0	0.1	0.1	0	0.4	0.1	0.1	0.1	0.1
KOK	3.9	13.7	5	1	4	7.9	2.3	3.1	2.7	7.3	8.0
TOTAL	24.9	35.9	31.2	22.3	18.9	14.2	17.1	26.9	23.1	38.8	25.9

Î Catches prior to 1988 also reported in Chisholm et al. (1989)

Ï Abbreviations explained in Methods section under Fish Abundance.

Ð Prior to 1983, very few hybrids were identified as such, although they were probably present in the samples.

Table 8. Average catch per net in sinking gillnets set during spring in the Rexford area of Libby Reservoir, 1975 through 2000.

	YEAR										
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
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
Number of Sinking Nets	27	28	28	28	28	28	28	28	27	28	14
Reservoir Elevation	2358	2330	2333	2352	2405	2386	2365	2350	2417	2352	2371
Average number of fish caught per net for individual fish species Î											
RBĐ	0.1	0.1	0.1	0.3	0.2	0.2	0.7	0.1	<0.1	1.1	0.3
WCT	<0.1	0.0	0.1	0.0	<0.1	0.1	0.1	0.2	0.0	0.3	0.1
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
SUB-TOTAL	0.1	0.2	0.2	0.3	0.2	0.3	0.9	0.3	0.0	1.4	0.4
MWF	0.2	0.3	0.9	0.1	0.3	1.5	1.6	1.3	1.2	0.7	0.8
CRC	104.8	31	119	63.3	94.2	54.1	60.9	51.1	171.7	54.4	76.4
NSQ	6.0	2.0	4.2	3.8	7.6	8.0	10.0	13.1	15.1	14	12.6
RSS	<0.1	0.0	0.5	0.0	0.0	0.0	0.0	0.1	1.0	0.1	0.4
DV	1.2	0.5	2.3	1.2	3.0	2.3	3.5	3.1	2.5	3.6	6.2
LING	0.2	0.4	0.6	0.3	0.1	0.1	0.5	0.4	0.4	0.4	0.3
CSU	5.8	2.4	12.9	9.8	9.0	12.0	19.9	14.3	21.1	8.3	10.6
FSU	1.8	1.1	2.9	4.1	6.5	3.0	4.8	4.7	9.5	5.9	5.1
YP	4.7	2.1	1.8	1.1	0.7	2.5	3.7	4.75	2.4	1.8	1.3
KOK	2.0	1.0	0.4	3.5	0.3	2.1	2.0	1.4	1.3	5.3	1.0
TOTAL	120.7	40.0	145.3	84.3	121.9	86.3	107.1	93.25	226.2	95.9	115.1

Î Abbreviations explained in Methods section under Fish Abundance.
Ï Rainbow trout includes wild and hatchery rainbow trout (Kamloops).

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 (Table 7). 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 (Table 8). Spring floating and fall sinking net data are not included in this report due to a lack of standardization in net placement. 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.

Results and Discussion

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). Kamloops were first introduced in 1985 by British Columbia Ministry of Environment (BCMOE). BCMOE and MFWP continue to stock two different strains of rainbow trout into the reservoir; MFWP stocks hatchery reared Duncan strain and BCMOE stocks Gerrard strain. Eastern brook trout are not native to the Kootenai Drainage, but were present in the river before impoundment and rarely appeared in gillnets. Peamouth and northern pikeminnow were rare in the Kootenai River before impoundment, but have increased in abundance in the reservoir. Mountain whitefish, rainbow trout, westslope cutthroat trout and redside shiner were all common in the Kootenai River before impoundment, but have decreased in abundance since impoundment. Two predacious species, bull trout and burbot, were native to the Kootenai River before impoundment, and subsequent gillnet catches show no clear population trends. Gillnets are not the best gear type for capture of burbot; bull trout are commonly captured in gillnets.

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.

Average length of kokanee varied among years. Average length and weight between 1988 and 2000 was 297.1 mm and 250.4 gm, respectively (Table 9), while maximum average size occurred in 1992 (350 mm, 411 gm).

Table 9. Average length and weight of kokanee salmon captured in fall floating gillnets (Tenmile and Rexford) in Libby Reservoir, 1988 through 2000.

YEAR	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	AVG.
Sample size (n)	2150	1259	517	624	250	111	291	380	132	88	76	200	209	
Length (mm)	315.5	275	257.3	315.8	350	262.7	270.2	300.2	293.7	329.6	333.9	291.6	267.3	297.1
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	167.2	250.4

More reliable estimates of kokanee density and year class strength are possible by combining hydroacoustic estimates and vertical gillnetting. Kokanee entrainment through Libby Dam has been determined a substantial factor in determination of population abundance and resultant size of adults in Libby Reservoir (Skaar et al. 1996). MFWP will continue to explore these relations with hydroacoustic and entrainment-deterrence studies.

We used multiple linear regression to determine which factors correlate to the size and condition factor (weight divided by length cubed) of kokanee salmon in the reservoir. As we previously noted, kokanee mean length and Daphnia mean length are correlated (see Zooplankton Section). However, the best-fit model to predict kokanee length included Daphnia mean length and peamouth spring condition factor ($p = 0.001$; $r^2= 0.716$). Both covariates were positively correlated to kokanee mean length. Similarly, fall kokanee condition factor was positively correlated to fall peamouth condition factor ($p= 7.8*10$^-6; $r^2= 0.822$). We believe that competition between kokanee peamouth likely occurs in the reservoir. Fall kokanee condition factor is also negatively correlated to the peamouth catch in our fall gillnets ($p= 0.027$; $r^2= 0.347$). However when we included both fall peamouth condition factor and fall peamouth catch as covariates to predict fall kokanee condition factor, fall peamouth catch was no longer significant. We attribute this to colinearity between peamouth condition factor and fall peamouth gillnet catch ($p= 0.030$; $r^2= 0.336$). These data suggest that interspecific and intraspecific competition is occurring in the reservoir between peamouth and kokanee salmon, respectively. It is also likely that kokanee salmon growth within the reservoir is density dependent. Fall kokanee length is negatively correlated to kokanee escapement estimates provided by the British Columbia Ministry of Environment for the years 1996-2001 ($p= 0.026$; $r^2= 0.748$).

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 23a). Catches in the initial years following impoundment were high, possibly due to the remnant population from the Kootenai River. Catch rates after 1988 remained low; mountain whitefish comprised less than 1% of the spring catch during 1988 through 1996. Reasons for whitefish decline in Libby Reservoir may include conversion from lotic to lentic environment, barriers to spawning habitat and poor quality of that habitat, and loss of spawning substrate in the old Kootenai River channel.

Rainbow and Westslope Cutthroat Trout

Catch of rainbow and westslope cutthroat trout remained relatively stable between 1988 and 2000 (Figure 23b,c). Westslope cutthroat catch increased slightly from 1990 to 1993 (0.2 to 0.9 per net), which may be related to hatchery stocking densities (Table 10).

Table 10. Westslope cutthroat trout caught in the Rexford and Tenmile areas in fall floating gillnets, average length, average weight, number stocked directly into Libby Reservoir, and corresponding size of stocked fish between 1988 and 2000.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
No. Caught	23	21	17	17	22	31	11	8	11	3	4	4	2
Avg. Length (mm)	295	264	238	261	275	260	251	314	252	225	267	305	302
Avg. Weight (gm)	249	196	146	191	211	191	156	316	161	128	228	296	271
No. Stocked	none	5,779	40,376	67,387	72,376	72,367	1,360	none	none	none	none	none	none
Length (mm)	n/a		33	104	216	190	287	n/a	n/a	n/a	n/a	n/a	n/a

Causes for decline of rainbow and westslope cutthroat trout may include reductions in hatchery stocking, migration of hatchery stock out of the reservoir into the Kootenai River, and poor habitat quality and reservoir-created barriers in tributaries. Competition for food with the abundant planktivores (kokanee) in the reservoir, as well as competition in tributaries with non-native brook trout, likely affects these populations.

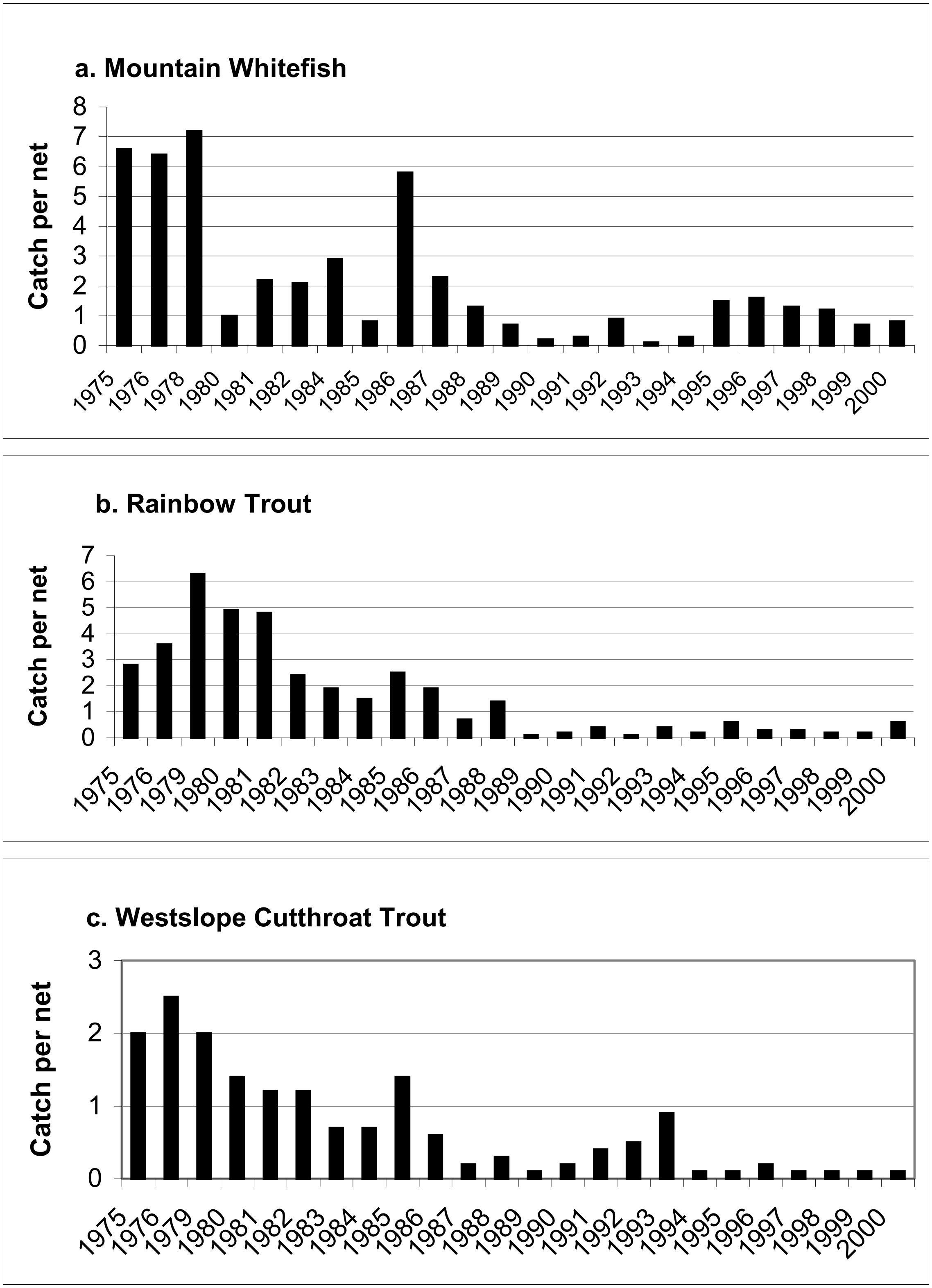

Figure 23. Catch per net of three native species (mountain whitefish (a) in spring sinking gillnets in the Rexford area, rainbow and westslope cutthroat trout (b) and (c) in floating gillnets from Tenmile and Rexford areas) in Libby Reservoir, 1975 through 2000.

Kamloops Rainbow Trout (Duncan Strain)

The current population status of Kamloops rainbow trout is unclear. Kamloops captured in fall floating gillnets was correlated (P=0.02) with number of hatchery fish planted the previous summer (Table 11) for 1988 through 1996. Low catch (0 to 18 fish per season) dictates that these data be viewed with caution. Catches since 1996 have remained low.

Table 11. Kamloops rainbow trout captured in fall floating gillnets in the Rexford and Tenmile areas of Libby Reservoir, 1988 through 2000.

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
No. Caught	3	0	18	6	3	4	0	12	2	1	2	3	3
Avg. Length mm)	289	n/a	301	383	313	460	n/a	313	460	395	376	378	395
Avg. Weight (gm)	216	n/a	243	589	289	373	n/a	311	1192	518	450	504	555
No. Stocked	20,546	73,386	36,983	15,004	12,918	10,831	16,364	15,844	12,561	22,610	16,368	13,123	none
Length (mm)	208-327	175-198	175-215	180-190	198-208	165-183	168-185	165-178	170.5	152-178	127-152	255-280	n/a

Bull Trout

Few bull trout have been captured in the fall gillnetting series since impoundment. The primary reasons are that sampling dates purposely coincided with the period in which adults were in spawning tributaries, and that bull trout are not traditionally captured in floating gillnets. Bull trout catches in the spring have increased, presumably in response to the closure of the bull trout season in 1994 in the Montana portion of Libby Reservoir, and special management regulations implemented in the British Columbia portion of the Kootenai Basin.

Burbot

Burbot catch in spring sinking gillnets were low in the first years following impoundment; catch averaged 0.47 per net from 1975 through 1987 (Table 8). Numbers gradually increased to 1.2 fish per net in 1988, then declined to levels comparable to early post-impoundment.

Gillnetting is a poor indicator of burbot population trends. Evidence suggests that baited hoopnets are a more efficient capture method (Jensen 1986, Bernard et al. 1991). Burbot may not be highly active during spring gillnetting periods, compounding the inefficiency of gillnets.

Burbot movement, spawning requirements, varial zone use, age and size class composition and angler creel investigations have occurred in Libby Reservoir since 1995. These data are available in the annual report compiled by the Deep Drawdown Mitigation Project (Montana FWP, 1999).

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. The increasing trend for spring gillnet catches (Figure 24) is indicative of an increase in the biomass of species that prefer reservoir habitats: peamouth chub, suckers, northern pikeminnow, etc. The decreasing trend for fall nets (Figure 24) is indicative of a decrease in the biomass of trout species and whitefish typically captured in floating gillnets. The trend also is reflective of an aging reservoir which experiences low hydraulic residence times (roughly 0.6 year) and highly fluctuating varial zones.

Species that were dependent on the mainstem river, or are dependent on tributaries, for spawning and rearing continue to decline, while species not reliant on these habitats are increasing (Table 12). The predicted period of trophic equilibrium (Kimmel and Groeger 1986) has not been observed, primarily due to the introduction of kokanee salmon, which increased in numbers until 1988, but have fluctuated annually since. The introduction of Kamloops rainbow trout has not provided the expected trophy fishery.

Total standing stock of fish in Libby Reservoir, as indicated by spring sinking gillnet captures, is increasing predominantly because of peamouth, which use limnetic production. The numerical dominance of peamouth became apparent in the late 1980's (10-15 years after impoundment) and has continued to dominate the spring catch.

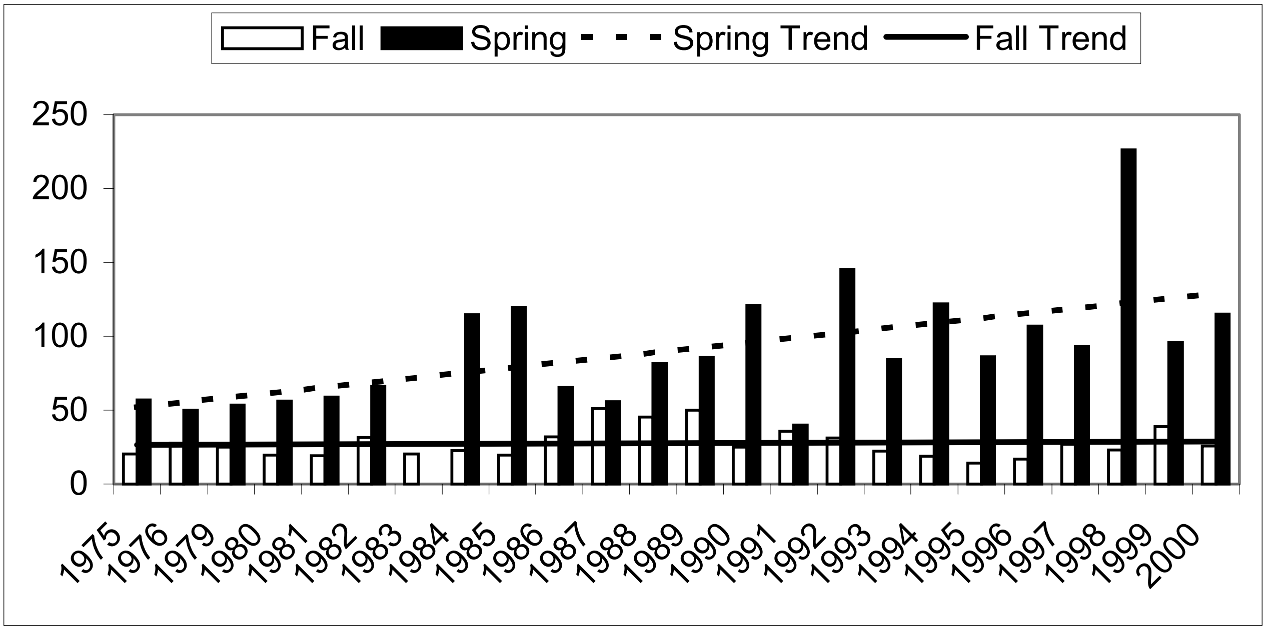

Figure 24. Catch per net (all species combined) in fall floating and spring sinking gillnets and associated trend lines in Libby Reservoir, 1988 through 1996.

Table 12. Percent composition of major fish species caught in fall floating and spring sinking gillnets in Libby Reservoir, 1988 through 2000. Blank entries in table indicate either no fish were captured or that they occurred in only extremely rare instances.

	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.
RBT	1.4		0.1		0.2		0.4		0.1		0.4		0.2		0.6		0.3	
WCT	0.8		0.2		0.5		0.6		0.7		0.9		0.1		0.1		0.2	
ONC*	2.2	0.7	0.3	0.4	0.7	0.1	1.0	0.4	0.9	0.1	1.3	0.3	0.3	0.2	0.7	0.4	0.5	1.0
MWF	0.3	1.6	0.1	0.8	0.2	0.2	0.5	0.7	0.2	0.6	0.3	0.2	0.4	0.3	0.3	1.7	0.3	1.5
CRC	18.7	63.8	35.6	66.0	18.2	82.6	18.4	76.5	23.3	81.7	17.1	73.9	10.4	77.0	1.2	62.9	11.7	56.9
NPM	1.4	7.7	2.1	7.4	1.8	4.8	2.1	5.0	1.8	2.9	2.2	5.0	3.4	6.2	2.7	9.3	1.8	8.7
RSS	0.4	0.2	0.1	0.1	0	0.0	0.1	0.0	0	0.3	0	0.0	0.3	0.0	0.2	0.0	0.1	0.0
FSU		2.3		1.6		1.5		2.6		2.0		5.2		5.3		3.5		4.4
CSU	<0.1	12.7	0.1	10.3	0.1	4.5	0.1	5.9	0	8.8	0.1	9.7	0.1	7.3	0	13.9	0.4	18.6
KOK	22.4	1.7	11.8	2.1	3.9	1.5	13.7	1.6	5	0.3	1	3.4	4	0.2	7.9	2.4	2.3	1.8
YEP		5.5		9.4		3.7		5.2		1.2		1.1		0.9		2.9		3.4
DV		2.4		1.4		1.0		1.1		1.7		1.1		2.5		2.8		3.3
LING		1.4		0.5		0.1		1.0		0.4		0.1		0.1		0.1		0.4

	1997		1998		1999		2000	
	Fall	Spr.	Fall	Spr.	Fall	Spr.	Fall	Spr.
RBT	0.3		0.2		0.2		0.6	
WCT	0.1		0.1		0.1		0.1	
ONC*	0.4	0.3	0.3		0.3	1.4	0.7	0.4
MWF	0.5	1.3	0.4	1.2	0.1	0.7	0.1	0.8
CRC	17.8	51.1	14.4	171.7	24.3	54.4	12.9	76.4
NPM	4.0	13.1	4.9	15.1	6.4	14	3.9	12.6
RSS	1.0	0.1	0.3	1.0	0.3	0.1		0.4
FSU		4.7		9.5		5.9		5.1
CSU	0.1	14.3	0.1	21.1	0.1	8.3	0.1	10.6
KOK	3.1	1.4	2.7	1.3	7.3	5.3	8.0	1.0
YEP		4.75		2.4		1.8		1.3
DV		3.1		2.5		3.6	0.2	6.2
LING		0.4		0.4		0.4		0.3

*ONC= Combined Rainbow, westslope cutthroat and hybrid trout.

UPPER BASIN HABITAT IMPROVEMENT PROJECTS and MONITORING

Glen Lake Irrigation Diversion Project

Grave Creek is a major bull trout and westslope cutthroat trout spawning and rearing tributary to Lake Koocanusa. It is the only significant bull trout spawning stream within the Upper Kootenai River south of the Canadian border, and it supports a healthy, genetically pure westslope cutthroat population.

The Grave Creek Drainage encompasses approximately 48,200 acres, the majority of which is high elevation, densely timbered ground. The lower three miles of Grave Creek flows through lower valley private farm lands, and is characterized as Rosgen "C" and "D" type stream channel with a low gradient and a moderate to high sinuosity (Rosgen 1996). The upper reaches of the stream are classified as being a Rosgen "B" channel type with a moderate gradient (>2%), and a moderate entrenchment ratio of 1.4 to 2.2.

The Glen Lake Irrigation Diversion is located on Grave Creek, four miles upstream from the confluence of Grave Creek with the Tobacco River. It is approximately 8 miles Southeast of Eureka, Montana, within the SW ¼ of Section 6, Township 35N, Range 25W.

The Glen Lake Irrigation Ditch was constructed in 1915 to supply irrigation water to much of the farm and ranch land throughout the Tobacco Valley. In 1923 the Glen Lake Irrigation District (GLID) constructed a log diversion dam across Grave Creek and a headgate at the ditch intake to enhance their water drawing capabilities. The point of diversion was located on USFS property, so at the time of dam construction GLID was required to obtain a special use permit. This permit mandated that GLID supplied and maintained fish passage over the dam, and screened the ditch to prevent entrainment of fish into the ditch.

Prior to the 1970s, the fish passage and screening requirements were virtually unmet. In 1976 MFWP collaborated with USFS to modify the diversion dam for the purpose of providing fish passage over the structure. This modification did appear to provide some fish passage, but the dam was still considered to be a partial barrier for upstream migrants. The ditch however remained unscreened. In 1985 planning and design for a new head gate with a removable screen occurred and in 1986 the modifications were made. The screen was partially employed for one season, but was not used after the first season due to maintenance problems and flow restrictions.

In 1998 GLID, MFWP, USFWS, and the USFS worked collaboratively to evaluate alternatives to modify the structure to meet fish passage and water usage needs. USFS hydrologists identified that the existing diversion dam had elevated the base level of the stream approximately 7 feet, which caused a large amount of aggradation in the streambed, and allowed the deposition of nearly 2000 cubic yards of bed material behind the dam (Figure 25). The channel became unstable, which promoted scour on a large mass wasting bank, and increased the sediment supply within the stream. The old log diversion dam was showing signs of deterioration, and potential for failure. This was a major concern, because failure of the dam would cause the massive amount of bed load deposited behind the dam to flush into Grave Creek, likely causing additional hydrologic problems downstream.

MFWP, GLID, USFWS and USFS formulated a proposal that would alleviate the problems and meet all of the project goals. This proposal consisted of four steps: removal of the existing log dam; construction of a proper functioning stream channel to maintain its natural channel dimension and effectively transports sediment; development of an efficient water diversion that would facilitate upstream fish migration; and installation of an efficient, self-maintaining fish screen in the ditch.

Project implementation began in the fall of 2000 and was completed during spring of 2001. Stream reconstruction required the removal of approximately 2000 cubic yards of bedload that had been deposited behind the dam and construction of approximately 300 feet of stable Rosgen type "B" channel with a 50 foot bankfull width through the project site (Figure 25). Four rock cross-vanes were installed in the new channel (Figure 25) to allow for effective water delivery to the ditch system, and help maintain the proper stream dimension, pattern and profile required for appropriate sediment transport. New channel construction greatly enhanced upstream fish migration, by replacing the 7 foot high jump with four; 1-1.5 foot, low grade steps with a 4 to 7 foot deep plunge pool below each step.

During negotiations, GLID requested that the diversion and fish screen be capable of passing 80 cubic feet of water per second and still be relatively maintenance free. This request was consistent with GLID's legal water right. There were a number of options to produce a self-maintaining fish screen, but very few options would deliver the volume of water GLID requested and still stay within the allotted project budget. The technical work group's preferred alternative was a static screen system that would use flowing water to clean the screens. Approximately 60 feet of static screens were then placed in the side channel immediately above the ditch, parallel to water flow direction in the side channel (Figure 25). This created a water velocity differential where the water velocity traveling across the face of the screens was much greater than the velocity passing through the screens, thereby creating high shear stress across the screen faceto flush debris. The screens operate most efficiently when a minimum of 50% of the available water passes by the screen, hence this design required an off-stream channel capable of conveying twice the desired flow in the ditch.

A headgate was installed adjacent to the top cross-vane in the project to control flows into the side channel above the diversion screen. The headgate was placed 1 foot below the throat elevation of the top cross-vane structure to ensure flows in the side channel during low water conditions.

Figure 25. The upper photograph of the Glen Lake Irrigation District (GLID) the unscreened ditch. The lower photograph shows the new diversion side channel, fish screens, and check dam.

We also installed a check dam in the side channel below the screens to control the water head elevation at the screens (Figure 25). Since the diversion was designed to take the majority of the water at low stream flows it was essential to provide adequate passage for upstream migrating fish through the side channel. We facilitated fish passage by constructing a series of short, deep step pools within the side channel and providing adequate flow and passage at the check dam structure (Figure 25). We will continue to monitor the project to ensure that it functions as designed.

Grave Creek

Grave and Fortine creeks join to form the Tobacco River approximately 14.5 km southeast of Eureka, Montana. Grave Creek is one of the most important spawning tributaries for bull trout in the Kootenai system. Unfortunately, Grave Creek is currently functioning below its historic biological potential. . Human impacts including timber harvest, grazing, agriculture, road development, and channel alterations have disrupted the dynamic equilibrium in Grave Creek causing channel instability and habitat deterioration.

We established a representative sampling reach on Grave Creek to perform population estimates. The shocking section begins at the Vukonic property bridge and extends downstream 1,000 feet to the beginning of the demonstration project area. Baseline fish population data for Grave Creek will be used to compare trends after completion of this demonstration project and extensive channel reconstruction planned for lower Grave Creek beginning in 2002.

Due to the high volume of water in lower Grave Creek, a CPUE was conducted rather than the usual depletion population estimate (Table 13). A Coleman Crawdad electrofishing boat with a mobile electrode was used 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 $\geq$ 75 mm long (total length, TL) for consistency with data previously collected on other Kootenai River tributaries.

Table 13. Lower Grave Creek trout CPUE (1,000 ft).

Year	2000
Grave Creek - Vukonic Bridge	
Westslope Cutthroat Trout	4
Rainbow Trout	1
Brook Trout	1
Bull Trout[A]	9
Mountain Whitefish	54
Longnose Dace	6
Effort (minutes)	44

Four bull trout ≥ 490 mm were likely lacustrine/adfluvial fish from Lake Koocanusa.

Sinclair Creek

Sinclair Creek is a second order stream located on the west slopes of the Whitefish Mountains (T36N,R26W) south of the town of Eureka, Montana; it is a tributary of the Tobacco River. Sinclair Creek is a very important westslope cutthroat trout spawning and rearing tributary to the Tobacco River. The quality and quantity of habitat has been compromised due to improper land management. Roads, logging, and livestock grazing have contributed to stream instability, increased sediment, and decreased habitat. The majority of the Sinclair Creek watershed is privately-owned farm and ranch land. These lands have historically been managed for agriculture, with little regard for proper stream or associated riparian management.

The Sinclair Creek Drainage encompasses 13.1 square miles and the bankfull discharge ($Q^{1.5}$) is approximately 86 cubic feet per second. The majority of Sinclair Creek is characterized as a C4 channel type using Rosgen stream classification. Reference reach measurements show that the bankfull cross-sectional area, bankfull width and bankfull mean depth are approximately 18 square feet, 15 to 17 feet and 1 to 1.2 feet, respectively.

Approximately 4,000 feet of Sinclair Creek is within the Purdy Ranch. Agricultural management for nearly a century has deteriorated the riparian habitat in this portion of the stream. Continual cropping and trampling of the riparian vegetation by livestock have greatly decreased bank stability and increased the sediment supply throughout the reach. The channel has become over-widened and unstable, which has promoted lateral migration and bank scour. The long-term suppression of riparian vegetation has also resulted in a loss of westslope cutthroat trout habitat through increases of fine sediment supply and decreased recruitment of large woody debris, hiding cover and thermal protection.

We are using passive and active techniques to help restore the stream health and fish habitat in the Purdy portion of Sinclair Creek. The passive measures are focused on excluding livestock from the riparian area and allowing the stream and associated riparian area to reestablish naturally. The active measures include physical restoration of highly impacted portions of the stream channel, installation of fish habitat structures and re-vegetation of raw banks and riparian soils.

In 1997, we fenced off approximately 800 linear feet of stream and associated riparian area with two-strand electric fence. In 1998 we fenced off the rest of the stream with three-strand barbed wire and constructed off-stream corrals in the barnyard area. In 1999 we analyzed effectiveness of our fencing projects. We documented some improvements in stream and riparian health, but we also identified a few problems. The stock watering gaps were being severely impacted by hoof shear and it appeared that cattle were using these areas to enter the riparian enclosure. We also identified a number of raw cut banks that were actively eroding and one hillside that had sloughed and created a 4-foot dam of highly erosive material in the stream channel.

In January of 2001, we constructed 500 feet of new channel away from sloughing hillside (Figure 26). The new channel was designed using reference reach data collected from a stable portion of Sinclair Creek. The channel was constructed to convey bankfull flows and transport sediment without aggrading or degrading. We also constructed a proper floodplain that would handle over-bank flood flows and minimize near bank scour. Due to the lack of large woody debris in this portion of the stream, we installed eight rootwads and three log cross-vanes for habitat enhancement, bank stabilization and grade control. After the construction was complete we seeded the area with a riparian mix, and planted sandbar willow and alder.

We also developed an off-stream livestock watering system and eliminated the watering gap in January of 2001. The system consists of two 150 gallon water tanks that are gravity fed by a nearby artesian spring. The spring supplies water at a near constant temperature, which does not freeze during the winter and appears to be preferred by the livestock.

Figure 26. Sinclair Creek, shortly after the channel reconstruction work completed in 2001.

Sinclair Population Estimates

Population estimates on Sinclair Creek were conducted using depletion methods similar to Shepard and Graham (1983). A block net was placed at the lower end of the section and electrofishing was conducted from the upper end of the section towards the lower end. Two such passes were completed. If, based on captures made during the first two passes, probability of capture (P) was ≥ 0.6, a third pass was conducted.

$$P = C1 - C2 / C1$$

Where: C1 = number of fish captured during first catch and
C2 = number of fish captured during second catch.

Fish < 100 mm long (total length, TL) were not used for our estimates in 1997. However, population estimates for years 1998-2000 includes fish ≥ 75 mm, in order to make estimates consistent with historic data collected prior to 1997. All sections were sampled using a backpack electrofisher powered by DC current. Population estimates and associated 95% confidence intervals were estimated using *Microfish 2.2* (Van Deventer and Platts 1983).

We established three sites in Sinclair Creek to perform population estimates. Sections one and two were located within a disturbed reach of Sinclair Creek targeted for project restoration activities. Section three represented our hydrological relic reach, due to it's stable channel and comparable channel type. A location description for each site follows.

Section 1: 442 m upstream of the Hwy 93 culvert; known as the'Purdy project site' (T36N,R27W, Sec24).

Section 2: 209 m upstream of the upper boundary of Section 1.

Sections 1 and 2 are located in a disturbed reach of Sinclair Creek.

Section 3: 163 stream meters, located in the Willow Fire Ranch property, approximately 4.8 stream kilometers upstream from the Purdy project site (NE1/4, Sec. 18 T36N,R26W).

Results

Three years of fish population surveys in Section one of Sinclair Creek suggest a relatively sharp increase in the number of cutthroat trout from 1997 through 1999. However, brook trout did not increase as sharply as cutthroat trout during the same period, which resulted in a relative shift in species abundance from one dominated by brook trout in 1997 and 1998, to a cutthroat trout dominated community in 1999 (Table 14; Figure 27). We observed a similar results in Section two during the period 1997 to 2000 (Table 14; Figure 28). Determining fish population trends for Section 3 of Sinclair Creek during the period 1985 through 1999 is difficult due to data gaps between 1985 and 1997. However, if we disregard the 1985 data, the remaining data suggest an in crease in the abundance of cutthroat trout from 1997 to 1999. Brook trout abundance remained relatively stable during this time period (Table 14; Figure 29). The increased abundance of cutthroat trout in all three sections of Sinclair Creek through time, and relatively stable abundance of brook trout resulted in a general increase in trout abundance throughout Sinclair Creek. Bull trout were only observed in Section 2 in 1999 and 2000 and in Section three in 1998.

Table 14. Sinclair Creek population estimates and associated 95% upper confidence intervals for fish ≥ *75* mm per 1,000 ft. Estimates were obtained by performing multiple pass electrofishing. N/A indicates that these data were not collected.

Year	1985	1997	1998	1999	2000

Section 1					
Westslope Cutthroat Trout	N/A	6 (6.16)	35 (42.27)	129 (134.22)	N/A
Brook Trout	N/A	40 (41.73)	95 (110.30)	89 (90.16)	N/A
Bull Trout	N/A	0	0	0	N/A
Total Population [A]	N/A	47 (48.60)	132 (149.68)	221 (225.64)	N/A
Water Temp. °C	N/A	13	15	N/A	N/A
Discharge (cfs)	N/A	N/A	3.2	5.4	
Section 2					
Westslope Cutthroat Trout	N/A	8 (9.79)	52 (69.33)	153 (158.31)	89 (122.65)
Rainbow Trout	N/A	8 (8.88)	0	4	0
Brook Trout	N/A	43 (63.56)	64 (71.33)	63 (66.61)	68 (71.32)
Bull Trout	N/A	0	0	7 (10.08)	1
Total Population [A]	N/A	56 (70.43)	116 (131.81)	226 (233.79)	149 (164.97)
Water Temp. °C	N/A	12	12	N/A	N/A
Section 3					
Westslope Cutthroat Trout	308 (314.85)	139 (172.33)	258 (292.35)	239 (253.37)	N/A
Brook Trout	43 (49.98)	66 (162.11)	64 (67.14)	82 (85.77)	N/A
Rainbow Trout	26 (27.75)	2	0	32 (33.79)	N/A
Bull Trout	0	0	1	0	N/A
Total Population [A]	378 (388.63)	232 (320.50)	320 (348.97)	354 (369.01)	N/A
Water Temp. °C	N/A	12	16	N/A	N/A
Discharge (cfs)	N/A	14.7	3.2	N/A	N/A

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

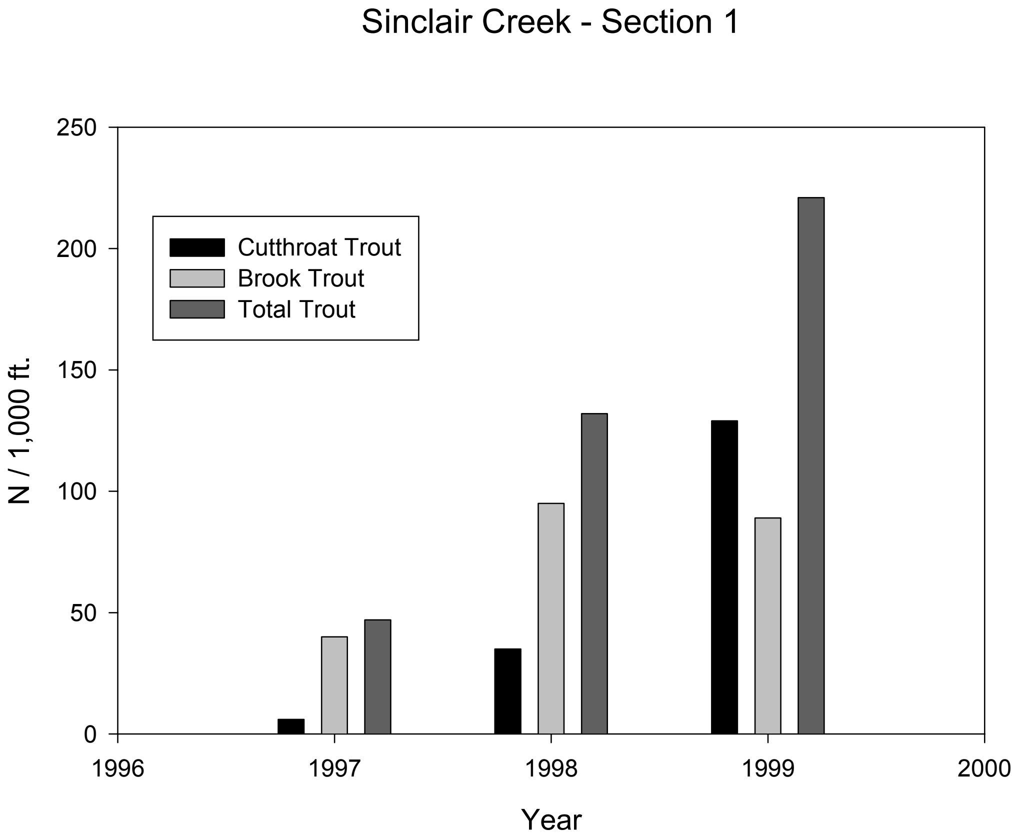

Figure 27. Density of trout in Section 1 of Sinclair Creek, Montana, 1997 through 1999.

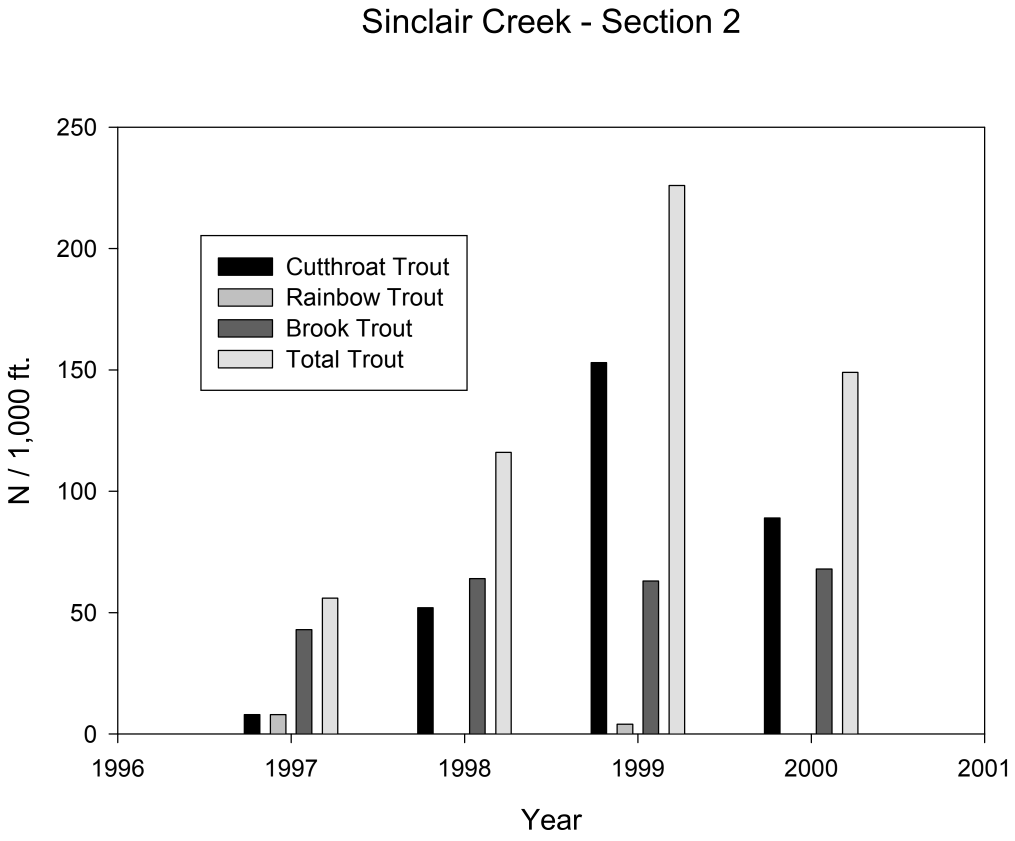

Figure 28. Density of trout in Section 2 of Sinclair Creek, Montana, 1997 through 2000.

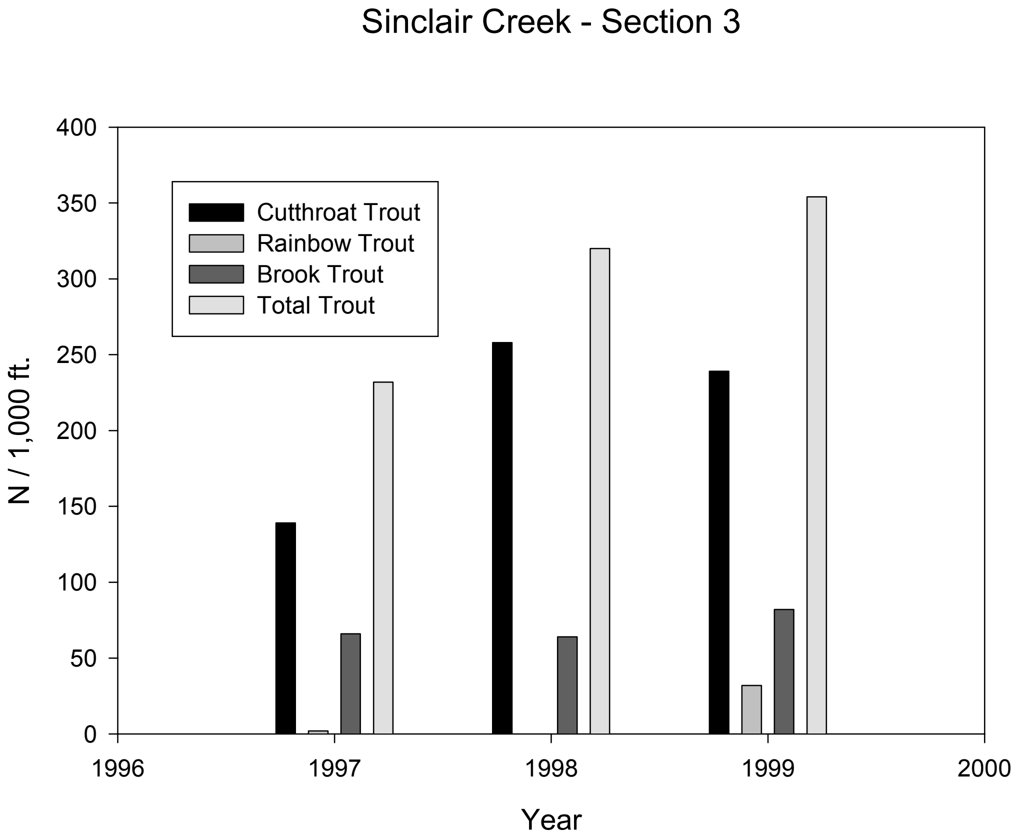

Figure 29. Density of trout in Section 3 of Sinclair Creek, Montana, 1997 through 1999.

Therriault Creek

Therriault Creek Population Estimates

Therriault Creek is located on the west slopes of the Whitefish Mountains (T36N,R26W) and flows into the Tobacco River approximately 8 kilometers upstream from the town of Eureka. Riparian grazing on the creek has decreased bank stability, reduced the potential for woody debris recruitment and eliminated overhead cover in the lower 8 kilometers of the creek. The lack of riparian vegetation may also degrade thermal regimes of the stream. Fine sediment caused by timber management practices and road construction on USFS and private property in the headwaters have further degraded the historic spawning habitat in the creek.

Population estimates on Therriault Creek were conducted using depletion methods similar to Shepard and Graham (1983). A block net was placed at the lower end of the section and electrofishing was conducted from the upper end of the section towards the lower end. Two such passes were completed. If, based on captures made during the first two passes, probability of capture (P) was ≥ 0.6, a third pass was conducted.

$$P = C1 - C2 / C1$$

Where: C1 = number of fish captured during first catch and
C2 = number of fish captured during second catch.

Fish < 100 mm long (total length, TL) were not used for our estimates in 1997. However, population estimates for years 1998-2000 includes fish ≥ 75 mm, in order to make estimates consistent with historic data collected (prior to 1997). All sections were sampled using a backpack electrofisher powered by DC current. Population estimates and associated 95% confidence intervals were estimated using *Microfish 2.2* (Van Deventer and Platts 1983).

Three sections were sampled in Therriault Creek from 1997 through 1999. Therriault Creek was not sampled in 2000. Descriptions of the three reference reaches in Therriault Creek are as follows. Section one is an 82 m long reach located above Highway 93. This section is much shorter section than two and three due to difficult electrofishing conditions. Section 1 had been electrofished prior to 1997. Section 2 starts at the first culvert above highway 93 downstream and is 120 m in length. The property is privately owned and the stream channel is highly entrenched with unstable banks. Section 3 starts at the second culvert above highway 93 downstream and is 131 m long. This section is moderately stable and is 400 m upstream from the highly entrenched reach of Therriault Creek.

Results

Rainbow trout was the most abundant species in Section 1 of Therriault Creek for all years sampled (1997-1999; Table 15). No cutthroat trout were observed in Section 1 of Therriault Creek during any of the years we sampled. It is difficult to determine population trends with only three years of data. However, given the limited time period, it appears that the abundance of rainbow trout and brook trout has remained relatively stable during the time period 1997-1999 in Section 1 of Therriault Creek (Figure 30, Table 15). Section 2 is the only sample section we captured bull trout. Although we collected four age classes of bull trout during the surveys, the trend of bull trout abundance through time is decreasing (Figure 32; Table 15). The overall increasing trend for all trout species from 1997-1998 is mostly attributable to an overall increase in the abundance of brook trout and rainbow trout between years (Figure 31; Table 15). The abundance of rainbow trout and brook trout in Section three of Therriault Creek increased from 1997 to 1999and is reflected in the overall increase in the trout population during this period (Table 15; Figure 33).

The population dynamics of bull trout in Therriault Creek are not fully understood. Redd surveys conducted the fall of 1997 recorded six redds with an average size of 0.6 m x 1 m. Due to the presence of brook trout in the stream, further observations are needed to differentiate bull trout redds from brook trout redds. Continued electrofishing efforts will allow us to determine distribution and spawning success of bull trout in the system. Because the species is designated as threatened under the Endangered Species Act, future monitoring that will guide management alternatives is warranted.

Table 15. Therriault Creek population estimates and associated 95% upper confidence intervals for fish ≥ *75* mm per 1,000 ft. Estimates were obtained by performing multiple pass electrofishing. N/A indicates that these data were not collected.

Year	1997[A]	1998	1999
Section 1			
Rainbow Trout	123 (260.84)	130 (150.91)	82 (89.15)
Brook Trout	41 (46.52)	49 (56.27)	60 (63.67)
Total Population [B]	149 (213.70)	182 (206.89)	141 (149.12)
Water Temp. ^{0}C	N/A	N/A	N/A
Section 2			
Rainbow Trout	36 (41.36)	79 (81.62)	76 (83.34)
Brook Trout	56 (57.53)	125 (136.96)	72 (80.47)
Bull Trout	47 (48.87)	15 (16.42)	3
Total Population [B]	92 (95.90)	205 (216.88)	149 (162.50)
Water Temp. ^{0}C	N/A	12	N/A
Discharge (cfs)	8.6	8.5	N/A
Section 3			
Rainbow Trout	49 (53.81)	164 (169.82)	177 (205.30)
Brook Trout	33 (37.37)	82 (87.79)	110 (116.71)
Total Population [B]	66 (92.68)	248 (256.53)	284 (307.71)
Water Temp. ^{0}C	N/A	N/A	10
Discharge (cfs)	N/A	8.5	N/A

A) Includes fish ≥ 100 mm instead of ≥ 75 mm.

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

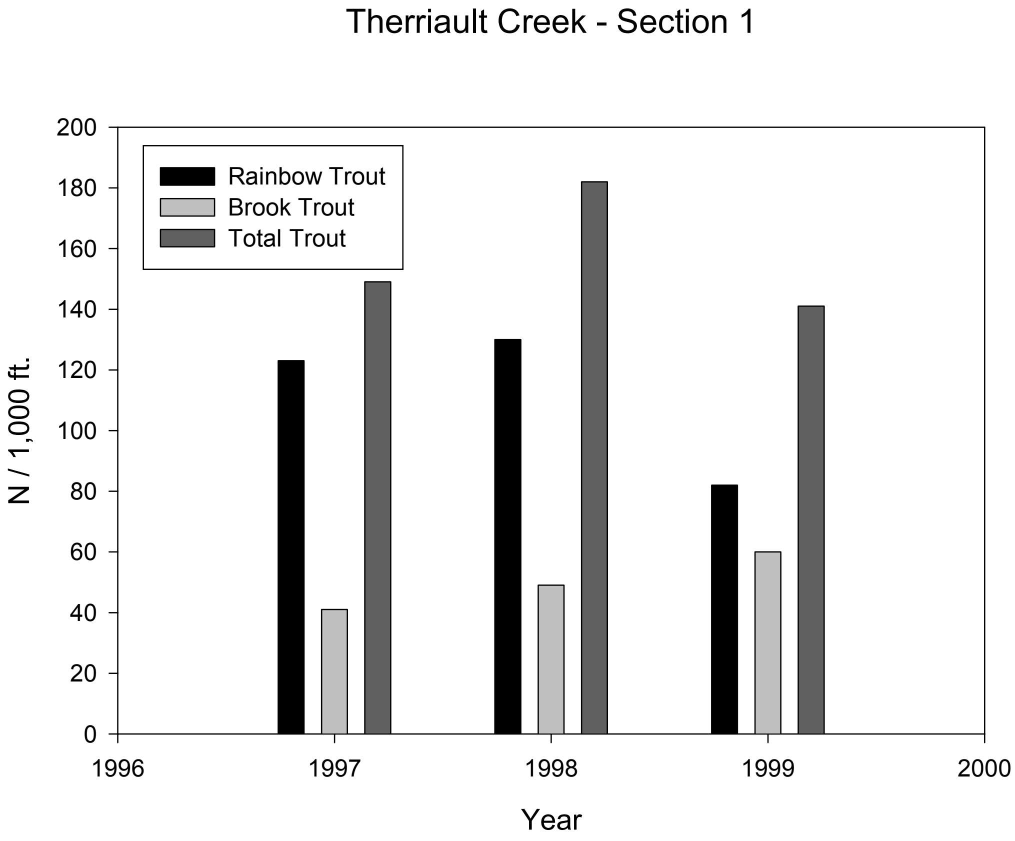

Figure 30. Density of trout in Section 1 of Therriault Creek, Montana, 1997 through 1999.

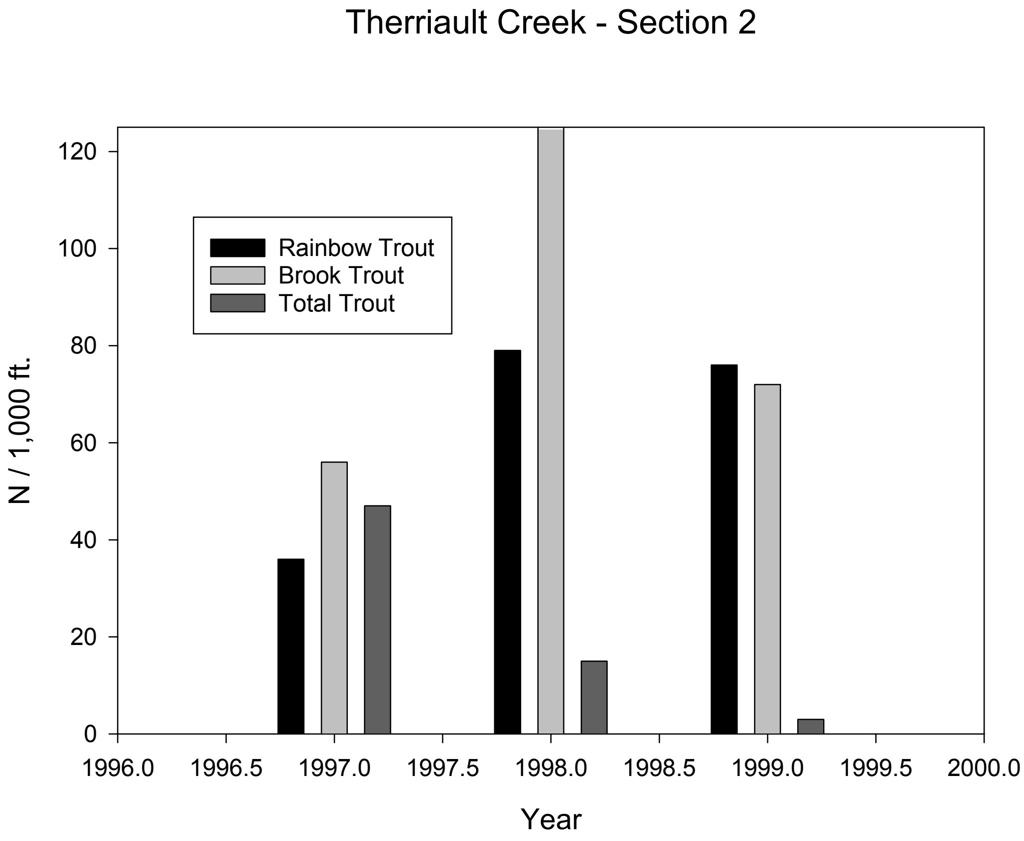

Figure 31. Density of trout in Section 2 of Therriault Creek, Montana, 1997 through 1999.

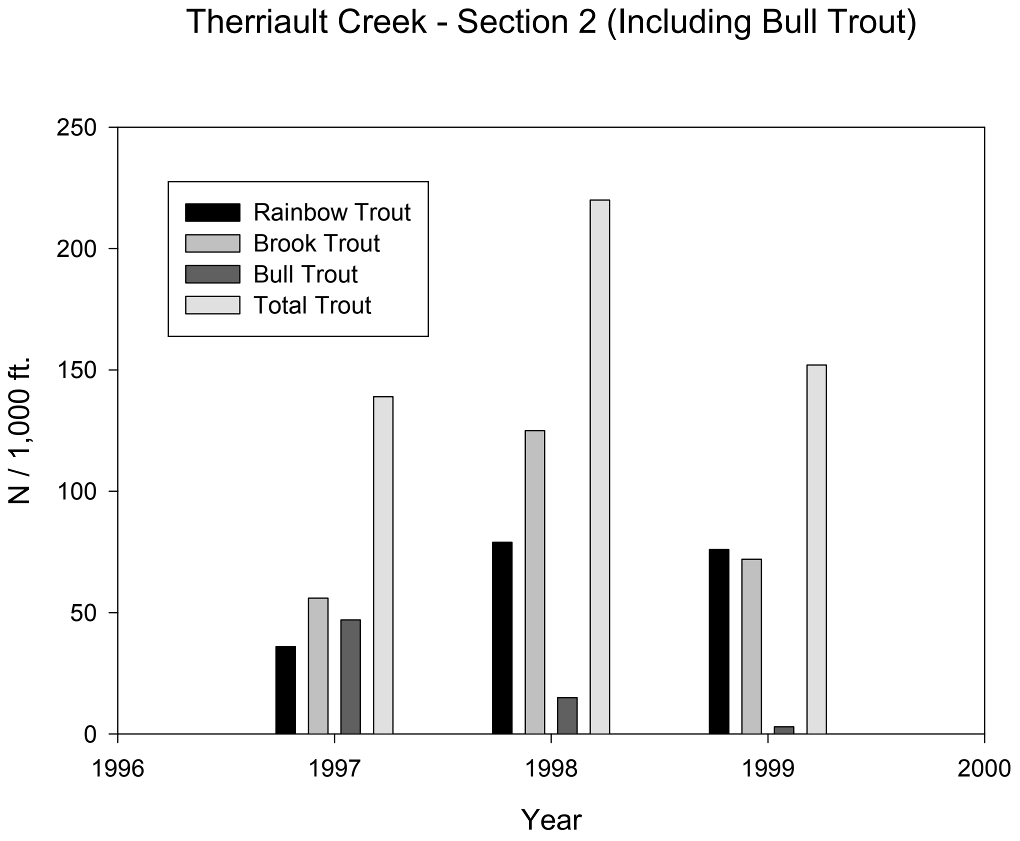

Figure 32. Density of trout in Section 2 of Therriault Creek, Montana, 1997 through 1999.

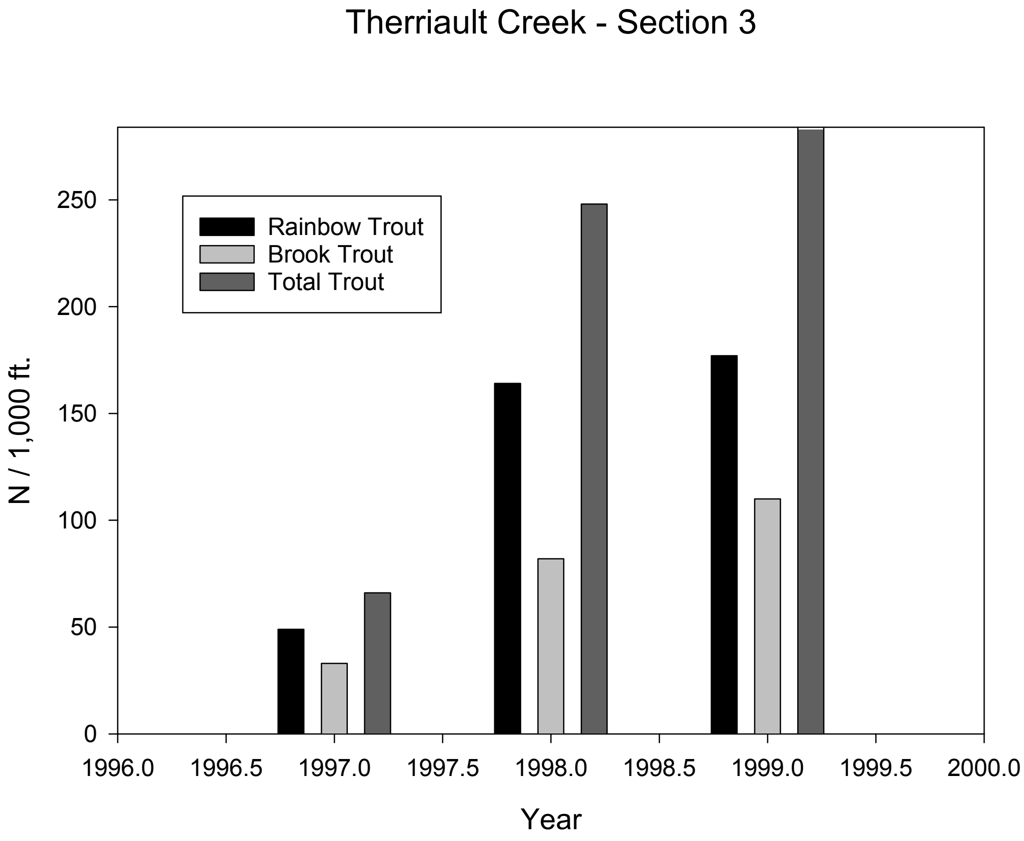

Figure 33. Density of trout in Section 3 of Therriault Creek, Montana, 1997 through 1999.

Young Creek

Introduction

Young Creek is a 17 km long tributary to Libby Reservoir, 5 km south of the Montana-British Columbia border that drains a 119 km^2 basin of the Purcell Mountains. Median annual low and high flows range from 5 to 100 cfs, respectively.

Fish population data collected by MFWP, prior to the construction of Libby Dam, indicates that Young Creek contained a fish species assemblage consisting mainly of brook trout *Salvelinus fontinalis* and cutthroat trout *Oncorhynchus clarki lewisi*. Prior to reservoir impoundment, the lower seven miles of the stream supported a fluvial run of cutthroat trout from the Kootenai River. When population estimates were first conducted in Young Creek 1967 to 1969, the headwaters of Young Creek supported mostly resident cutthroat. Brook trout were a large percentage of the fish population in the lower seven miles of Young Creek (Huston 1972). In 1969 Young Creek was chosen as a study stream by MFWP and the Army Corps of Engineers (ACOE) to determine the feasibility of converting other Kootenai River tributaries to spawning areas for Libby Reservoir. MFWP and ACOE designed and constructed a permanent cement fish weir in Young Creek near its confluence with Libby Reservoir. The weir is capable of capturing adult fish migrating upstream and juvenile fish emigrating downstream.

In August of 1970, MFWP chemically treated a seven mile section starting four miles from the confluence (T37N, R28W, Sec.5), removing all fish. The lower four miles of stream were not treated. In July, 1975, MFWP removed over 500 brook trout from the meadow section located in the lower four miles of Young Creek, using electrofishing gear.

Starting in 1970, MFWP began stocking westslope cutthroat fry into Young Creek in consecutive years through 1974, averaging about 50,000 fish per year (Table 16). The goal of the first four years of stocking was to create an adfluvial population of westslope cutthroat in the reservoir that would return to Young Creek as adults to spawn (May and Huston 1976). In addition, MFWP stocked about three million cutthroat trout directly into the reservoir from 1972 through 1975. Stocking of cutthroat trout in Young Creek was continued in 1985 with the stocking of 9,840 fingerlings and approximately 20,000 fry. In 1992, 7,000 westslope cutthroat fry were stocked into Young Creek. Stocking of hatchery cutthroat in Young Creek continued through 1995.

Table 16. Stocking summary of westslope cutthroat trout in Young Creek by the state of Montana.

Date	**Number Fish**	**Size (mm)**[a]
9/8/70	50,706	25
8/24/71	25,344	25
9/8/71	25,156	25
7/12/72	32,375	25
8/28/72	21,840	25
6/20/73	31,873	25
7/23/74	30,636	25
8/14/74	14,052	25
8/5/75	59,536	25
7/18/85	9,840	178
9/10/85	19,950	25
8/3/92	7,000	23
9/15/93	7,126	46
7/27/94	6,554	36
7/27/94	3,606	33
8/23/94	8,009	36
8/11/95	4,191	33
8/22/95	10,100	36

a) Average length at time of stocking

Westslope cutthroat thrived in Libby Reservoir from the early 1970s through the early 1980s, adfluvial runs of cutthroat in Young Creek were abundant during this period. After 1984 there was a sharp decrease in adult cutthroat trout migrating into Young Creek. Three years after the adults decreased, juvenile cutthroat trout emigrating from Young Creek into Libby Reservoir decreased dramatically as indicated by the number of fish captured by the fish trap in Young Creek (see section below). Westslope cutthroat captured in fall gillnets declined significantly (Kruskall-Wallis (P<0.01) between 1978 and 1982 (Huston et al. 1984). Gill net catches of westslope cutthroat remained relatively stable between 1988 and 1996 (Dalbey et. al. 1997). Declines in the reservoir cutthroat population may be attributed to natural aging of the reservoir, increased predation and food competition. Cutthroat are also lost to the reservoir by entrainment through Libby Dam, approximately 60 percent of tags returned by anglers from fish tagged in 1973 and 1974 were captured below the dam (May and Huston 1975). During these years the reservoir experienced excessive drawdown levels.

The decrease in the adfluvial population in Young Creek is likely linked to the reservoir population, but other factors such as habitat degradation and species competition in Young Creek may have also contributed to the Young Creek population decline. During the 1970s timber harvest and road construction increased sediment into Young Creek. From 1975 to

1987, 50 kilometers of new roads were constructed to access timber sales on USFS land in the Young Creek Drainage (USFS Eureka District files). Residential Land development has increased, affecting the lower four miles of Young Creek, also livestock grazing has adversely effected habitat quality of Young Creek. Effects of roads and low bank cover ratings negatively correlate to densities of westslope cutthroat trout (Shepard et. al. 1998). In addition, ACOE channelized a 180 meter section of Young Creek in the lower four miles for flood prevention. The lower four miles of the stream was historically very important to westslope cutthroat trout, as most redds were observed in this reach of the stream during the 1970s and 1980s (MFWP files).

Remote Site Incubators

From 1996-2000 we utilized remote site incubators (RSIs) in Young Creek in an effort to increase the abundance of adfluvial and resident westslope cutthroat in Young Creek. This is an experimental pilot project to assess the effectiveness of RSIs for re-establishing cutthroat in Libby Reservoir tributaries and possibly the reservoir itself. RSIs have been used successfully in the state of Washington using green salmon eggs to reestablish runs in costal streams (Manuel 1992).

We deployed RSIs with eyed westslope cutthroat eggs from the Washoe Park State Fish Hatchery in Anaconda, Montana from 1996 to 2000. In 1996, approximately 50,000 westslope cutthroat trout fry emerged from RSIs placed in Young Creek, and some westslope cutthroat eyed eggs were placed in artificially constructed redds. From 1997 to 2000 we used only RSIs, purchased from the USFWS in Washington. A total of 194,818 west slope cutthroat eyed eggs were placed in 18 RSIs, ranging from 8,000 to 17,600 eggs in each incubator (Table 17). Approximately 60,000 fry emerged from the RSIs in 1997. In 1998, the number of eggs placed in each incubator was lowered to 5,000 in an attempt to increase egg to fry survival. One incubator from each lot was monitored to calculate egg to fry survival, which ranged from 53 percent to 65 percent from 1996-1998 (Table 17). In 1997 and 1998 we used water displacement ratios to calculate fry numbers when emergence levels were high. We counted the number of fry to displace one milliliter of water in a graduated cylinder to calculate displacement ratios. Egg to fry survival increased to 70 to 75% during 1999 and 2000 respectively, likely due to the decreased time the eggs were in the RSIs. We believed that two factors influenced egg to fry survival in the RSI's between years; the number of eggs per incubator and the time to emergence. Both factors varied between years and made determining the optimal number of eggs per incubator difficult. However, we recommend keeping densities relatively low (approximately 5,000 – 6,000 per incubator) in order to reduce egg fungus mortality. During 1997 - 98 all RSI's were placed within one mile above and below the Forest Service Road 303 bridge (approximately river mile 5.5 on Young Creek). We deployed five incubators near the channelized section in 1999 and 2000 (approximately river mile 4.0 on Young Creek). The remaining RSI's were deployed near the road 303 bridge in 1999 and 2000.

Table 17. Summary of westslope cutthroat trout eggs stocked in Young Creek, Montana using remote site incubators (RSIs) 1997-2000.

Date	**Egg Lot #**	**No. Incubators**	**No. Eggs per Incubator**	**Total Eggs**	**Estimated Fry**
6/5/97	1	6	8,303	49,818[a]	20,453
6/18/97	2	5	17,600	88,000[a]	17,192
7/8/97	3	5	8,000	40,000[a]	14,348[b]
7/9/97	4	2	8,500	17,000[a]	5,000[c]
1997 Total		**18**		**194,818**	**56,993**
6/6/98	1	6	5,000	30,000[d]	19,500[d]
6/13/98	2	6	5,000	29,574[d]	17,449
6/20/98	3	6	4,250	25,000[d]	13,250[d]
6/29/98	4	6	8,500	30,000	19,500[d]
1998 Total		**24**		**114,574**	**69,699**
6/7/99	1[e]	5	10,000	50,000	46,070
6/17/99	2	5	6,000	30,000	25,455
6/27/99	3	5	5,000	25,000	6,800
7/4/99	4	5	5,500	27,500	11,350
1999 Total		**20**		**132,000**	**89,675**
6/12/00	C3[e]	6	8,310	56,000[f]	19,314[f]
6/19/00	D4	5	11,200	29,574[f]	22,450[f]
7/5/00	G4	6	8,310	56,000[f]	37,860[f]
2000 Total		**17**		**141,574[f]**	**79,624[f]**

a) Egg numbers were calculated by using number of eggs/ounce obtained from hatchery records, then measured before eggs were placed in RSIs.
b) Most eggs died in two incubators from loss of water into the incubators.
c) Most eggs were killed due to vandalism of incubators
d) Emerged fry numbers were estimated by calculating egg to fry survival in the monitored incubator from each egg lot. Initial egg mortality averaged 5% for each incubator.
e) Placed near the channelized section of Young Creek.
f) Initial egg mortality averaged 20-30% because eggs were not picked at the hatchery, number of eggs reported here does not take into account this mortality.

Otoliths of incubating trout were thermally marked during from 1997 through 2000. Thermal marking of otoliths has been used successfully on early life stages of Pacific salmon *Oncorhynchus spp*., in Washington and Alaska for identification purposes. (Schroder et al. 1996 ; Munk et al.1993; Hagen et al. 1995). Thermal marking has also been used successfully on lake trout *Salvelinus namaycush* in Minnesota (Negus 1997). This marking method utilizes temperature changes to vary growth ring densities in otoliths of fish during the fry stage of development. These bands are retained throughout the fishes' life.

Observing thermal marks requires a microscope of 400X power. This scope, fitted with computerized image scanning capability will allow us to detect thermal marks in otolith samples (OPTIMAS Corp. Software). Most information available on thermal marking of otoliths is from procedures performed on fish during the fry stage of development. We are hopeful that these procedures will work on fish during the eyed egg stage of development. Otolith thermal marking technology will allow us to sample juvenile and adult westslope cutthroat trout in Young Creek and Libby Reservoir to assess the effectiveness of the RSI pilot study. Washington Department of Fish and Wildlife mounted otoliths from cutthroat fry that were sampled from incubators. The otolith lab attempted to identify our marks, allowing us to assess our marking techniques. However, the marking techniques we used during 1997 and 1998 did not leave an identifiable mark on the otoliths. In 1999 we modified our marking techniques and the thermal marks were visible on otoliths from 1999 and 2000 cutthroat trout fry leaving the incubators [this seems to fit with my question above. Combine paragraphs?]. An analysis to determine the feasibility of thermally marked fish from the 1999 and 2000 broodyears is ongoing.

Young Creek Fish Trap

MFWP operated the Young Creek fish trap in 1998, the first time since 1991 to monitor juvenile recruitment and adult escapement from Young Creek and Libby Reservoir respectively, in order to assess the success of the RSI project. Historically most cutthroat remained in the reservoir for at least two years before returning to Young Creek as spawning adults (May and Huston 1976). Because most cutthroat emigrate as two to three year old and spend one to two years rearing in the reservoir, the first significant number of adult cutthroat trout originating from the RSI project would be in 2000 and 2001.

In 1998, MFWP personnel began operating the trap in April, similar to past years of operation. We modified the downstream weir so it could be run with less maintenance. We recorded species and length of all fish captured in both upstream and downstream weirs. We generally began capturing emigrating juvenile cutthroat in April with the peak number of cutthroat captured during June and July 1998 through 2001 (Figure 34). The mean capture date of all westslope cutthroat trout captured in the Young Creek trap from 1998 to 2001 was June 21. The mean cumulative passage dates for 25, 50 and 75% passage during the period 1998 – 2001 were June 10, June 23, and July 5, respectively. Cutthroat trout were marked with a fin clip and released above the trap to estimate trap efficiency. The estimated juvenile trap efficiency from 1998 to 2001 averaged 48.6% (range 25.5 – 74.8%; Table 18).

The historic mean catch of emigrating juvenile cutthroat trout < 250 mm at the Young Creek trap is 879 fish (Table 18). The average catch of cutthroat trout during the period that includes most emigrating RSI juvenile cutthroat trout (1998-2001; 435 fish) is almost exactly half the historic average. Adult cutthroat trout escapement into Young Creek reached a peak within a decade after reservoir construction, and has averaged 194 adult cutthroat trout since 1970 (Table 18). Adult cutthroat trout escapement since 1998 has averaged only 13.4 fish per year. In 1998 we began collecting samples of juvenile cutthroat trout at the Young Creek trap in order to estimate the total number of emigrating juveniles produced from the RSI's we began using in 1996. Juveniles were collected through 2001. The first potential adult cutthroat trout may have returned from Libby Reservoir to Young Creek in 2000, but we did not capture any adult cutthroat trout in 2000 for otolith analysis. In 2001 we collected both juvenile and adult cutthroat trout for otolith analysis. All otolith preparation and analysis are currently ongoing, with results to be reported in future annual reports.

Table 18. Total catch of adult (> 250 mm total length [TL]) and juvenile (< 250 mm TL) westslope cutthroat trout (WCT) captured in the Young Creek trap from 1970 to 2001. Catch numbers have not been adjusted for trap efficiency.

Year	WCT Adults (> 250 mm TL)	WCT Juveniles (< 250 mm TL)	Trap Efficiency (%)
1970	21	498	
1971	54	161	
1972	8	352	
1973	115	1408	
1974	305	1558	
1975	390	1341	
1976	750	1850	
1977	750	N/A	
1979	345	N/A	
1980	380	1850	
1983	260	1321	
1984	318	962	
1985	82	1274	
1986	83	1629	
1987	55	451	
1988	14	118	
1991	17	176	
1998	4	457	39.0
1999	6	639	55.2
2000	0	191	25.5
2001	44	454	74.8
Mean	**194**	**879**	**48.6**

Peak discharge usually occurs in Young Creek during mid/late May to early June (Figure 34). Although catch in the Young Creek juvenile trap is usually low during peak flow periods

(Figure 34), we can not determine if passage is truly low during these periods or if our data merely reflect low trap efficiency during periods of excessive discharge. We cannot operate the trap during stream discharges of in excess of 80 cfs. Future trapping efforts at the Young Creek trap will evaluate the efficacy of estimating trap efficiency during varying flow conditions within a year.

The length frequency distribution of all emigrating cutthroat trout at the Young Creek downstream trap for years 1998 – 2001 has been very similar (Figure 35). Although age analyses based on scale and otolith samples for this period are still ongoing, the length frequency information (Figure 35) and age data prior to 1998 (MFWP, unpublished data) suggests that most migrants are two and three year old juveniles. The mean total lengths of all cutthroat trout emigrants captured in the Young Creek trap in 1998 – 2001 were 164.9, 160.9, 168.3 and 160.3 mm, respectively. Although the length frequency distributions and the mean lengths between years were similar, an analysis of variance and subsequent Fisher's Least Significant Difference (Zar 1996) test did determine significant differences in the mean total length between years. All potential comparisons between years were significantly different except the 1998/2000 and 1999/2001 comparisons ($p=0.05$). Although most of the multiple comparisons between years were significantly different, we believe that these differences are not likely to be biologically significant. While westslope cutthroat trout migrants entering the reservoir at a larger size would have a competitive advantage compared to cutthroat entering at a smaller size, and may be less susceptible to predation, we discount the potential for the small differences in mean total length observed between years to alter the population dynamics of this population.

We monitored water temperature in Young Creek in 2000 to determine if temperature was a potential limiting factor to the success of the RSIs and cutthroat trout production in general. July and August had the highest mean daily water temperatures of 56.6 and 56.8 degrees F, respectively (Figure 36). Maximum daily temperatures were also observed in July and August. We concluded that water temperature was not likely to be a limiting factor for juvenile cutthroat trout in Young Creek in 2000.

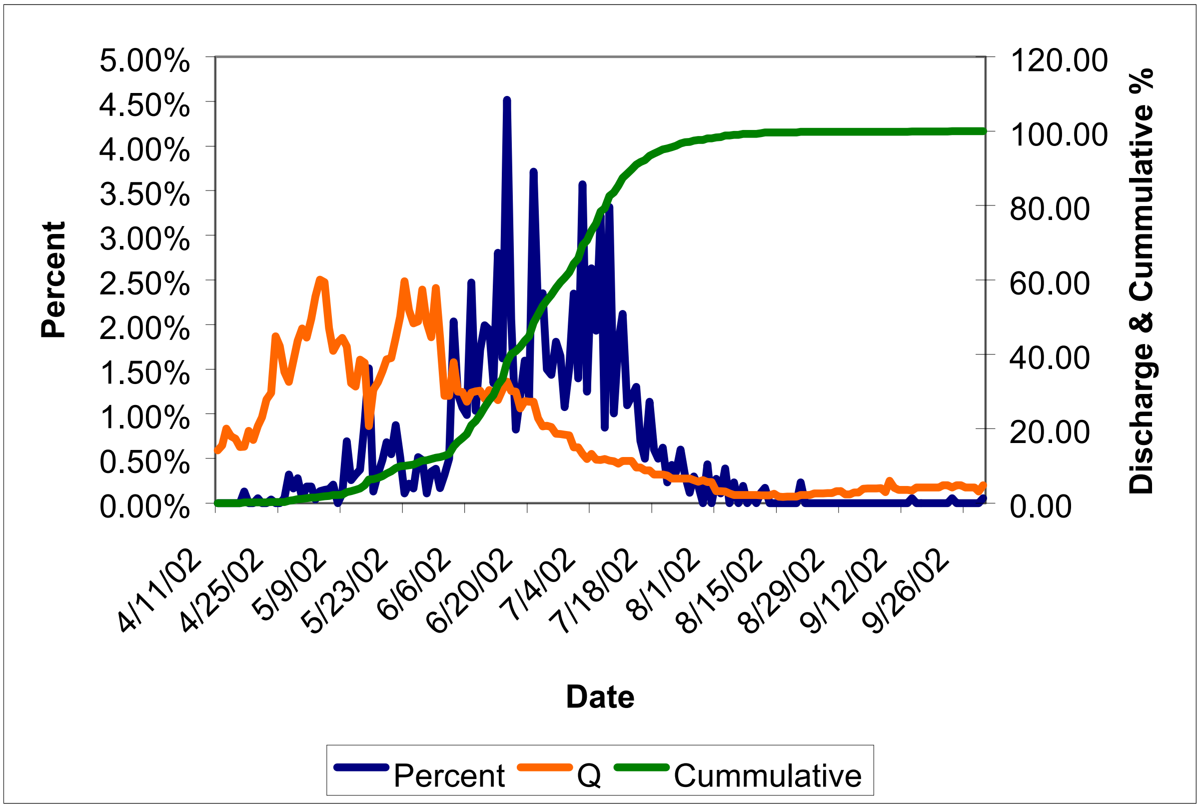

Figure 34. Mean daily and cumulative percent (secondary Y axis) catch of westslope cutthroat trout < 250 mm total length at the Young Creek juvenile trap 1998-2001. Mean daily Young Creek flow (Q) for years 1998, 2000, and 2001 (the secondary Y axis).

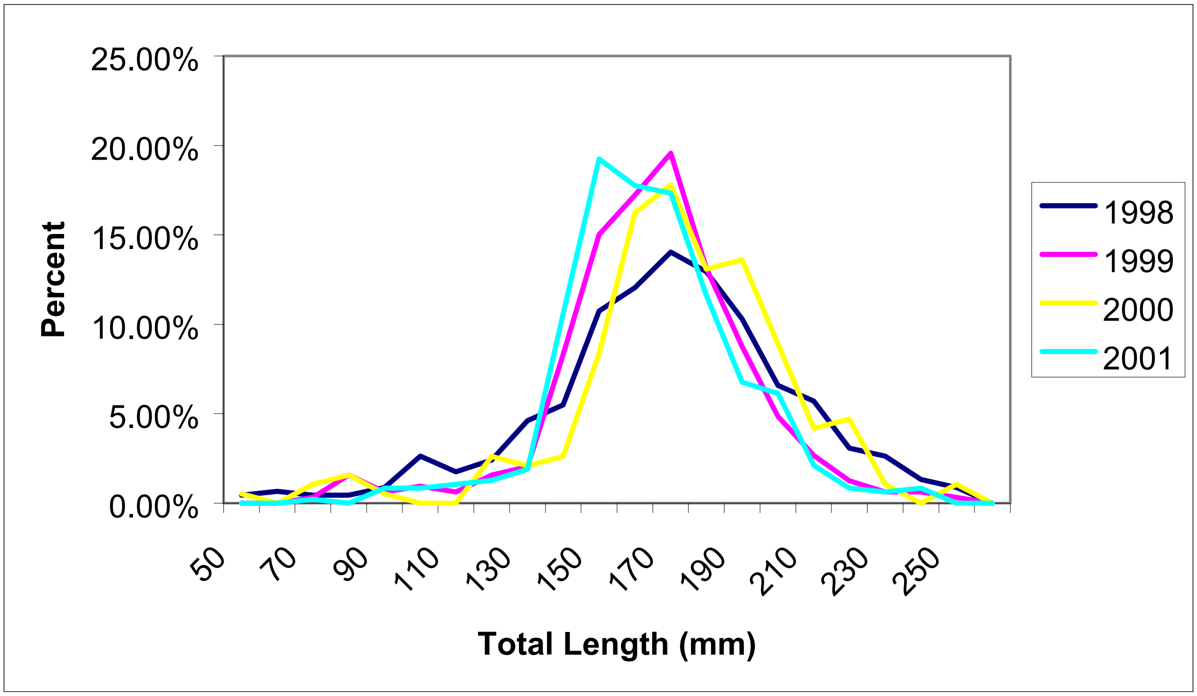

Figure 35. Length frequency distributions for juvenile westslope cutthroat trout < 250 mm total length at the Young Creek trap 1998-2001.

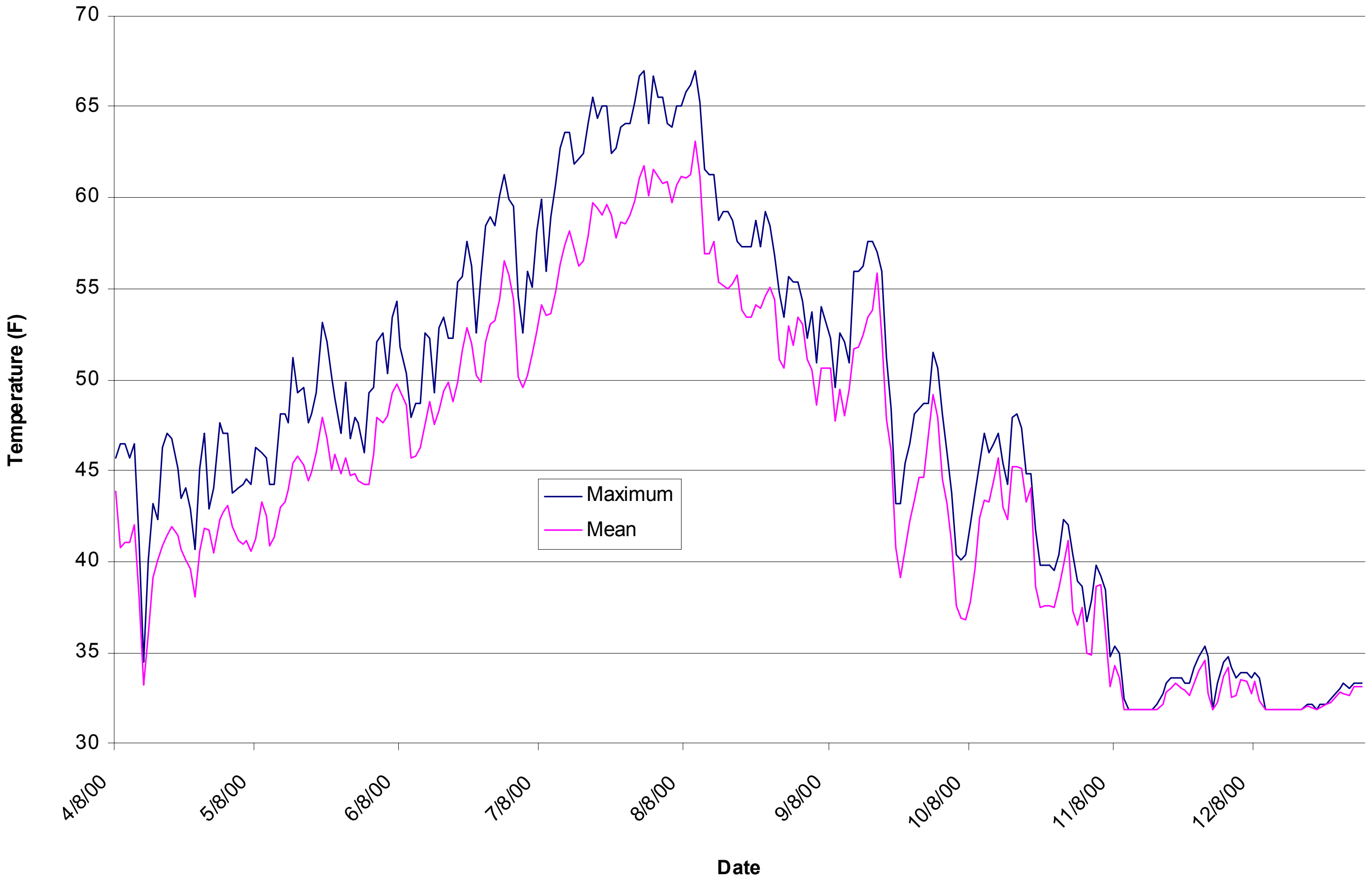

Figure 36. Mean daily and daily maximum water temperature in Young Creek, Montana, 2000.

Young Creek Population Estimates

In addition to migration data, MFWP conducted population estimates in 1996 through 2000. All estimates were conducted during the months of September and October. Population estimates on Young Creek were conducted using depletion methods similar to Shepard and Graham (1983). A block net was placed at the lower end of the section and electrofishing was conducted from the upper end of the section towards the lower end. Two such passes were completed. If, based on captures made during the first two passes, probability of capture (P) was ≥ 0.6, a third pass was conducted.

$$P = C1 - C2 / C1$$

Where: C1 = number of fish captured during first catch and
C2 = number of fish captured during second catch.

Fish < 100 mm long (total length, TL) were not used for our estimates in 1997. However, population estimates for years 1998-2000 includes fish ≥ 75 mm, in order to make estimates consistent with historic data collected prior to 1997. All sections were sampled using a backpack electrofisher powered by DC current. Population estimates and associated 95% confidence intervals were estimated using *Microfish 2.2* (Van Deventer and Platts 1983).

There are five reference reaches on Young Creek which MFWP has collected fish population information historically. 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: North Fork 92 meters from confluence of North and South Forks (Sec. 5,T37N,R29W).

Results

Population estimates obtained from electrofishing efforts from Section one of Young Creek indicates a similar trend for brook trout and cutthroat trout during the time period 1997 to 1999, with both species increasing in abundance through time (Table 19; Figure 37). However, a shift in the species composition occurred from 1998 to 1999. Prior to 1999, brook trout outnumbered *Oncorhynchus* species, but in 1999 cutthroat trout abundance exceeded rainbow trout and brook trout combined (Table 19). In all other sections of Young Creek sampled, cutthroat trout outnumber brook trout. Sections three and four show similar trends in cutthroat trout abundance, with abundance increasing up to 1998 and then decreasing slightly in 1999 (Table 19; Figures 38 and 39). A decreasing trend in the abundance of brook trout in Section five was evident (Table 19).

Table 19. Young Creek population estimates and associated 95% upper confidence intervals for fish ≥ *75* mm per 1,000 ft. Estimates were obtained by performing multiple pass electrofishing. N/A indicates that these data were not collected.

Year	1996	1997[A]	1998	1999	2000
Section 1 (Tooley)					
Westslope Cutthroat Trout[C]	Note[B]	3	36 (37.05)	139 (147.55)	N/A
Rainbow Trout[C]	Note[B]	19 (22.37)	62 (69.51)	3	N/A
Brook Trout	Note[B]	11 (17.18)	120 (124.02)	102 (105.00)	N/A
Total Population [B]	12 (13.33)	36 (40.19)	220 (227.99)	248 (257.80)	N/A
Water Temp. °C	N/A	N/A	N/A	N/A	N/A
Section 3 (303 A Rd.)					
Westslope Cutthroat Trout	N/A	148 (157.82)	416 (451.97)	314 (336.40)	N/A
Rainbow Trout	N/A	Note[B]	Note[B]	Note[B]	N/A
Brook Trout	N/A	Note[B]	Note[B]	1	N/A
Total Population [B]	N/A	148 (157.82)	416 (451.97)	316 (338.29)	N/A
Water Temp. °C	N/A	4.4	12.0	N/A	N/A
Section 4 (303 Rd.)					
Westslope Cutthroat Trout	155 (228.67)	100 (113.50)	439 (500.27)	352 (367.35)	N/A
Rainbow Trout	Note[B]	Note[B]	Note[B]	Note[B]	N/A
Brook Trout	Note[B]	Note[B]	Note[B]	3	N/A
Total Population [B]	155 (228.67)	100 (113.50)	439 (500.27)	358 (373.17)	N/A
Water Temp. °C	5.6	N/A	N/A	N/A	N/A
Discharge (cfs)	9.5	5.6	12.0	7.0	N/A
Section 5 (State)					
Westslope Cutthroat Trout	N/A	N/A	216 (226.81)	256 (290.16)	126 (152.62)
Rainbow Trout	N/A	N/A	0	0	0
Brook Trout	N/A	N/A	62 (70.63)	52 (65.33)	19 (21.86)
Total Population [B]	N/A	N/A	280 (294.47)	314 (352.96)	113 (119.14)
Water Temp. °C	N/A	N/A	N/A	N/A	N/A

A) Includes fish ≥ 100 mm instead of ≥ 75 mm.
B) Includes rainbow trout, rainbow trout x cutthroat trout hybrids, westslope cutthroat trout, and brook trout. Bull trout were not included in the total population estimate.
C) Westslope cutthroat trout and rainbow trout were combined.

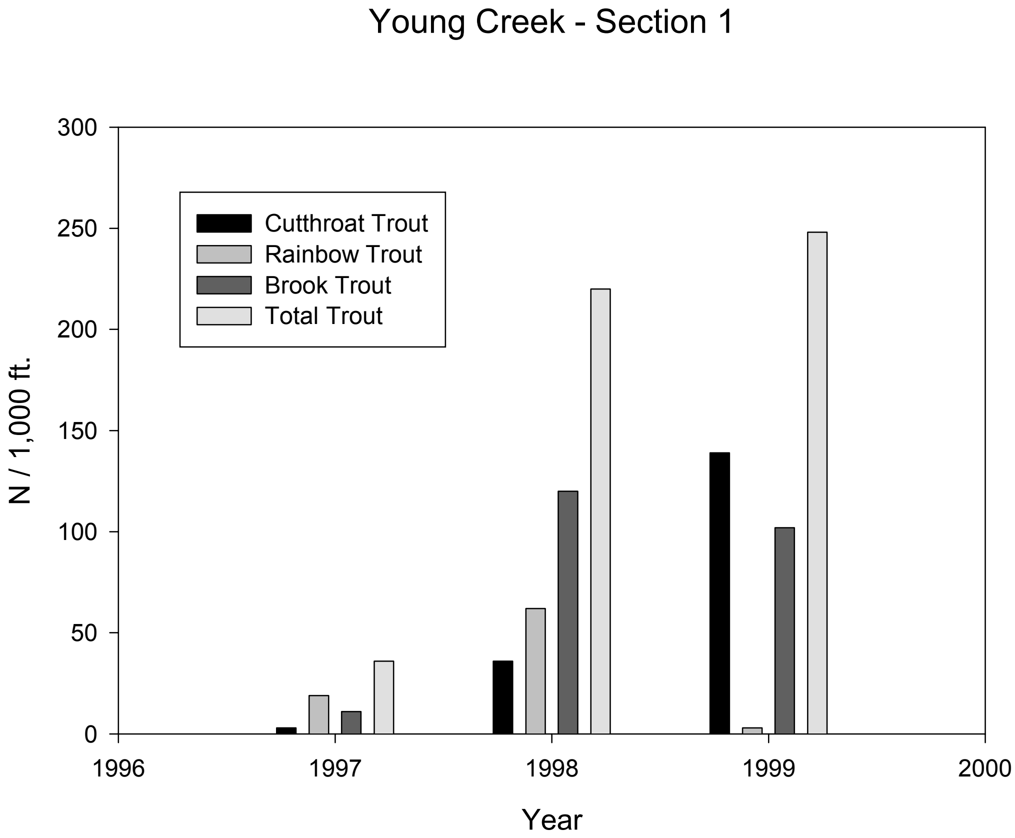

Figure 37. Density of trout in Section 1 of Young Creek, Montana, 1997 through 1999.

The dataset for cutthroat trout in Section five of Young Creek was not sufficient to determine long-term population trends (Figure 40). We observed increase in age 2+ westslope cutthroat trout (140-165 mm) in Section four of Young Creek in 1997. These fish were not present in the 1996 population estimate as age 1+ fish, which suggests that these fish may have been produced from the 1996 remote site incubators. In the future we will continue to perform population estimates in Young Creek to assess population trends and the success of the RSI project.

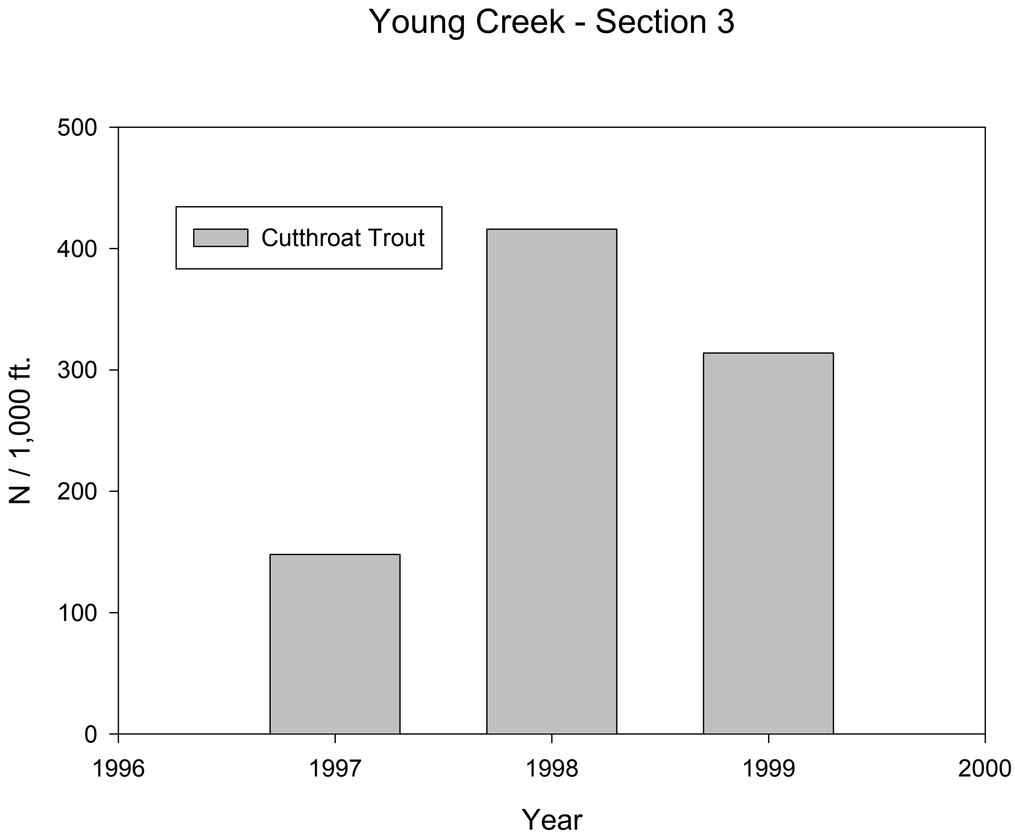

Figure 38. Density of cutthroat trout in Section 3 of Young Creek, Montana, 1997 through 1999.

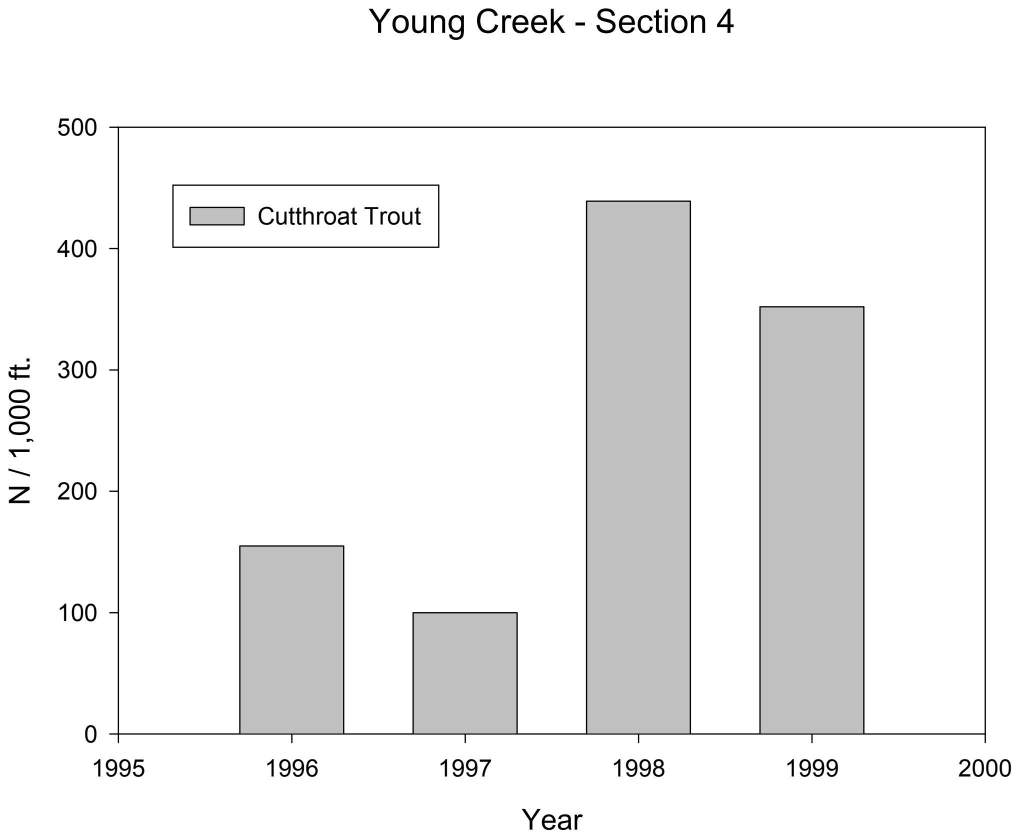

Figure 39. Density of cutthroat trout in Section 4 of Young Creek, Montana, 1996 through 1999.

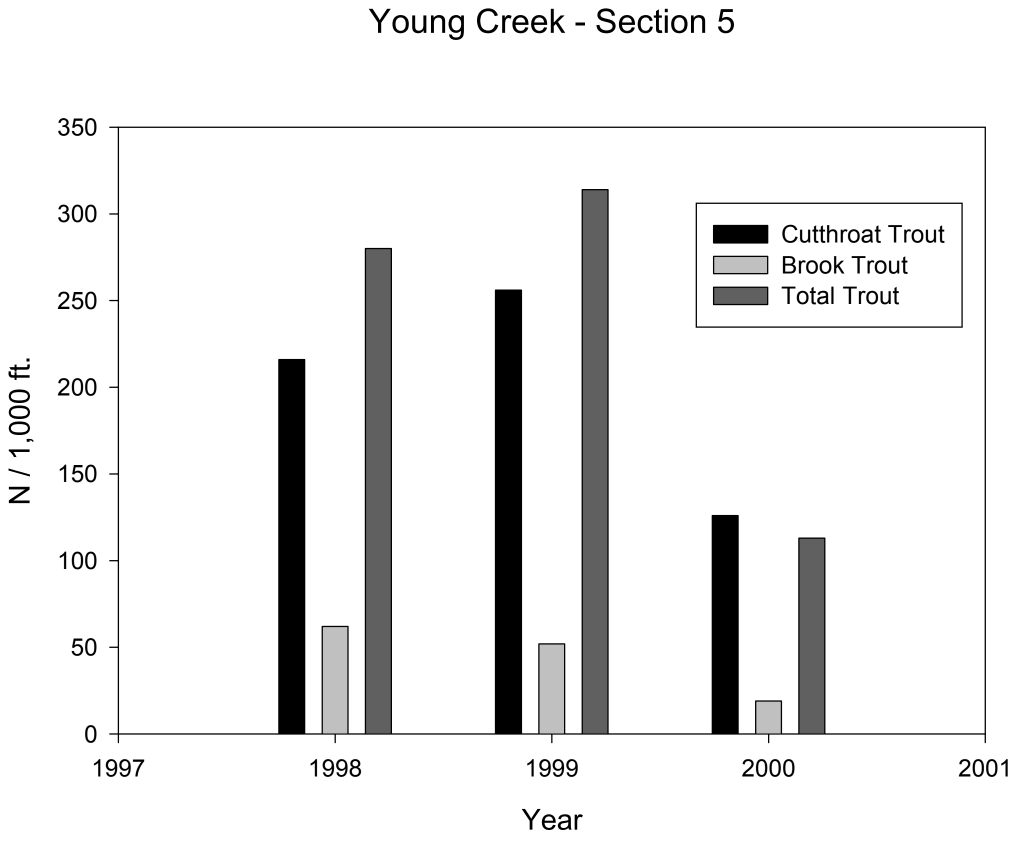

Figure 40. Density of trout in Section 5 of Young Creek, Montana, 1998 through 2000.

LINCOLN COUNTY FAIRGROUNDS POND

We began working with the Lincoln County Fairgrounds board of directors to build a fishing pond on the fairgrounds property in Eureka in 2000 (Figure 41). Construction was begun, but due to the untimely death of our lead engineer in the Design and Construction division with FWP in Helena, the project was delayed from being completed in 2000. We will complete the project in 2002. This project will be completed in cooperation with FWP's regional fisheries staff.

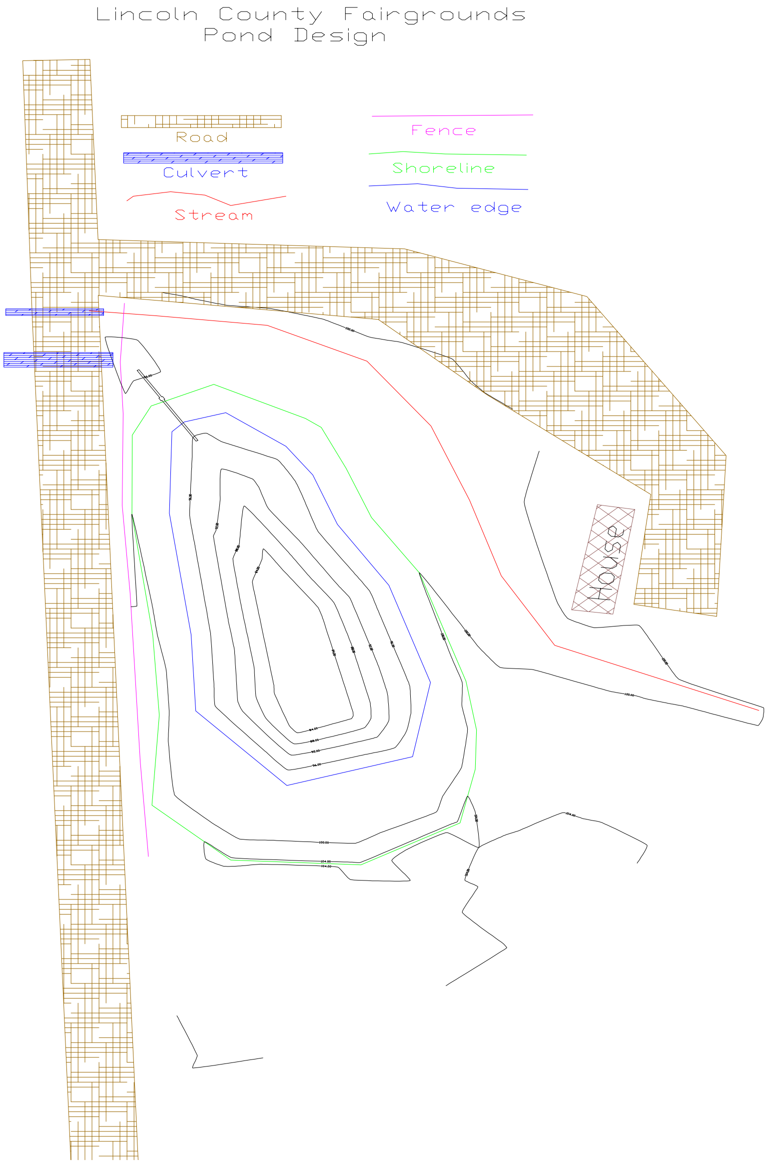

Figure 41. Site plan for the Lincoln County Fairgrounds pond, Eureka, Montana.

WIGWAM RIVER TEMPERATURE MONITORING

The Wigwam River, located in British Columbia, Canada, is the most important spawning tributary for the bull trout population of Libby Reservoir. In cooperation with the British Columbia Ministry of the Environment, we began monitoring water temperatures in the Wigwam River in 1998 due to increased land management activities within the drainage. The current Forest Development Plan calls for a total timber harvest of 657.3 ha over a three to four year period. This level of harvest represents 0.79% of the entire watershed or approximately 3.9% of the forested land base, and most harvest units will be clear cuts (B. Westover, British Columbia Ministry of the Environment, personal communication). We deployed `Stowaway` water temperature data loggers manufactured by the Onset Corporation within three reaches of the river to collect temperature data. The purpose of collecting these data is to monitor any negative impacts on water quality caused by increased management practices in the drainage. The reaches are roughly divided into the upper (Montana; Figure 42), middle (above Bighorn Creek; Figure 43) and lower (below Bighorn Creek; Figure 44) sections. By monitoring several locations in the basin, we can potentially isolate tributaries or specific reaches potentially contributing to thermal pollution. We configured temperature recorders to record temperature every two hours. We felt that by selecting a temperature recording interval of two hours, we maximized the probability of capturing the actual maximum and minimum daily temperatures, while optimizing battery life and available memory.

Results

The Wigwam River currently provides excellent coldwater habitat, with maximum summer temperatures (June – September) of 55 to 59^0 F and summer mean temperatures of $42\text{-}45^0$F (Figures 42-44). Temperatures in excess of 59^0 F are thought to limit bull trout distribution (Rieman and McIntyre 1993). Optimum water temperatures for rearing bull trout are about 44.6 to 46.4^0 C (Goetz 1989). Mean and maximum water temperatures are relatively consistent for each sample site. Maximum summer water temperatures were slightly higher (2- 3^0 F) in the Montana site compared to the lower sites. Winter water temperatures (December – February) remained above 32^0 F, preventing excessive anchor ice formation. This is important for winter rearing for juvenile bull trout. Also, optimum temperatures for bull trout egg incubation are between 35.6 – 39.2^0F (McPhail and Murray 1979). In the first three years of data collection, the temperature regime appears to be very consistent and conducive for all bull trout life history forms. We will continue monitoring the temperature in the Wigwam River in the future.

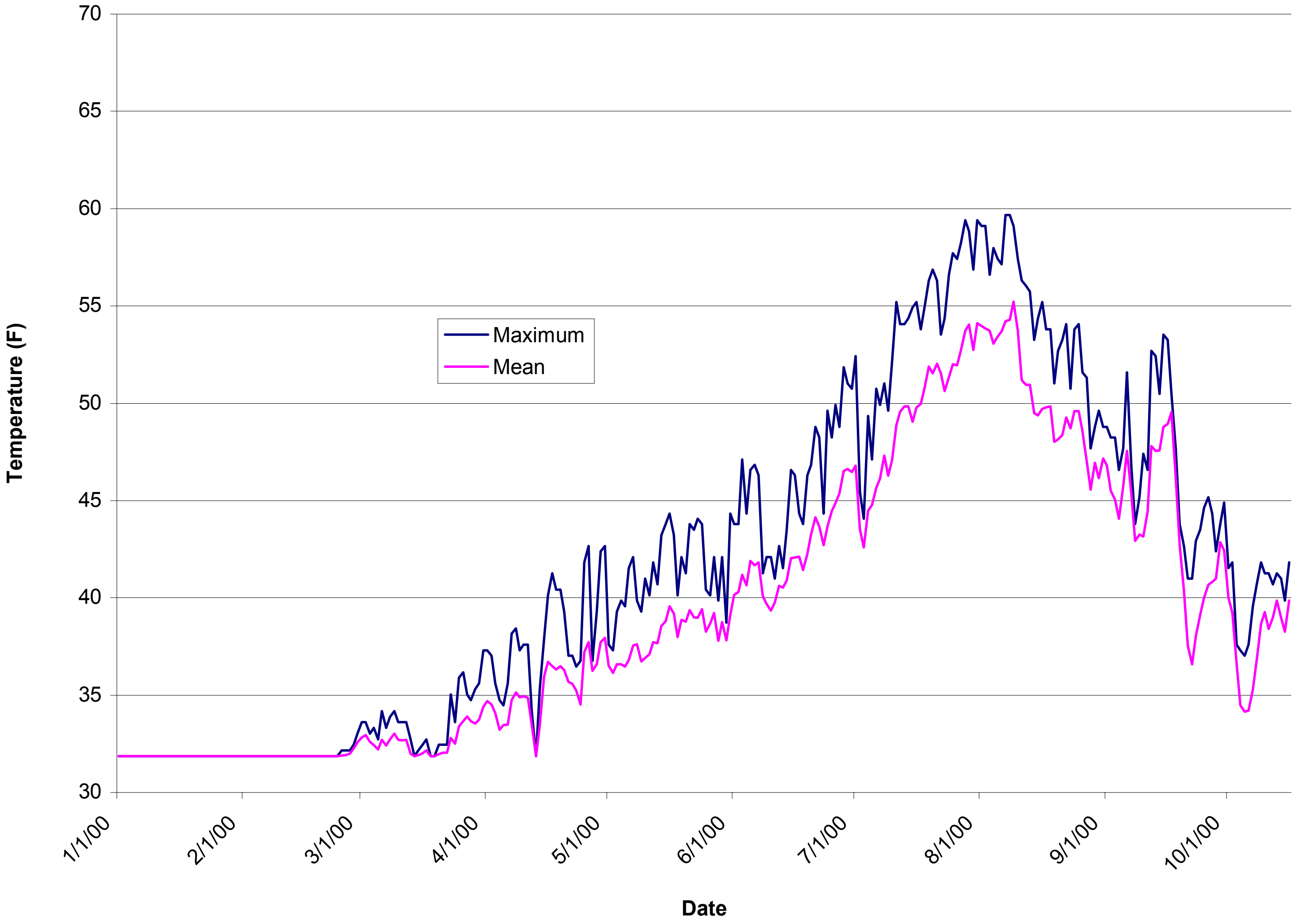

Figure 42. Mean daily and daily maximum water temperature in the upper Wigwam River, Montana, USA, 2000.

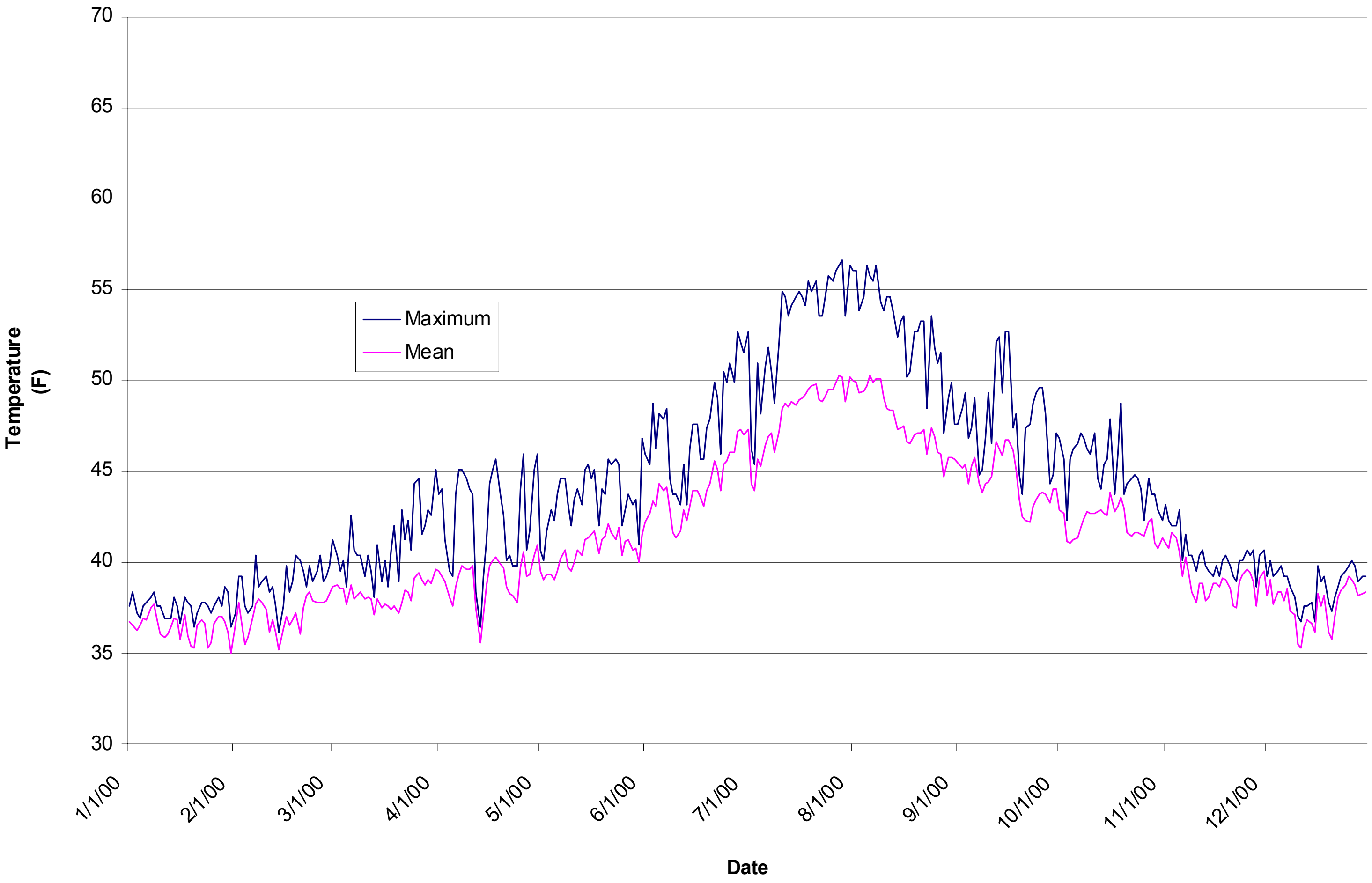

Figure 43. Mean daily and daily maximum water temperature in the middle Wigwam River (upstream of Bighorn Creek), 2000.

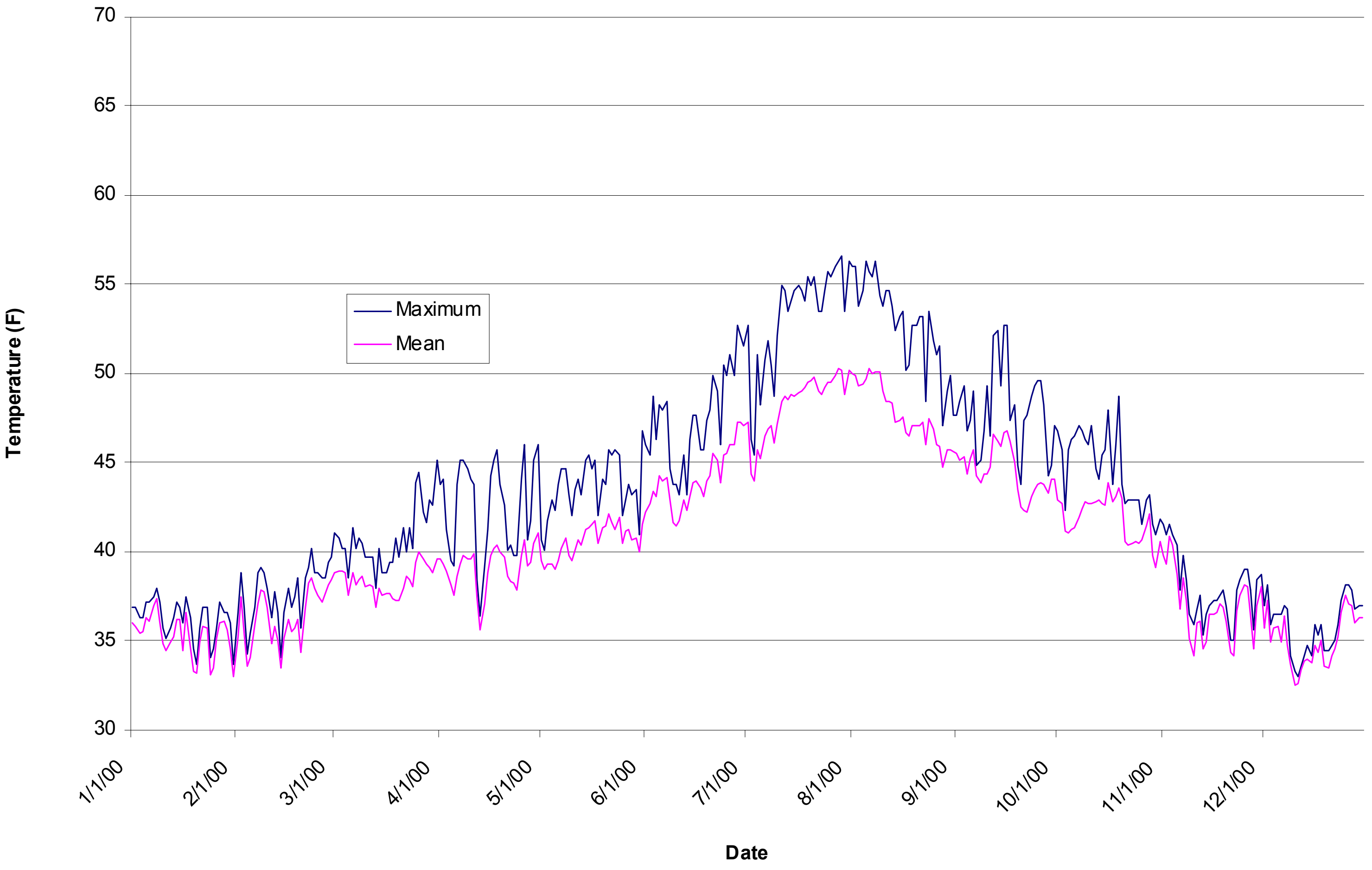

Figure 44. Mean daily and daily maximum water temperature in the lower Wigwam River (downstream of Bighorn Creek), 2000.

LOWER BASIN HABITAT IMPROVEMENT PROJECTS and MONITORING

Libby Creek

Population estimates on Libby Creek were conducted using depletion methods similar to Shepard and Graham (1983). A block net was placed at the lower end of the section and electrofishing was conducted from the upper end of the section towards the lower end. Two such passes were completed. If, based on captures made during the first two passes, probability of capture (P) was ≥ 0.6, a third pass was conducted.

$$P = C1 - C2 / C1$$

Where: C1 = number of fish captured during first catch and
C2 = number of fish captured during second catch.

All population estimates for include fish ≥ 75 mm. All sections were sampled using a backpack electrofisher powered by DC current. Population estimates and associated 95% confidence intervals were estimated using *Microfish 2.2* (Van Deventer and Platts 1983).

MFWP has collected fish population information in three reference reaches on Libby Creek from 1998 through 2000. These three sections include the following: Section 1: a 274 m long reach located ~ 2.4 km below the Highway 2 bridge. Section 2: a 171 m long reach located ~100 m upstream of the Highway 2 bridge. Section 3: a 171 m long reach located on the upper Cleveland property. The Cleveland property has been heavily impacted by historic mining activities (Sato 2000). Baseline population information at these three reference reaches was collected in anticipation of future habitat improvement and bank stabilization projects (Table20).

O'Brien Creek Projects

O'Brien Creek flows into the Kootenai River approximately four miles below Kootenai Falls. The stream is the only core area for the Lower Kootenai Bull Trout Recovery Area (Montana Bull Trout Scientific Group 1996a); it provides five miles of spawning habitat for adfluvial bull trout residing in the Kootenai River.

Table 20. Libby Creek depletion population estimates for fish ≥ 75 mm per 1,000 ft, and associated upper bounds for the 95 % confidence interval in parentheses. N/A indicates that these data were not collected.

Year	1998	1999[A]	2000[A]
Section 1 – below Hwy 2			
Rainbow Trout	81 (126.80)	26	125
Brook Trout	6 (8.27)	6	13
Bull Trout	0	0	0
Total Population [B]	90 (115.89)	32	138
Water Temp. °C	9	N/A	16
Discharge (cfs)	6.9	N/A	N/A
Section 2 -above Hwy 2			
Rainbow Trout	203 (225.20)	N/A	N/A
Brook Trout	7	N/A	N/A
Bull Trout	5 (6.26)	N/A	N/A
Total Population [B]	208 (228.39)	N/A	N/A
Water Temp. °C	5	N/A	N/A
Discharge (cfs)	6.9	N/A	N/A
Section 3 - upper Cleveland			
Rainbow Trout	N/A	N/A	170 (193.73)
Brook Trout	N/A	N/A	0
Bull Trout	N/A	N/A	3
Total Population [B]	N/A	N/A	170 (193.73)
Water Temp. °C	N/A	N/A	14

A) Section 1 population estimates in 1999 and 2000 were single pass catch-per-unit-effort estimates due to low catchability. 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.

Delta Project

Delta growth at the mouth of O'Brien Creek has accelerated due to the change of the Kootenai River hydrograph caused by Libby Dam. During high spring flows in O'Brien Creek, when most bedload is transported, the Kootenai River is no longer at historical high flow discharge, and no longer has the ability to transport the bedload being transported by O'Brien Creek, causing increased deposition at the confluence of O'Brien Creek.

O'Brien Creek changed course around its delta during high flows in 1998-99. This channel displacement created a head-cut up the lower 450' of the channel. The stream channel down-cut approximately two feet, creating accelerated bank erosion and channel instability. This eroded bank material was deposited at the stream mouth, further enlarging the delta into the Kootenai River (Figure 45). Because of the importance of O'Brien Creek as a core spawning tributary for Kootenai River bull trout, MFWP agreed to aid adjacent landowner Bob Egbert with design and implementation of a stream stabilization project at the delta. MFWP purchased material and Mr. Egbert paid for contracting equipment to construct the project.

We coordinated with Plum Creek Timber Company (PCTC) during design and installation of a new bridge at the project site. PCTC engineers used our stream channel data to design and construct a bridge with proper deck height and channel dimensions to prevent future channel instability associated with the road crossing.

Methods

We surveyed lower O'Brien Creek intensively and determined that the most cost effective and lowest risk restoration approach was to construct a new channel in the lower 250 ft. of stream. We determined that the appropriate location of the channel was the abandoned, filled historic channel. We installed three cross-vanes above the new channel to prevent further channel degradation and to protect the new bridge (Figure 46). We constructed five cross-vanes in the newly excavated channel as grade control.

The channel was designed as a B3 channel type with a 3.5% average stream channel gradient and bankfull width of 32 feet. The channel pattern, dimension and profile were designed using Dave Rosgen natural channel design techniques and our reference reach data collected on O'Brien Creek. We filled the existing lower 250 feet of degraded channel above the bankfull elevation with excavated material from the new channel and delta and re-vegetated with grasses and riparian shrubs to prevent erosion. We revegetated all of the raw banks in the former channel and re-graded them to a 3:1 slope (Figure 47).

The project eliminated passage restriction for adult bull trout and improved rearing habitat for juvenile bull trout and other native fish species. During the October 2000, MFWP personnel observed bull trout spawning below one of the cross vane structures in the project site.

Figure 45. O'Brien Creek Delta Project site with eroded bank highlighted.

Figure 46. O’Brien Delta Project photo showing cross-vanes and new bridge.

Figure 47. O’Brien Creek delta project after construction, 2001.

Troy Water Works Project

The original water supply diversion on O'Brien Creek for the City of Troy was constructed in the early 1900's. The original log diversion dam has caused bedload deposition above it over the years, decreasing the channel gradient. Streams with lower channel gradients typically have higher channel sinuosity Rosgen (1996). Thus, the stream channel began to migrate laterally to increase it's sinuosity, causing bank erosion and channel instability. The diversion dam began to fail in 1998, preventing water from effectively reaching the water cistern adjacent to the dam, and threatening fish passage above the structure; left unattended, the structure may have caused a fish migration barrier in the foreseeable future.

City of Troy officials contacted MFWP to help design a new diversion. The objectives of this project were to provide year-round water flow into the water cistern without compromising fish populations in O'Brien Creek and to stabilize the stream channel.

Methods

We designed a new water diversion structure after surveying the project site and creating a topographic map. We moved the point of diversion approximately 490 feet upstream by burying a 10 inch diameter plastic pipe at a 3.3% gradient to the cistern. We constructed a J-hook vane in the stream below the pipe inlet to divert water into the system during all flows and to prevent large debris from plugging the pipe.

We removed the old log diversion dam and replaced it with a cross vane, lowering the streambed to its original elevation. This will allow the stream to re-establish its historic channel and stabilize the reach above the diversion dam. MFWP will monitor this reach and perform channel maintenance if needed.

In addition to the instability of the stream channel and diversion dam, the old screen covering the water cistern outlet pipe needed replacement (Figure 48). We were able to utilize a standpipe structure that we originally purchased for the Libby Field Station spring pond outlet; the structure was inefficient for that purpose, but proved appropriate and cost-effective for this application (Figure 49). The screened cover is constructed with wedge shaped stainless steel well screen. This cover provides a smooth, screened surface, prevents fish from entering the outlet pipe and reduces the required maintenance of the system. An outflow channel from the cistern to O'Brien Creek provides passage for entrained fish from the cistern back to the stream.

Figure 48. City of Troy water cistern O'Brien Creek, with old outlet pipe screen cover.


Figure 49. Troy water cistern O'Brien Creek, after change in diversion and installation of new outlet pipe screen cover.

Troy Urban Fish Pond Project

The Troy fishing pond is currently being constructed and is a cooperative effort of Lincoln County, MFWP, BPA and the city of Troy, MT. This project will enhance fishing and educational opportunities for young anglers on land located at the Troy Recreational Park. When completed, the pond will cover 2 acres of land and have a maximum depth of 17 feet (Figure 50).

Since the city began using a modern water system, the city has maintained the O'Brien Creek water system for an emergency water supply. Water from the historic O'Brien system currently flows into the Kootenai River from a pressure relief pipe. This overflow water will be used to irrigate the new recreation site, and excess water will be piped into the fishing pond.

The fishing pond will initially be stocked by MFWP with approximately 1,000 westslope cutthroat trout grown at Murray Springs Hatchery in Eureka, MT. Remote site incubators could be used to stock the pond and provide an educational opportunity in future years.

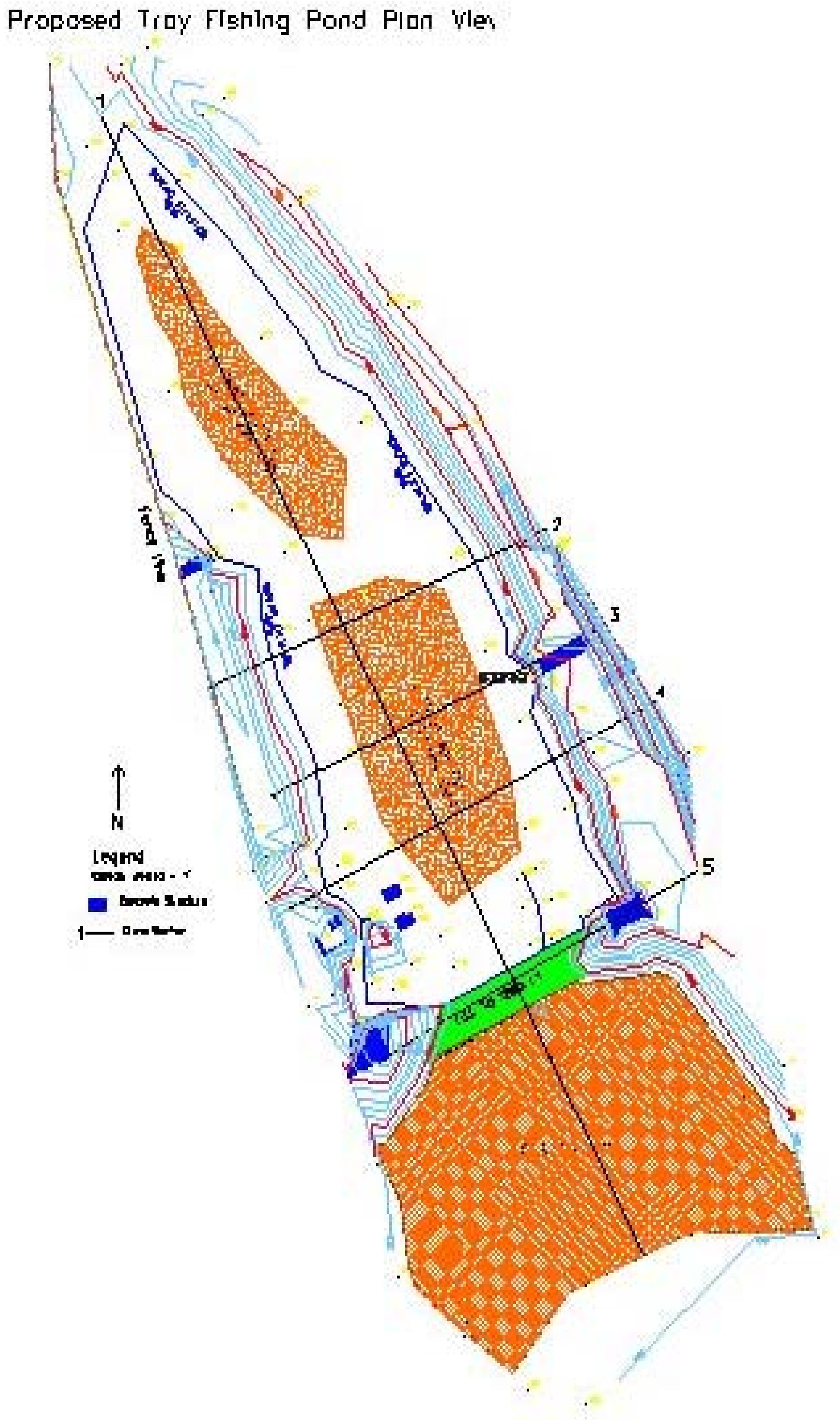

Figure 50. Site map for fishing pond in Troy, Montana.

Parmenter Creek

The history of the Parmenter Creek drainage is one of repetitive flooding. Parmenter Creek is generally stable until it exits the valley; from the point that land is developed, it has become very unstable due to the channel modifications. The valley mouth is an alluvial fan, which is a natural depositional area. Over time, the stream channel has been confined to the highest point on the alluvial fan, and many houses have been built at lower elevations on the perimeter of the alluvial crest. The stream has been channelized in an attempt to control flooding to adjacent subdivisions. The stream typically goes dry during base flow conditions due to its location on the porous alluvial fan, deep bedload deposits, and lack of a properly functioning floodplain. Water Consulting, Inc. was retained by Lincoln County to develop and oversee the implementation of a stream relocation and re-naturalization project on Parmenter Creek. Lincoln County obtained funding for this project through the contributions of various local business and government agencies, along with a grant from the Federal Emergency Management Agency's "Project Impact". However, as a result of several cost over-runs, FWP committed additional funds from the Libby Mitigation program to complete the project. FWP personnel also assisted with fisheries data collection (Table 21) and surveying during the design and construction of the project, and began monitoring fisheries recovery in the newly constructed channel.

The purposes of the project were as follows:

- flood hazard reduction;
- habitat enhancement designed to benefit native trout;
- enhancement of the aesthetics of the stream and adjacent riparian ecosystem;
- reduce bank erosion and excessive sediment sources;
- convert the channelized portions of the stream into a channel type that is self-maintaining and will accommodate floods without major changes in channel pattern or profile;
- use natural stream stabilization techniques that will allow the stream to adjust slowly over time and be representative of a natural stream system.

Table 21. Parmenter Creek (prior to channel reconstruction) depletion population estimate for fish ≥ 75 mm per 1,000 feet using 95 % confidence intervals.

Year	2000
Parmenter Creek –Dome Mtn. Road Bridge	
Rainbow Trout	92 (110.65)
Brook Trout	18 (19.20)
Total Population	108 (122.56)
Water Temp. °C	14.4

Libby Field Station Spring Creek Project

During construction of the Libby fish hatchery, currently the MFWP Libby Area Office, the spring flowing through the compound was channeled and used for raising fish. After the hatchery shut down much of the spring creek was a shallow, over-widened channel or multiple shallow channels. We designed and built a single, stable stream channel to facilitate antimyicin treatment of the spring creek to remove nonnative trout and increase the quality of fish habitat. Existing ponds at the site were enlarged and contoured to provide trout rearing habitat. A self-cleaning fish barrier was installed to isolate the facility from Libby Creek downstream. . This was a cooperative effort with MFWP management to establish redband trout *Oncorhychus mykiss gairdneri* in the spring creek and newly excavated pond.

Methods

After surveying the current conditions of the spring creek, we designed a stable hydraulically efficient stream channel for the spring creek. In areas where the channel was wide and shallow we used a small hydraulic excavator to deepen and narrow 700 feet of channel. In the lower 350 feet of channelized stream, we diverted the stream into a newly constructed channel. By constructing a new channel we added 200 feet of stream length and created a stable E-4/C4 channel type. The new channel has an average gradient of 0.8% and an average width of 4 feet with a lower width to depth ratio (Figure 51). By providing more diverse habitat components in the stream, we increased available quality fish habitat for red-band rainbow trout.

To prevent redband trout from leaving the spring creek and pond, we installed an electric rotating drum screen in the pond outlet channel (Figure 52). This self-cleaning screen will prevent fish from invading or escaping the spring/pond complex.

Figure 51. Reconstructed channel at Libby Field Station spring creek, Libby, MT.

Figure 52. Fish screen at Libby Field Station spring pond, Libby, MT.

We treated the newly renovated spring creek and pond with antimycin (Table 22) on November 1, 2000 to remove eastern brook trout and non-native rainbow trout. Native redband trout from Basin Creek were stocked into the pond and spring creek in early May 2001 to provide a future source of eggs for restoring redband stocks within their historic range in the Kootenai River basin. The isolation facility will also provide a source of native redband for use as an alternative to stocking lakes and private ponds with non-native fish.

Table 22. Antimycin delivered to spring creek and spring pond, Libby Field Station, Libby, Montana.

Drip Station	1st Fill (3 2 Hrs.)	2nd Fill (3 2 Hrs.)	3rd Fill (3 2 Hrs.)
1	172 ml	172 ml	86 ml
2	86 ml	86 ml	86 ml
3	86 ml	86 ml	0
4	86 ml	86 ml	0
5	86 ml	86 ml	0
Total	516 ml	516 ml	172 ml

Hand sprayer Run	Time	Milliliters Antimycin
1 (4 sprayers)	1130	215 ml
2 (2 sprayers)	1330	129 ml

TOTAL ANTIMYCIN USED - 1548 ml   APPROXIMATE COST - $1,200.00

The pond was drained prior to starting the drip stations to minimize the amount of chemical to be applied, and all downstream flow was blocked at the bottom of the treatment area when the drip stations were started. Backpack sprayers and drip stations were used to ensure total coverage of the stream. After the treatment was complete, the toxin was nutralized with a potassium permanganate ($KMnO_4$) drip station (Table 23) located in the outlet as stream flow out of the pond resumed. The $KMnO_4$ drip station was refilled once during the night and ran for approximately 4 hours. Personnel looked for stressed or dead fish to the confluence of the spring creek and Libby Creek and for approximately 1/4 mile downstream of the confluence on Libby Creek. No fish mortality was observed below the detoxification drip station.

Table 23. Detoxification procedure for spring creek and spring pond, Libby Field Station, Libby, Montana.

Fill Number	Duration/rate	$KMnO_4$ Delivered
1	22 gallons solution in 4 Hours	2740 grams
2	22 gallons solution in 4 Hours	2740 grams

CALCULATIONS

DETOXIFICATION

Solubility of $KMnO_4$ = 5 g/ 100 ml

Q = 0.28 acre feet/ hour

2 ppm = 7.566 kg/1,000,000 gallons water = 2.45 kg/acre foot
2.45 kg/acre foot x 0.28 acre feet/ hour = 0.686 kg/hour of $KMnO_4$

Drip rate = 5.37 gallons/hour 0.686 kg/hr x 4 hours = 2.74 kg

Each fill consisted of 22 gallons of water mixed with 2.74 kg of $KMnO_4$ delivered to the creek over 4 hours.

ANTIMYCIN

1 cfs = 0.083 acre feet/hour
Q = 3.39 cfs=0.281 acre feet / hour

Station 1 delivered 172 ml antimycin in 3.5 hours to 0.98 acre feet
172 ml/0.98 acre feet=175.5 ml/acre feet

12.3 ml/acre feet= 1 ppb (From Fintrol table) thus the concentration achieved by station 1 = 175.5 ml per acre feet/12.3 ml per acre feet=14.3 ppb. The other stations delivered 2 *the antimycin resulting in 7.1 ppb. The actual concentrations were higher due to hand spraying and close proximity of the drip stations.*

DETERMINING THE AMOUNT OF ANTIMYCIN NEEDED

Example: Treat 2.5 acre feet/hour of stream flow at 10 ppb.

From the table on the Fintrol label, 123.0 ml antimycin yields 10 ppb in 1 acre foot. Thus, 123.0 ml/acre foot x 2.5 acre feet/hour=307.5ml/hr

Chemically Treated Lakes

The Libby Mitigation project has rehabilitated 4 lakes since 1997. Three of the lakes (Bootjack, Topless, and Cibid) are in the Thompson Chain of Lakes between Libby and Kalispell. We treated Bootjack and Cibid Lakes with rotenone during November 1997, to remove stunted populations of illegally introduced yellow perch and pumpkinseed sunfish. We treated Topless Lake during April 1998, to remove black bullheads, yellow perch, and pumpkinseed sunfish. MFWP stocked the lakes with westslope cutthroat trout and rainbow trout following a detoxification period. Natural reproduction of trout is not possible in the closed-basin lakes and the fisheries will be managed as put-grow-take. Based on gillnet data (Table 24) and reports from anglers, the treatments were a success.

We applied rotenone in Carpenter Lake, near Eureka, during early November 1998, to remove illegally introduced bluegill, yellow perch, northern pike, and largemouth bass, which were causing trout stocked by FWP to attain smaller sizes and densities due to competition for food resources. Westslope cutthroat trout and rainbow trout were restocked during spring of 1999, and have since provided a quality fishery. Zooplankton and crayfish numbers are increasing. Unfortunately, MFWP has since verified reports of the presence of largemouth bass, smallmouth bass, and bluegills in Carpenter Lake. The presence of smallmouth bass, which were not present prior to treatment, indicates an illegal introduction. Largemouth bass and bluegills may have survived rotenone treatment, though none were captured during monitoring surveys in the months immediately following treatment.

We collected zooplankton samples from lakes that had been treated with rotenone in the recent past to remove illegally introduced or undesirable fish species. We collected 3 samples from each lake prior to treatment in June and/or 3 samples in October using a 0.3 m, 153 μ Wisconsin net taken as deep as possible (up to 20 m and no shallower than 5 m). The treated lakes will be sampled for 3 years after rehabilitation to document zooplankton recovery. With the exception of Carpenter Lake, zooplankton numbers have returned to pre-treatment densities or greater (Figures 53 - 56).

Table 24. Summary of catch in gillnets set to monitor lakes pre- and post-treatment with rotenone.

Lake	Date	Species*	Number per net	Mean Length (mm)	Range (mm)	Mean Weight (g)	Range (g)
PRE-TREATMENT							
Bootjack	10-02-96	RBT	7.0	227	205-346	127	90-426
		YEP	2.0	254	243-271	237	210-296
		PKS	3.5	116	100-166	35	18-98
Topless	10-02-96	RBT	8.0	199	156-342	100	36-428
		PKS	8.0	122	96-139	37	14-50
Cibid	09-10-97	RBT	6.7	236	166-415	158	50-820
		YEP	8.7	212	143-320	182	32-452
		PKS	3.7	102	95-112	18	14-22
Carpenter	05-28-97	RBT	0.5	415	394-428	783	602-904
		WCT	0.2	426		808	
		NOP	0.5	735	574-1,054	4,201	1,392-9,525
		BLG	1.7	133	127-187	63	26-146
POST-TREATMENT							
Bootjack	06-07-99	RBT	10.0	316	165-347	433	38-532
		WCT	2.0	313	312-313	387	386-388
Topless	06-07-99	No Fish					
Cibid	06-08-99	WCT	8.0	244	200-285	153	58-284
Carpenter	06-22-00	RBT	11.0	290	174-420	276	60-770
		WCT	5.0	308	250-355	332	170-452
		LMB	0.5	255		278	
Bootjack	05-30-00	RBT	1.0	385		578	
		WCT	4.0	286	218-356	301	102-498
Topless	05-30-00	WCT	10.5	309	236-352	373	162-556
Cibid	05-30-00	RBT	2.0	332	330-333	427	398-456
		WCT	5.0	305	272-325	308	216-394

* Species abbreviations: RBT = rainbow trout, WCT = westslope cutthroat trout, PKS = pumpkinseed, YEP= yellow perch, NOP = northern pike, LMB = largemouth bass, BLG = bluegill.

Carpenter Lake

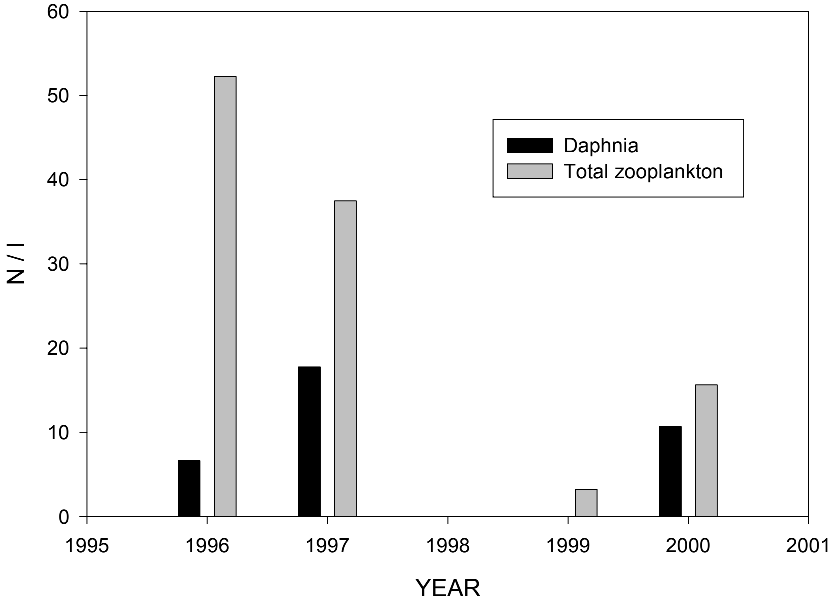

Figure 53. *Daphnia* density in Carpenter Lake, Montana, before and after treatment with rotenone (November 1998).

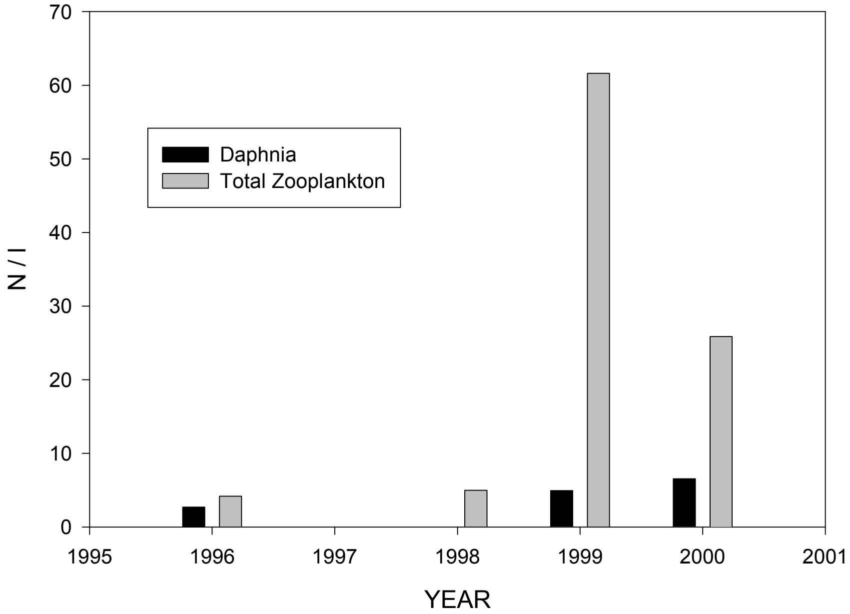

Figure 54. *Daphnia* and total zooplankton density in Bootjack Lake, Montana, before and after treatment with rotenone (November 1997).

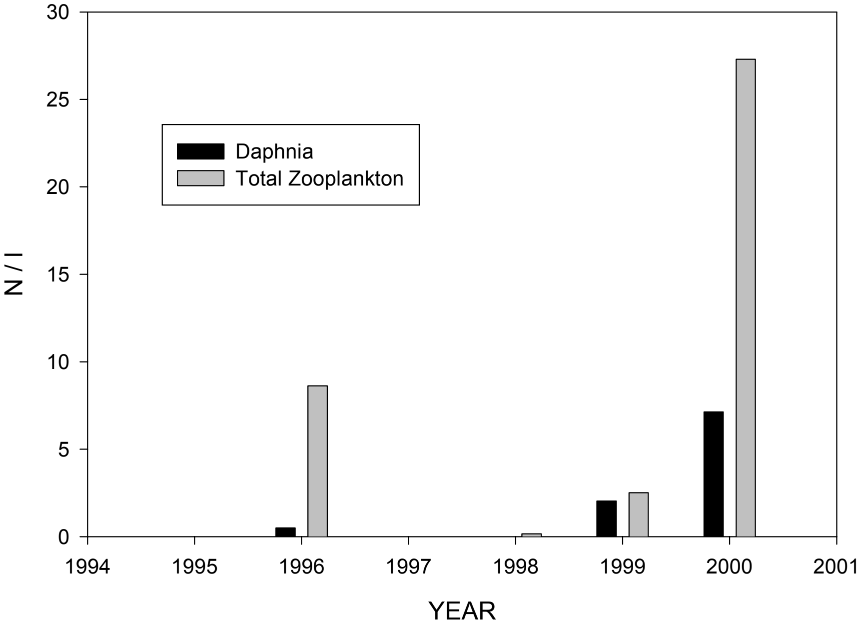

Figure 55. *Daphnia* and total zooplankton density in Topless Lake, Montana, before and after treatment with rotenone (April 1998).

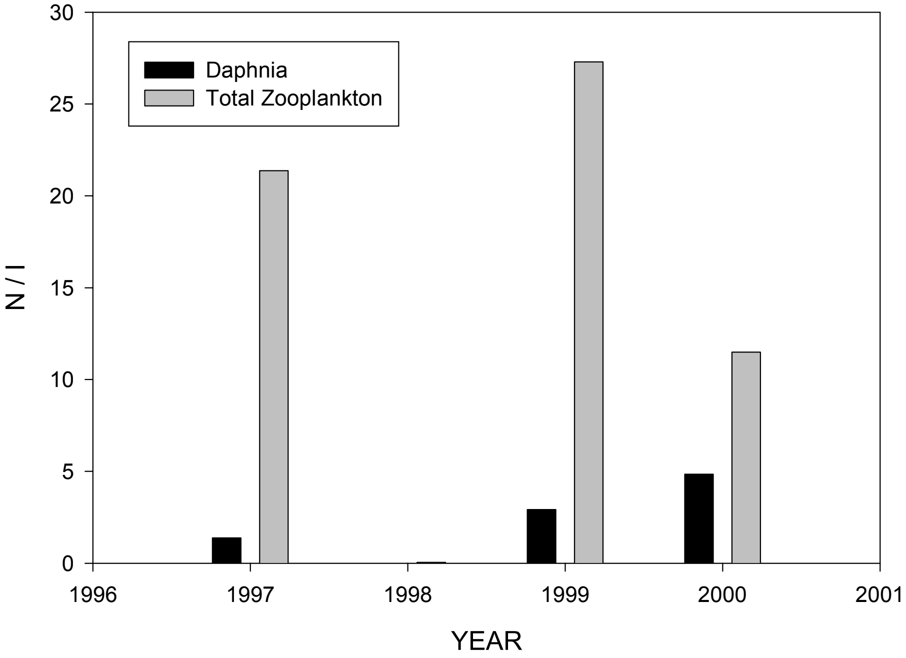

Figure 56. *Daphnia* and total zooplankton density in Cibid Lake, Montana, before and after treatment with rotenone (November 1997).

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Appendix A. Tables of mean zooplankton density and variance for zooplankton tows in Lake Koocanusa, 1997 – 2000.

Table A1. 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 1997. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.08	0.00	0.15	7.82	0.00	15.56	0.00
		0.00	0.00	0.01	26.94	0.00	288.29	0.00
May	(3)	0.39	0.02	0.03	6.54	1.41	26.46	0.02
		0.26	0.00	0.00	74.13	2.00	1672.07	0.00
June	(3)	0.63	0.28	0.04	3.66	3.77	24.52	0.03
		0.07	0.05	0.00	0.87	10.15	330.83	0.00
July	(3)	4.86	0.05	0.54	4.55	8.01	128.26	0.06
		0.40	0.00	0.01	2.36	2.67	7159.13	0.00
August	(3)	4.93	0.22	1.19	7.12	2.83	132.69	0.07
		2.54	0.06	0.04	0.68	14.00	3516.38	0.01
September	(3)	2.06	0.03	2.29	5.12	0.24	248.03	0.14
		5.13	0.00	1.53	15.62	0.17	12,521.78	0.05
October	(3)	2.12	0.20	0.92	3.39	0.00	66.86	0.02
		1.11	0.02	0.05	0.65	0.00	599.83	0.00
November	(3)	0.94	0.25	0.43	1.77	0.24	26.69	0.01
		0.04	0.01	0.02	0.24	0.17	81.31	0.00

Table A2. 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 1997. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.04	0.01	0.02	1.42	0.00	0.00	0.00
		0.00	0.00	0.00	5.44	0.00	0.00	0.00
May	(3)	0.18	0.00	0.03	10.85	2.83	10.37	0.02
		0.01	0.00	0.00	29.93	13.48	322.82	0.00
June	(3)	4.52	0.04	0.15	22.84	30.18	4.15	0.13
		26.80	0.00	0.05	696.45	1235.23	51.67	0.01
July	(3)	6.43	0.00	0.49	8.70	7.78	34.14	0.13
		6.84	0.00	0.12	5.45	13.48	883.83	0.00
August	(3)	4.59	0.00	0.94	6.29	4.25	145.42	0.17
		0.91	0.00	0.01	0.43	3.51	14,051.44	0.00
September	(3)	0.44	0.00	1.19	4.13	0.24	139.77	0.44
		0.07	0.00	0.04	3.07	0.17	5,333.98	0.04
October	(3)	1.65	0.16	1.66	3.70	0.00	64.89	0.02
		1.27	0.01	0.52	3.75	0.00	8,403.81	0.00
November	(3)	0.63	0.15	0.53	2.26	0.00	12.10	0.00
		0.03	0.00	0.02	0.48	0.00	220.10	0.00

Table A3. 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 1997. *Epischura* and *Leptodora* were measured as number per m^3.

Month	(N)	*Daphnia*	*Bosmina*	*Diaptomus*	*Cyclops*	*Leptodora*	*Epischura*	*Diaphanosoma*
May	(3)	0.01	0.00	0.00	0.09	0.00	0.26	0.00
		0.00	0.00	0.00	0.00	0.00	0.21	0.00
June	(3)	11.13	0.00	0.07	11.85	28.29	0.00	0.03
		15.44	0.00	0.00	98.42	155.67	0.00	0.00
July	(3)	7.28	0.00	0.42	7.89	5.48	18.86	0.17
		25.01	0.00	0.02	1.84	1.97	266.77	0.00
August	(3)	4.42	0.00	0.96	3.97	3.38	78.56	0.09
		9.53	0.00	0.04	6.88	0.24	4,264.85	0.01
September	(3)	1.58	0.00	2.74	7.59	0.94	48.33	0.25
		0.84	0.00	3.64	18.59	0.89	1,483.01	0.03
October	(3)	4.47	0.11	2.63	6.22	0.00	77.57	0.03
		12.38	0.01	0.40	2.30	0.00	10,402.62	0.00
November	(3)	1.08	0.07	0.93	2.50	0.00	13.11	0.00
		0.09	0.01	0.40	3.54	0.00	137.66	0.00

Table A4. 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 1998. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.51	0.03	0.09	0.73	0.00	13.77	0.00
		0.10	0.00	0.00	0.26	0.00	190.01	0.00
May	(3)	2.66	4.32	0.37	15.40	4.72	32.06	0.00
		0.88	0.91	0.01	1.21	16.21	3,084.17	0.00
June	(3)	1.77	0.04	0.87	9.26	16.03	168.82	0.00
		4.74	0.00	1.13	42.06	187.28	26,754.15	0.00
July	(3)	5.17	0.02	2.63	13.39	0.47	165.04	0.24
		2.47	0.00	2.55	17.34	0.66	13,306.43	0.04
August	(3)	2.28	0.57	2.60	10.77	0.00	267.36	0.13
		0.39	0.23	2.05	1.69	0.00	15,335.01	0.00
September	(3)	2.44	0.56	3.68	10.06	1.18	116.00	0.98
		0.42	0.24	0.40	2.59	2.17	312.15	0.02
October	(3)	1.28	0.06	2.45	10.25	0.24	132.22	0.94
		0.10	0.00	0.89	16.84	0.17	951.00	0.11
November	(3)	0.54	0.24	0.98	4.47	0.00	31.50	0.12
		0.13	0.02	0.07	4.03	0.00	1,593.33	0.00

Table A5. 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 1998. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.54	1.62	0.16	8.04	0.24	19.80	0.00
		0.06	0.12	0.01	0.06	0.17	1,176.52	0.00
May	(3)	2.59	2.02	0.35	15.72	7.31	37.72	0.02
		2.92	3.66	0.10	55.89	23.16	4,269.15	0.00
June	(3)	5.78	0.00	3.45	28.23	25.94	106.57	0.03
		2.32	0.00	7.31	209.77	116.73	15,484.28	0.00
July	(3)	4.56	0.00	2.95	10.70	4.95	78.65	0.25
		2.79	0.00	2.03	4.31	1.50	1,499.51	0.01
August	(3)	0.28	0.06	2.44	8.51	0.71	492.29	0.13
		0.02	0.01	2.93	18.09	0.50	75,429.41	0.01
September	(3)	1.73	0.12	3.67	8.54	0.00	115.15	0.95
		2.64	0.00	4.19	38.06	0.00	2,395.17	0.40
October	(3)	0.40	0.05	1.66	3.91	0.00	69.13	0.58
		0.01	0.00	0.00	1.03	0.00	945.63	0.03
November	(3)	0.94	0.25	0.93	4.46	0.00	26.69	0.19
		0.02	0.02	0.06	3.05	0.00	245.23	0.00

Table A6. 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 1998. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.16	4.15	0.20	4.36	0.81	52.26	0.03
		0.03	6.84	0.02	0.07	0.53	1,620.21	0.00
May	(3)	3.25	0.14	0.20	19.97	18.39	0.94	0.03
		8.31	0.01	0.04	275.38	734.35	2.67	0.00
June	(3)	3.74	0.00	0.72	12.10	8.89	33.73	0.09
		9.89	0.00	0.68	193.91	129.04	1,152.75	0.02
July	(3)	4.22	0.02	1.33	7.60	5.90	32.38	0.36
		0.46	0.00	0.85	25.09	6.17	23.42	0.10
August	(3)	0.26	0.02	2.72	1.01	0.00	967.58	0.17
		0.01	0.00	1.66	0.41	0.00	27,063.23	0.01
September	(3)	1.53	0.25	4.09	2.86	0.00	120.79	0.72
		0.70	0.11	0.94	8.54	0.00	1,251.56	0.15
October	(3)	3.69	0.69	10.06	7.40	0.00	46.59	2.41
		6.15	0.57	92.06	37.02	0.00	1,690.78	4.21
November	(3)	1.78	0.16	4.79	6.52	0.00	30.77	0.16
		0.12	0.01	39.54	4.64	0.00	501.37	0.01

Table A7. 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 1999. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.11	0.37	0.01	2.55	0.00	5.56	0.00
		0.00	0.02	0.00	8.60	0.00	42.44	0.00
May	(3)	0.91	3.94	0.17	28.01	0.24	361.20	0.08
		0.03	1.35	0.02	1,234.66	0.17	67,274.20	0.01
June	(3)	1.32	0.29	0.01	5.38	3.77	66.01	0.00
		0.53	0.18	0.00	5.87	11.18	371.23	0.00
July	(3)	1.68	0.15	0.04	6.86	21.22	116.76	0.02
		1.82	0.03	0.00	0.10	36.56	1,326.87	0.00
August	(3)	2.75	0.30	0.15	8.50	2.83	207.20	0.22
		0.39	0.02	0.00	5.13	0.50	441.57	0.00
September	(3)	1.94	0.99	1.13	11.82	2.36	95.25	0.31
		1.26	0.11	0.38	6.82	1.18	803.24	0.04
November	(3)	0.50	0.61	0.51	1.51	0.00	5.94	0.06
		0.02	0.03	0.06	0.01	0.00	29.85	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 Rexford area of Libby Reservoir during 1999. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.06	0.28	0.02	1.17	1.25	0.00	0.01
		0.00	0.03	0.00	0.52	0.07	0.00	0.00
May	(3)	0.04	0.55	0.02	2.14	0.55	147.05	0.04
		0.00	0.18	0.00	2.71	0.24	9,782.15	0.00
June	(3)	2.83	0.39	0.05	6.22	14.85	72.62	0.06
		4.32	0.02	0.00	24.84	571.89	691.13	0.00
July	(3)	6.50	0.06	0.04	14.76	28.76	108.08	0.08
		12.64	0.01	0.00	13.73	236.39	663.58	0.00
August	(3)	3.66	0.19	0.48	12.71	4.71	254.63	0.23
		1.38	0.02	0.29	7.07	8.18	55,833.22	0.01
September	(3)	3.44	1.84	1.35	17.52	2.05	53.76	0.52
		0.31	0.64	0.06	0.55	8.75	8,669.34	0.01
November	(3)	0.84	1.32	0.92	4.44	0.00	19.99	0.03
		0.02	0.03	0.02	1.09	0.00	588.12	0.00

Table A9. 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 1999. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
June	(3)	1.91	0.26	0.01	14.56	5.03	17.54	0.08
		3.35	0.08	0.00	194.99	53.69	490.84	0.00
July	(3)	3.35	0.00	0.07	5.22	21.06	64.32	0.07
		5.79	0.00	0.00	30.08	957.50	3,013.17	0.01
August	(3)	4.82	0.01	0.23	16.98	14.62	79.31	0.46
		1.86	0.00	0.04	2.58	148.23	837.29	0.05
September	(3)	2.70	2.86	0.58	13.17	1.50	22.63	0.65
		0.91	6.09	0.01	4.65	0.52	1,536.80	0.29
November	(3)	2.20	0.21	3.89	8.27	1.18	0.90	0.00
		13.51	0.05	42.23	183.33	4.18	0.61	0.00

Table A10. 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 2000. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.02	0.01	0.01	0.97	0.00	0.47	0.00
		0.00	0.00	0.00	1.04	0.00	0.66	0.00
May	(3)	0.42	0.05	0.09	10.70	2.83	145.80	0.00
		0.14	0.00	0.00	98.80	8.01	1,615.74	0.00
June	(3)	0.95	0.27	0.01	7.09	5.42	0.00	0.01
		0.15	0.06	0.00	16.77	5.17	0.00	0.00
July	(3)	1.72	0.12	0.07	4.73	11.32	6.34	0.00
		0.72	0.00	0.01	3.62	15.51	120.46	0.00
August	(3)	1.18	3.56	0.39	7.85	0.71	160.09	0.14
		0.05	5.53	0.02	0.09	0.50	16,482.47	0.00
September	(3)	0.44	2.79	0.43	7.20	1.65	77.33	0.10
		0.08	3.58	0.01	9.52	0.17	789.33	0.00
October	(3)	0.60	0.32	0.36	4.55	0.00	144.67	0.06
		0.06	0.02	0.01	4.94	0.00	15,290.22	0.00
November	(3)	0.86	0.40	0.58	6.82	0.00	5.85	0.01
		0.33	0.11	0.07	17.74	0.00	102.55	0.00

Table A11. 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 2000. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
April	(3)	0.13	0.01	0.02	1.81	0.00	0.00	0.00
		0.01	0.00	0.00	1.69	0.00	0.00	0.00
May	(3)	0.87	0.06	0.06	24.53	4.24	65.31	0.00
		1.14	0.01	0.01	1,233.43	45.48	5,901.49	0.00
June	(3)	1.39	0.27	0.05	7.06	5.42	0.00	0.00
		1.38	0.02	0.00	26.03	20.68	0.00	0.00
July	(3)	1.30	0.35	0.05	6.45	9.20	0.00	0.00
		0.55	0.04	0.00	12.61	0.49	0.00	0.00
August	(3)	1.15	0.71	0.46	7.36	1.18	141.84	0.16
		0.77	0.26	0.06	1.23	0.66	18,812.84	0.01
September	(3)	1.00	0.83	0.78	9.29	4.19	94.23	0.20
		0.99	0.18	0.09	12.99	9.96	11,582.23	0.02
October	(3)	1.23	0.30	0.60	7.89	0.00	21.08	0.09
		0.39	0.01	0.02	0.11	0.00	13.17	0.00
November	(3)	0.44	0.11	0.27	4.82	0.00	15.09	0.01
		0.00	0.00	0.00	0.07	0.00	683.12	0.00

Table A12. 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 2000. *Epischura* and *Leptodora* were measured as number per m^3.

Month	**(N)**	***Daphnia***	***Bosmina***	***Diaptomus***	***Cyclops***	***Leptodora***	***Epischura***	***Diaphanosoma***
May	(3)	0.12	0.00	0.01	15.37	0.00	0.00	0.00
		0.01	0.00	0.00	157.98	0.00	0.00	0.00
June	(3)	2.24	0.54	0.02	20.70	2.59	0.00	0.00
		1.07	0.18	0.00	18.75	8.18	0.00	0.00
July	(3)	2.08	0.06	0.07	5.95	7.32	0.00	0.01
		2.72	0.01	0.00	0.48	12.67	0.00	0.00
August	(3)	1.92	0.02	0.92	2.03	3.19	209.59	0.11
		1.64	0.00	0.39	3.65	5.32	21,745.48	0.02
September	(3)	2.42	0.18	1.25	3.57	2.89	83.29	0.18
		5.38	0.09	0.28	6.53	2.02	2,315.36	0.03
October	(3)	1.27	0.58	0.66	9.83	0.47	6.60	0.10
		0.19	0.34	0.09	13.64	0.66	130.68	0.03
November	(3)	0.96	0.28	1.00	8.26	0.00	0.00	0.01
		0.33	0.06	1.03	48.30	0.00	0.00	0.00

Table A13. 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