**Evaluation of the Biological Effects of the Northwest Power Conservation Council's
Mainstem Amendment on the Fisheries Upstream and Downstream of Libby Dam,
Montana**

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EXECUTIVE SUMMARY

A new project began in 2005 to monitor the biological and physical effects of improved operations of Hungry Horse and Libby Dams, Montana, called for by the Northwest Power and Conservation Council (NPCC) Mainstem Amendment. This operating strategy was designed to benefit resident fish impacted by hydropower and flood control operations. Under the new operating guidelines, July through September reservoir drafts will be limited to 10 feet from full pool during the highest 80% of water supply years and 20 feet from full pool during the lowest 20% of water supply (drought) years. Limits were also established on how rapidly discharge from the dams can be increased or decreased depending on the season. The NPCC also directed the federal agencies that operate Libby and Hungry Horse Dams to implement a new flood control strategy (VARQ) and directed Montana Fish, Wildlife & Parks to evaluate biological responses to this operating strategy. The Mainstem Amendment operating strategy has not been fully implemented at the Montana dams as of June 2008 but the strategy will be implemented in 2009. This report highlights the monitoring methods used to monitor the effects of the Mainstem Amendment operations on fishes, habitat, and aquatic invertebrates upstream and downstream of Libby Dam. We also present initial assessments of data and the effects of various operating strategies on physical and biological components of the systems upstream and downstream of Libby Dam.

Annual electrofishing surveys in the Kootenai River and selected tributaries, along with gill net surveys in the reservoir, are being used to quantify the impacts of dam operations on fish populations upstream and downstream of Libby Dam. Scales and otoliths are being used to determine the age structure and growth of focal species. Annual population estimates and tagging experiments provide estimates of survival and growth in the mainstem Kootenai River and selected tributaries. Radio telemetry will be used to validate an existing Instream Flow Incremental Methodology (IFIM) model developed for the Kootenai River and will also be used to assess the effect of changes in discharge on fish movements and habitat use downstream of Libby Dam. Passive integrated transponder (PIT) tags will be injected into rainbow, bull, and cutthroat trout throughout the mainstem Kootenai River and selected tributaries to provide information on growth, survival, and migration patterns in relation to abiotic and biotic variables. Model simulations (RIVBIO) are used to calculate the effects of dam operations on the wetted perimeter and benthic biomass in the Kootenai River below Libby Dam. Additional models (IFIM) will also be used to evaluate the impacts of dam operations on the amount of available habitat for different life stages of rainbow and bull trout in the Kootenai River.

INTRODUCTION

There are more than 79,000 dams in the United States according to the United States Army Corps of Engineers National Inventory of Dam database, with many additional small dams that have not been inventoried (USACE 2006; <http://crunch.tec.army.mil/nid/webpages/nid.cfm>). Dams throughout the world have been constructed for power production, flood control, municipal water sources, recreation, navigation, and a suite of additional reasons. Natural river conditions and processes present prior to dam construction are often lost due to flow regulation and separation of the rivers from the natural floodplain. Dam construction and its associated changes to habitats and hydrologic regimes is one of the leading threats to imperiled freshwater fauna in the United States (Richter et al. 1997).

Several concepts have been formulated to explain the functional and organizational structure of rivers, including the River Continuum Concept, the Serial Discontinuity Concept, and the Flood Pulse Concept (Vannote et al. 1980; Stanford et al. 1988; Junk et al. 1989). Unregulated rivers naturally exhibit seasonal variation in flow and water temperature, species compositional changes from headwaters to the mouth, and changes from allochthonous to autochthonous energy inputs depending on environmental conditions present (e.g., precipitation, temperature, and elevation). However, many of these natural river conditions and processes are altered by dam operations. Below dams, common changes include altered or reversed hydrographs, altered thermal conditions, lack of flooding and sediment transport, armoring of streambeds, changes in river channel morphology, unnatural variations in flow, changes in water quality, and blockage of fish migrations (Stanford 1975; Stanford and Hauer 1978; Ward and Stanford 1979; Fraley and Graham 1982; Hauer and Stanford 1982; Shepard et al. 1984; Cushman 1985; Fraley and Decker-Hess 1987; Hauer et al. 1994; Christenson et al. 1996; Zhong and Power 1996; Hauer et al. 1997; Pozo et al. 1997; Cereghino and Lavandier 1998a and 1998b; Ponton and Vauchel 1998; Marotz et al. 1999; Muhlfeld et al. 2000). Construction of Hungry Horse Dam, Montana and the subsequent formation of Hungry Horse Reservoir inundated 57 km of the South Fork of the Flathead River and portions of 37 tributary streams (Zubik and Fraley 1987). Hungry Horse Dam also blocked access to 38% of the drainage area previously available to fishes for spawning after migrating upstream from Flathead Lake. Winston et al. (1991) documented the extirpation of four minnow species and changes in species composition relative to streams not affected by Altus Dam, on the Red River in Oklahoma. Several studies have assessed fragmentation and isolation of populations, which can increase the likelihood of local species extinction (Rieman and McIntyre 1993, 1995, 1996; Dunham et al. 1997). Modified stream flows reduce fish community complexity (Bain et al. 1988) and streamflow variability can alter the functional organization of species assemblages (Poff and Allan 1995). Streamflow variability can also affect lower trophic levels, especially within the varial zone of the affected river (Ward 1976). Blinn et al. (1995) found that permanently submerged channels supported four times the macroinvertebrate mass than the varial zone in the Colorado River below Glenn Canyon Dam. The varial zone can become unproductive below dams because aquatic, terrestrial, and benthic vegetation that provide nutrients, forage, and cover do not establish due to fluctuating river discharge. Cereghino and Lavandier (1998a) documented that hydropeaking (i.e., rapid changes in flow) reduced densities and biomass of mayflies (Ephemeroptera) and altered stream temperatures in the River Oriege, France. Diel fluctuations in discharge also have

negative effects on both abundance and richness of mayflies (Malmqvist and Englund 1996). Density of insects was inversely correlated with hours of dewatering in the Skagit River, Washington and abundance of insects was 1.8-59 times higher under stable compared to fluctuating diel flow patterns (Gislason 1985).

Fish are also affected by construction of dams. Zhong and Power (1996) documented blocked migrations of both anadromous and semi-migratory fishes, spawning time delays of 20-60 days, abandonment of spawning grounds, extinction of one species, and a decrease in the number of freshwater species (from 96 to 85) below four dams in China. Ponton and Vauchel (1998) documented lower fish abundances and diversity of neotropical fishes below Petit-Saut Dam in South America. Fluctuating discharge may affect subadult bull trout using channel margins at night by affecting channel margin habitats used by forage species (Muhlfeld et al. 2003a). Effects of water fluctuation may be diminished if the rate of fluctuation is slowed or stabilized to create conditions closer to a free flowing river (Independent Scientific Advisory Board 1997b).

Dam operating strategies and water releases have been designed, evaluated, and modified in recent years to aid species recovery in both the upper and lower portions of the Columbia River Basin (Marotz et al. 1996; Marotz et al. 1999; ISAB 1997; USFWS 1999; NOAA-Fisheries 2000; Conner et al. 2003, NOAA-Fisheries 2004, NOAA-Fisheries 2008; USACE, BOR, and BPA 2004, USFWS 2006, USFWS 2000). A balance between a hydropower system's capability to provide power and flood control, and the conservation of numerous fish species within the system must be achieved while not extirpating, negatively affecting, or hindering recovery efforts for species within portions of the Columbia River Basin. The Mainstem Amendment operations were designed to provide a better balance for fishes in the upper and lower portions of the Columbia River basin. At Libby Dam, July through September reservoir drawdown will be limited to 10 feet from full pool (elevation 2449 feet) during the upper 80% of water supply years (i.e., all years except extreme drought), but may be increased to 20 feet (elevation 2439) from full pool during in drought years. Montana dam operations in the NPCC Mainstem Amendments (MA) were designed to stabilize water releases into the Kootenai and Flathead Rivers during the productive summer months and to protect aquatic resources in the headwaters reservoirs while contributing to suitable conditions for anadromous species in the lower Columbia River. In addition to limiting reservoir drawdown and improving the probability of reservoir refill, hourly and daily discharge ramping rates will be limited at Libby and Hungry Horse Dams. The ramping rates vary depending on the season, and the fastest rates occur during the less productive winter months. While the potential effects of dam or system operation changes can be modeled at Libby and Hungry Horse Dams, actual effects will remain unknown until the improved operations are fully implemented and monitoring and evaluation are complete. It will take at least one complete native fish life cycle (6-7 years) to detect and quantify actual effects at higher trophic levels.

Several methods are available to quantify the potential effects of Mainstem Amendment operations at Libby Dam. Instream Flow Incremental Methodology (IFIM; Bovee 1982) research performed by Montana Fish, Wildlife & Parks (MFWP; Hoffman et al. 2002) will allow quantification of physical habitat and habitat use relative to river discharge in the Kootenai River (Miller et al. 2003; Miller and Geise 2004). Restoring the most natural flow regime during the

summer months will protect ecosystem processes and may help restore native fish populations in the Kootenai and Flathead River basins (Marotz et al. 2002). Reservoir and river biology and habitat were assessed in the 1980s and 1990s, leading to the formation of several physical and biological models targeting aquatic systems above and below Libby and Hungry Horse dams (Woods 1979; Huston et al. 1984; Chisholm et al. 1989; Marotz et al. 1996; Snyder and Minshall 1996; Hoffman et al. 2002; Miller et al. 2003; Miller and Geise 2004; USACE 2006b). In addition to reservoir and river models, evaluation of the effects of the MA operations will incorporate other information obtained from annual gill netting, electrofishing, redd counts, population estimates, age and growth information, radio telemetry, and use of PIT tags.

The purpose of this report is to present preliminary results from monitoring data that will be used to assess the physical and biological effects of the Mainstem Amendment operations on fisheries upstream and downstream of Libby Dam, Montana for the work period of July 1, 2007 to June 30, 2008. The ten objectives for this project are:

Objective 1 – Use LRMOD to model the physical conditions in Libby Reservoir.

Objective 2 – Use LRMOD to model the biological conditions in Libby Reservoir.

Objective 3 – Compile or calculate age, growth, and condition information for game species in Libby Reservoir under various dam operating strategies and relate that information to environmental conditions in the reservoir if possible.

Objective 4 – Update reservoir model (LRMOD) to better predict or estimate the biological and physical conditions and unregulated flow component of the Libby Reservoirs and the Kootenai River.

Objective 5 – Use the Instream Flow Incremental Methodology (IFIM) and RIVBIO (wetted perimeter and benthic biomass) models to estimate the amount of habitat and benthic biomass accumulation under various dam operating strategies.

Objective 6 – Estimate salmonid cohort survival and mortality in the Mainstem Kootenai and River and relate survival and mortality to environmental conditions (e.g., temperature, discharge, discharge variation).

Objective 7 – Use radio telemetry to assess how ramping rates and changes in discharge affect movement and habitat use of fishes downstream of Libby Dam.

Objective 8 – Estimate survival, migration patterns, movement, and growth of fishes in Quartz Creek, a tributary to the Kootenai River downstream of Libby Dam, and relate those metrics to environmental and biological conditions.

Objective 9 - Compile or calculate age, growth, and fish condition information for game species in the Kootenai River under various dam operating strategies and relate that information to environmental conditions in the river.

Objective 10 - Develop conservation theory and methods for effective application of risk-based monitoring to inland salmonid populations, specifically bull trout.

STUDY AREA

The Kootenai River watershed is located in British Columbia (B.C.), Canada and Montana and Idaho, United States of America (U.S.A.; Figure 1). The Kootenai River drainage encompasses over 45,000 km² (17,600 mi²; Knudson 1994). The Kootenai River begins in Kootenay National Park, B.C., flows south into Montana before turning west northwest between the Cabinet and Purcell Mountains into Idaho and back into Kootenay Lake, B.C. The watershed is primarily forested, but has some agricultural areas in lower elevations along the Kootenai River near Bonners Ferry, Idaho.

Construction of Libby Dam began in 1966 after authorization by the Columbia River International Treaty of 1964 and was completed in 1972 (Knudson 1994; Figure 2). The Kootenai River was officially impounded at river mile 221.7 on March 21, 1972 creating Koocanusa Reservoir (Woods and Falter 1982; Table 1) approximately 25 km upstream of Libby Montana. Libby Dam was constructed to provide flood control capabilities, hydropower, and recreational opportunities (Bonde and Bush 1982). Construction and operation of the dam significantly altered the hydrograph of the Kootenai River. Before dam construction, peak spring discharge of the Kootenai River occasionally reached 2,264 m³/s (80,000 ft³/s) and the average peak was 1,839.5 m³/s (65,000 ft³/s; Figure 3). Since Libby Dam was completed, spring flows typically reach 600-700 m³/s (20,000-25,000 ft³/s). This reduction in spring peak flows has caused a build-up of sediment in river cobbles and the formation of deltas at tributary mouths, which are both detrimental to insect production, fish food availability, and cover. Tributary deltas have also formed seasonally impassible barriers of bull trout and other fishes during drought years. Power generation in the winter months has created higher than historical winter flows, and flow augmentation for anadromous fishes (NOAA-Fisheries 2000) established a second, unnaturally high summer peak in discharge (Figures 3 and 4). Flow variation was also highly variable on an hourly, daily, and seasonal basis after construction of Libby Dam (Hauer et al. 1997) with no constraints on rates at which flow could be altered. When fully implemented, the MA operation limits the frequency and magnitude of discharge fluctuations in the Kootenai River (Table 2; USFWS 2000 and 2006). Highly variable flows affect the abiotic and biotic conditions within and along the river margins, reducing productivity of the system and surrounding areas.

Water temperatures and the seasonal thermal regimes of the Kootenai River was unnaturally altered by the construction of Libby Dam (Fraley et al. 1989; Richards 1997). A selective withdrawal system was installed on Libby Dam in 1972 to control water temperature released from Libby Dam (USFWS 2006), with the system becoming operational in 1977. Although selective withdrawal capabilities enabled dam operators to release more natural water temperatures from late spring through fall, the system does not operate during winter months due to isothermal conditions in the reservoir. Consequently, winter water temperatures remain warmer than pre-dam water temperatures downstream of Libby Dam, possibly contributing to

the decline of burbot abundance in the Kootenai River (Paragamian et al. 2001). The reservoir water remains artificially warm during winter due to the large body of warmer (i.e., compared to pre-dam temperatures) water stored in the reservoir. The selective withdrawal system has trouble meeting Montana, Fish, Wildlife and Parks (MFWP) thermal targets during spring, because the epilimnion takes time to warm in the spring and dam operators cannot withdraw water within about 25 ft of the surface to avoid turbine cavitation.

Koocanusa Reservoir is approximately 145 km (90 mi) long, has a maximum depth of 107 m (350 ft), a mean depth of 38 m (126 ft), and covers an area of 46,500 acres at full pool (Table 1). Listed species under the Endangered Species Act (ESA) in the Kootenai River and Koocanusa Reservoir include the bull trout *Salvelinus confluentus* and white sturgeon *Acipenser transmontanus* in the Kootenai River, downstream of Kootenai Falls. The Kootenai River population of white sturgeon is listed as an endangered species and bull trout are listed as a threatened species under the ESA (U. S. Fish and Wildlife Service 1999; U. S. Fish and Wildlife Service 2002). Koocanusa Reservoir provides popular sport fishing opportunities for rainbow trout, kokanee, and in recent years, an experimental harvest fishery for bull trout. Koocanusa Reservoir also contains many other species of fish including northern pike *Esox lucius*, yellow perch *Perca flavescens*, peamouth *Mylocheilus caurinus*, and northern pikeminnow *Ptychocheilus oregonensis* (Table 3). Koocanusa Reservoir typically fills near the end of June. Recent spill events from Libby Dam have occurred in June and July 2002 and in June 2006. Maximum flows from Libby Dam in 2002 reached 1,132 m³/s (40,000 ft³/s) while peak flows were approximately 1,415 m³/s (55,000 ft³/s) in June 2006, the highest on record since completion of Libby Dam and regulation of flows from the dam (Dunnigan 2002, Marotz et al. 2007). These high flows were more typical of pre-dam flows and much greater than typical post dam discharges from Libby Dam (Figure 3). Koocanusa Reservoir was historically drafted more than 30 m (100 ft) but recent operations have resulted in shallower 15m drafts (40-50ft) of the reservoir, creating more area for biological productivity and additional water surface area for recreational activities. For a more detailed description of the Kootenai River portion of the study area including the climate, topography, soils, and geology see Dunnigan et al. 2003.

Figure 1. Location of the Kootenai River watershed in the United States and Canada along with several key features within the watershed (from Dunnigan et al. 2003).

Figure 2. Photograph of Libby Dam, constructed in the 1960's and 1970's east of Libby, Montana, U.S.A.

Figure 3. Average pre- (USGS station 12303000) and post-dam (USGS station 12301933) hydrographs of the Kootenai River below Libby Dam for the period of water year 1911-2006. Water years start on 1 October and end on 30 September. Leap year data for 29 February were excluded.

Figure 4. Water year 1999 discharge below Libby Dam. Notice the unnatural double summer peak resulting from flow augmentation for anadromous fishes called for by NOAA Fisheries Biological Opinion 2000 (NOAA-Fisheries 2000) and the unnatural winter peaks resulting from hydropower generation. The double summer peak has been greatly reduced during recent years due to an agreement with NOAA-Fisheries, although summer flows remain artificially high.

Table 1. Metrics of Koocanusa Reservoir (Libby Reservoir) located in northwest Montana, approximately 25 km upstream of Libby, Montana (from Chisholm et al. 1989).

Reservoir Metric	Value
Surface elevation	
Maximum pool	749.5 m (2459 ft)
Minimum operational pool	697.1 m (2287 ft)
Minimum pool	671.2 m (2222 ft)
Area	
Maximum pool	188 km ² (46500 acres)
Minimum operational pool	58.6 km ² (14487 acres)
Volume	
Maximum pool	7.24 km ³ (5869400 acre-ft)
Minimum operational pool	1.10 km ³ (890000 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	7.40 km (4.6 mi)
Storage ratio	0.68 yr
Drainage area	23271 km ² (8985 mi ²)
Drainage area : Surface area	124:1

Table 2. Daily and hourly ramping rates for Libby Dam, Montana as measured by daily flows. These ramp rates are part of the Northwest Power and Conservation Council's Mainstem Amendment operating strategy and USFWS 2006 Biological Opinion. The abbreviation kcfs equals thousand cubic feet per second, and QPHC equals powerhouse capacity.

		Summer (5/1-9/31)	
Ramp Direction	Discharge Range	Hourly	Daily
Up	4-6 kcfs	2500 cfs	1 unit
Up	6-9 kcfs	2500 cfs	1 unit
Up	9-16 kcfs	2500 cfs	2 units
Up	16-QPHC	5000 cfs	2 units
Down	4-6 kcfs	500 cfs	500 cfs
Down	6-9 kcfs	500 cfs	1000 cfs
Down	9-16 kcfs	1000 cfs	2000 cfs
Down	16-QPHC	3500 cfs	1 unit
		Winter (10/1-4/30)	
Ramp Direction	Discharge Range	Hourly	Daily
Up	4-6 kcfs	2000 cfs	1 unit
Up	6-9 kcfs	2000 cfs	1 unit
Up	9-16 kcfs	3500 cfs	2 units
Up	16-QPHC	7000 cfs	2 units
Down	4-6 kcfs	500 cfs	1000 cfs
Down	6-9 kcfs	500 cfs	2500 cfs
Down	9-16 kcfs	1000 cfs	1 unit
Down	16-QPHC	3500 cfs	1 unit

Table 3. List of fish species found in the Kootenai River watershed and the Kootenai River (updated and adapted from Hoffman et al. 2002 and Holton and Johnson 2003).

Common Name	Scientific Name	Native or Introduced	Abundance
Black bullhead	<i>Ameiurus melas</i>	Introduced	Rare
Bluegill	<i>Lepomis macrochirus</i>	Introduced	Rare
Brook trout	<i>Salvelinus fontinalis</i>	Introduced	Rare
Brown bullhead	<i>Ameiurus nebulosus</i>	Introduced	Rare
Brown trout	<i>Salmo trutta</i>	Introduced	Rare
Bull trout	<i>Salvelinus confluentus</i>	Native	Common
Burbot	<i>Lota lota</i>	Native	Common
Goldfish	<i>Carassius auratus</i>	Introduced	Rare
Kokanee salmon	<i>Oncorhynchus nerka</i>	Native	Common
Lake trout	<i>Salvelinus namaycush</i>	Introduced	Rare
Largemouth bass	<i>Micropterus salmoides</i>	Introduced	Rare
Largescale sucker	<i>Catostomus macrocheilus</i>	Native	Abundant
Longnose dace	<i>Rhinichthys cataractae</i>	Native	Rare
Longnose sucker	<i>Catostomus catostomus</i>	Native	Rare
Mottled sculpin	<i>Cottus bairdi</i>	Native	Rare
Mountain whitefish	<i>Prosopium williamsoni</i>	Native	Abundant
Northern pikeminnow	<i>Ptychocheilus oregonensis</i>	Native	Abundant
Northern pike	<i>Esox lucius</i>	Introduced	Rare
Peamouth	<i>Mylocheilus caurinus</i>	Native	Abundant
Pumpkinseed sunfish	<i>Lepomis gibbosus</i>	Introduced	Rare
Pygmy whitefish	<i>Prosopium coulteri</i>	Native	Rare
Rainbow trout	<i>Oncorhynchus mykiss</i>	Introduced	Abundant
Redband trout	<i>Oncorhynchus mykiss subspecies</i>	Native	Rare
Redside shiner	<i>Richardsonius balteatus</i>	Native	Common
Slimy sculpin	<i>Cottus cognatus</i>	Native	Common
Smallmouth bass	<i>Micropterus dolomieu</i>	Introduced	Rare
Torrent sculpin	<i>Cottus rhotheus</i>	Native	Rare
Western mosquitofish	<i>Gambusia affinis</i>	Introduced	Rare
Westslope cutthroat trout	<i>Oncorhynchus clarki lewisi</i>	Native	Common
White sturgeon	<i>Acipenser transmontanus</i>	Native	Rare
Yellow perch	<i>Perca flavescens</i>	Introduced	Rare

CHAPTER 1 – Modeling Physical Conditions Koocanusa Reservoir

Methods

Reservoir Modeling

Physical conditions of Koocanusa Reservoir were assessed using the quantitative reservoir model LRMOD (Marotz et al. 1996). Reservoir inflow, outflow, and surface elevation files were constructed for Libby Reservoir using data from the United States Army Corps of Engineers and the United States Geological Survey. Annual data files (inflow, surface elevation and discharge: *.dat files) were entered into the model interface and the output of physical and biological parameters was compiled in Microsoft Excel for analysis. An error in previous reports was found in the 1985 reservoir and river model simulations, due to several very low discharges in the input data. These errors were corrected and are now reflected in this report. Additional data including water temperatures and climatic information (e.g., precipitation, air temperatures) were gathered from the Western Regional Climate Center or the United States Army Corps of Engineers to help isolate the effects of dam operations from independent environmental conditions. Dam operation strategies and water years were evaluated and ranked according to modeled physical conditions in each of the reservoirs. Seasonal comparisons of physical conditions will be performed using the following seasonal criteria:

Fall = October-November
Winter = December-March
Spring = April- June
Summer = July-September

Statistical Analysis

Model simulations of physical conditions were summarized at monthly, seasonal, and annual levels using Microsoft Excel.

Results and Discussion

Fall inflows to Koocanusa Reservoir since 1977 are typically between three and nine thousand cubic feet per second (kcfs) and winter inflows are between 2 and 5 kcfs (Table 1-1). Average spring inflows to Koocanusa Reservoir have ranged from 13 to 32 kcfs and the average summer inflow is typically half of the average spring discharge. Fall outflows from Libby Dam are typically much greater than average fall inflows. Average fall outflows ranged from 5 to 22 kcfs from 1977-2007, but average outflows have decreased since 1977 (Regression $P < 0.0001$; Table 1-2). Winter outflows are higher than inflows, but no trends have been observed in

average daily outflows since 1977. Average spring inflows to Koocanusa Reservoir have steadily increased from 1977 to 2007. Average outflows in the spring from 1977 to 1993 were typically less than 10 kcfs, but since 1993, the frequency of average spring discharge greater than 10 kcfs has increased (Table 1-2). Linear regression showed a significant increasing trend in the average spring discharge (Linear regression $P < 0.0001$), caused by more normative spring flows for Kootenai River white sturgeon recovery and VARQ flood control operations since water year 2003. No significant trends have been observed in summer outflows from Libby Dam. This is counterintuitive with summer flows in the 1990s that were specifically increased for anadromous fish flow augmentation. The average summer flow (i.e., July-September) may have masked this difference since most of the water released for anadromous fishes was released in August. Water residence time is related to reservoir outflows, with longer residence times occurring at lower seasonal discharges (Figure 1-1). This trend shifts towards shorter residence times at lower discharges in the spring months due to lower reservoir elevations above Libby Dam. Modeled water residence time by month has been variable between and within months of each water year due to changes in dam operations since water year 1977 (Table 1-3) and monthly trends have shifted by decade. Recent operations beginning in water year 2000 have resulted in longer modeled water residence times in October, November, January, February, and March compared to previous decades (Figure 1-1; Table 1-3). Modeled June, July, and August water residence times in the 1990s and 2000s are shorter than during the 1970s and 1980s. This is likely due to deeper historical reservoir drafts, which attempt to capture the majority of spring runoff events. More recent dam operations attempt to pass some of the spring runoff with shallower reservoir drafts. Selective withdrawal elevation for water discharged from Libby Dam have been variable for fall, winter, and summer seasons since 1977 with variations up to about 50 feet (Table 1-4). Spring selective withdrawal elevations have shown an increasing trend ($R^2 = 0.23$, Linear regression P -value 0.0069; Figure 1-2) since 1977, with a pronounced increase since 2002. The increase since 2002 is likely a result of a requirement by the USFWS to release warmer water suitable for white sturgeon spawning and rearing in the Kootenai River near Bonner's Ferry, Idaho.

Table 1-1. Seasonal and annual average inflow (kcfs) and ranking of the Kootenai River flowing into Koocanusa Reservoir, Montana above Libby Dam from 1977-2008. A ranking of 1 equals the highest average inflow and 32 equals the lowest.

Water Year	Fall Average (kcfs)	Fall Rank	Winter Average (kcfs)	Winter Rank	Spring Average (kcfs)	Spring Rank	Summer Average (kcfs)	Summer Rank	Annual Average (kcfs)	Annual Rank
1977	4.96	18	2.72	29	13.72	31	8.25	25	7.23	31
1978	4.73	22	3.42	19	23.75	15	14.19	6	11.42	12
1979	6.19	9	3.52	18	17.30	30	7.34	31	8.37	29
1980	2.91	32	2.33	32	26.10	8	8.30	24	9.86	20
1981	4.72	23	4.33	9	25.92	9	16.79	3	12.92	5
1982	4.76	21	3.61	14	25.22	10	13.43	7	11.66	10
1983	5.64	12	4.49	7	21.81	20	13.12	10	11.17	13
1984	5.79	10	3.15	21	18.37	27	11.83	14	9.58	24
1985	4.18	24	2.76	27	20.57	24	8.20	26	8.81	26
1986	6.32	8	4.32	10	24.91	11	11.03	17	11.48	11
1987	6.84	5	3.58	15	21.46	21	7.74	29	9.63	22
1988	3.37	28	2.67	30	19.59	25	7.65	30	8.26	30
1989	5.52	13	3.01	22	22.40	16	11.08	16	10.30	18
1990	7.06	4	4.50	6	29.05	5	14.79	5	13.64	4
1991	6.80	6	5.24	2	31.01	3	18.44	1	15.25	2
1992	5.41	14	3.54	17	17.62	29	8.54	23	8.62	28
1993	4.87	19	2.90	25	19.30	26	13.24	9	9.92	19
1994	4.86	20	3.95	12	21.98	18	8.02	27	9.62	23
1995	3.17	30	3.26	20	24.04	14	12.66	11	10.79	16
1996	7.71	3	6.13	1	31.52	2	16.63	4	15.37	1
1997	5.03	17	4.42	8	32.85	1	13.25	8	13.84	3
1998	6.40	7	3.57	16	24.23	13	9.31	21	10.64	17
1999	3.98	26	3.95	13	24.89	12	16.85	2	12.43	6
2000	8.79	2	5.06	3	20.87	23	10.95	18	11.11	14
2001	3.76	27	2.63	31	12.55	32	6.08	32	6.16	32
2002	2.91	31	2.96	23	28.24	7	12.64	12	11.69	9
2003	3.37	29	2.73	28	21.31	22	7.82	28	8.75	27
2004	5.38	15	2.94	24	17.96	28	12.32	13	9.46	25
2005	5.72	11	4.86	4	21.96	19	11.09	15	10.84	15
2006	9.24	1	4.00	11	29.55	4	8.59	22	12.40	7
2007	5.30	16	4.67	5	29.04	6	10.29	20	12.27	8
2008	4.09	25	2.77	26	21.99	17	10.39	19	9.70	21

Table 1-2. Seasonal and annual average outflow (kcfs) ranking of the Kootenai River downstream of Koocanusa Reservoir, Montana from 1977-2008. A ranking of 1 equals the highest average outflow and 32 equals the lowest.

Water Year	Fall Average (kcfs)	Fall Rank	Winter Average (kcfs)	Winter Rank	Spring Average (kcfs)	Spring Rank	Summer Average (kcfs)	Summer Rank	Annual Average (kcfs)	Annual Rank
1977	15.02	12	11.26	23	5.48	24	8.75	14	9.82	18
1978	13.76	15	7.86	25	4.66	15	11.35	26	8.93	28
1979	16.59	5	11.78	28	3.42	31	5.44	13	8.90	29
1980	15.74	10	8.86	19	6.58	25	8.17	23	9.27	24
1981	14.51	14	14.35	20	6.49	2	16.40	8	12.93	4
1982	12.83	20	14.79	15	8.34	22	9.56	6	11.53	10
1983	16.14	8	14.72	24	4.82	17	10.67	7	11.47	11
1984	12.40	21	12.14	27	3.75	16	10.85	11	9.77	19
1985	13.74	16	12.57	31	3.12	28	7.66	10	9.17	27
1986	18.71	3	9.93	22	6.05	5	13.89	16	11.43	12
1987	22.69	1	7.52	29	3.24	19	10.13	30	9.65	20
1988	16.50	6	11.87	32	3.00	26	7.93	12	9.44	22
1989	8.16	9	3.13	30	10.46	18	17.09	18	9.32	25
1990	16.76	4	14.29	13	8.59	12	12.86	9	12.92	5
1991	14.70	13	19.69	10	10.69	4	15.27	1	15.50	2
1992	22.65	2	7.14	18	7.03	21	9.53	31	10.31	16
1993	15.03	11	9.03	21	6.22	30	5.95	20	8.56	31
1994	16.46	7	9.49	11	9.78	32	4.95	19	9.58	21
1995	11.63	23	8.62	6	12.57	23	9.52	24	10.33	17
1996	12.36	22	16.72	1	18.51	7	13.67	4	15.67	1
1997	13.40	18	14.94	4	14.92	14	11.98	5	13.93	3
1998	13.18	19	9.00	8	11.13	10	13.21	21	11.29	14
1999	6.44	29	16.83	17	7.11	11	13.05	3	11.72	9
2000	13.46	17	17.56	14	8.40	27	7.88	2	12.15	8
2001	7.51	26	7.37	26	4.02	29	6.05	32	6.23	32
2002	6.15	30	9.72	9	10.86	1	16.59	17	11.14	15
2003	5.30	32	7.64	12	9.27	8	13.62	29	9.16	26
2004	6.69	28	7.71	16	7.60	13	12.07	28	8.61	30
2005	9.84	25	8.45	7	11.87	3	15.93	25	11.42	13
2006	10.03	24	8.87	2	17.84	9	13.32	22	12.42	6
2007	7.22	27	10.29	3	17.28	6	13.77	15	12.40	7
2008	5.92	31	7.78	5	13.04	20	10.09	27	9.36	23

Table 1-3. Summary of modeled water residence time in Koocanusa Reservoir by month from water year 1977 to 2008.

Water Year	Month											
	October	November	December	January	February	March	April	May	June	July	August	September
1977	0.48	0.46	0.42	0.42	0.45	0.40	0.41	0.75	1.08	0.49	0.66	0.72
1978	0.47	0.26	0.5	0.29	0.28	0.63	0.94	0.87	0.82	0.58	0.80	0.70
1979	0.57	0.33	0.26	0.26	0.71	0.86	1.05	1.13	1.67	1.92	1.37	1.01
1980	0.54	0.30	0.33	0.36	0.51	0.88	1.35	1.42	0.50	0.85	1.08	1.08
1981	0.54	0.43	0.35	0.26	0.22	0.47	1.11	1.17	0.53	0.30	0.60	0.90
1982	0.61	0.51	0.31	0.26	0.25	0.34	0.36	0.25	0.96	0.82	0.75	0.80
1983	0.57	0.35	0.34	0.24	0.22	0.45	0.67	0.63	1.40	0.69	0.77	0.74
1984	0.56	0.57	0.30	0.27	0.56	0.92	0.96	1.17	1.16	0.73	0.63	0.78
1985	0.58	0.43	0.25	0.20	0.44	0.67	1.00	1.03	2.07	1.39	1.10	0.66
1986	0.36	0.30	0.36	0.22	0.82	0.70	0.82	1.28	0.66	0.49	0.91	0.44
1987	0.26	0.24	0.74	0.36	0.37	0.95	1.53	1.49	1.67	0.95	0.84	0.57
1988	0.31	0.45	0.52	0.19	0.18	0.44	0.70	0.97	1.57	2.00	1.64	0.37
1989	0.35	0.28	0.21	0.33	0.25	0.63	0.75	1.08	1.82	1.31	0.42	0.79
1990	0.37	0.36	0.27	0.86	0.16	0.20	0.37	0.93	0.38	0.43	0.72	0.76
1991	0.37	0.66	0.25	0.17	0.13	0.18	0.18	0.29	0.39	0.40	0.59	0.58
1992	0.36	0.22	0.24	0.76	0.84	0.93	0.69	0.54	0.67	1.56	0.72	0.41
1993	0.46	0.26	0.26	0.40	0.38	0.28	0.54	0.69	0.45	1.45	1.48	0.81
1994	0.48	0.32	0.22	0.43	0.91	0.85	0.91	0.56	0.35	1.14	1.75	1.46
1995	0.73	0.45	0.60	0.30	0.84	1.01	0.97	0.33	0.31	0.85	0.58	1.16
1996	1.12	0.40	0.31	0.20	0.31	0.46	0.21	0.29	0.23	0.44	0.47	0.82
1997	0.58	0.46	0.31	0.22	0.18	0.46	0.30	0.29	0.26	0.53	0.60	0.71
1998	0.56	0.46	0.40	0.58	0.47	0.99	1.06	0.47	0.30	0.49	0.33	0.55
1999	0.94	1.14	0.30	0.22	0.15	0.27	0.59	0.90	0.38	0.65	0.50	0.62
2000	0.61	0.45	0.25	0.18	0.18	0.47	0.79	1.04	0.30	0.76	0.81	0.87
2001	1.07	0.66	0.66	0.92	0.42	0.99	1.08	1.12	1.43	1.03	1.09	1.06
2002	1.05	0.94	0.62	0.38	0.35	0.72	0.94	0.72	0.31	0.29	0.43	1.02
2003	1.22	1.34	0.32	1.33	1.3	1.28	1.26	1.65	0.36	0.48	0.44	0.87
2004	1.47	0.72	0.38	0.69	1.17	1.22	1.25	1.25	0.45	0.59	0.58	0.65
2005	1.16	0.50	0.29	1.18	1.32	1.37	1.40	0.59	0.35	0.36	0.43	0.75
2006	1.42	0.45	0.32	1.21	1.33	0.70	1.22	0.44	0.24	0.43	0.53	0.76
2007	1.51	0.65	0.34	0.39	0.82	0.90	0.28	0.25	0.38	0.44	0.44	0.90
2008	1.42	0.90	0.39	1.27	0.64	1.14	1.15	0.41	0.28	0.50	0.75	1.07

Figure 1-1. Average modeled monthly water residence time in Koocanusa Reservoir in the 1970's, 1980's, 1990's, and 2000's.

Table 1-4. Summary of the average modeled selective withdrawal elevation (feet) for water releases from Libby Dam into the Kootenai River from water year 1977 to 2008.

Water Year	Month											
	October	November	December	January	February	March	April	May	June	July	August	September
1977	2389	2373	2245	2222	2222	2222	2297	2308	2339	2351	2346	2351
1978	2344	2326	2282	2222	2222	2222	2276	2307	2359	2390	2397	2394
1979	2389	2374	2253	2222	2222	2222	2301	2320	2362	2384	2388	2387
1980	2379	2358	2249	2222	2222	2222	2293	2346	2387	2397	2397	2393
1981	2388	2374	2267	2222	2222	2222	2291	2325	2379	2397	2398	2396
1982	2390	2377	2345	2222	2222	2222	2280	2288	2346	2392	2398	2396
1983	2392	2376	2289	2222	2222	2222	2286	2309	2364	2392	2398	2395
1984	2384	2379	2278	2222	2222	2222	2311	2320	2357	2392	2396	2389
1985	2383	2370	2274	2222	2222	2222	2283	2310	2364	2385	2388	2385
1986	2374	2355	2249	2222	2222	2222	2303	2325	2383	2397	2397	2388
1987	2371	2341	2264	2222	2222	2222	2304	2349	2382	2396	2396	2388
1988	2369	2346	2253	2222	2222	2222	2260	2292	2344	2370	2377	2370
1989	2351	2333	2265	2222	2222	2222	2263	2305	2357	2385	2384	2381
1990	2370	2356	2286	2222	2222	2222	2270	2303	2362	2392	2398	2396
1991	2382	2368	2337	2222	2222	2222	2245	2278	2349	2389	2398	2391
1992	2378	2351	2236	2222	2222	2222	2304	2327	2351	2371	2376	2366
1993	2351	2334	2269	2222	2222	2222	2263	2291	2337	2363	2381	2383
1994	2378	2359	2234	2222	2222	2222	2309	2338	2363	2376	2383	2383
1995	2380	2365	2248	2222	2222	2222	2321	2328	2363	2388	2393	2391
1996	2393	2383	2307	2222	2222	2222	2303	2310	2358	2389	2393	2388
1997	2382	2370	2296	2222	2222	2222	2277	2305	2369	2386	2391	2387
1998	2382	2371	2240	2222	2222	2222	2323	2339	2358	2367	2359	2344
1999	2373	2369	2308	2222	2222	2222	2264	2293	2351	2383	2395	2390
2000	2382	2377	2331	2222	2222	2222	2280	2310	2348	2365	2372	2372
2001	2367	2363	2244	2222	2222	2222	2325	2332	2359	2372	2372	2371
2002	2366	2362	2248	2222	2222	2222	2312	2327	2374	2397	2386	2377
2003	2377	2373	2241	2222	2222	2222	2343	2357	2388	2393	2383	2373
2004	2372	2371	2263	2222	2222	2222	2340	2359	2376	2387	2384	2383
2005	2383	2378	2305	2222	2222	2222	2352	2367	2387	2393	2383	2374
2006	2379	2380	2264	2222	2222	2222	2344	2369	2396	2394	2386	2377
2007	2372	2372	2277	2222	2222	2222	2329	2337	2373	2391	2383	2374
2008	2372	2322	2222	2222	2222	2222	2332	2341	2370	2382	2381	2377

Figure 1-2. Average modeled selective withdrawal elevation during the spring (April through June) for water released from Libby Dam from water year 1977-2008 compared to the maximum forebay water elevation.

CHAPTER 2 –Modeling Biological Conditions in Koocanusa Reservoir

Methods

Reservoir Modeling

Model simulations of biological responses of Libby Reservoir to varying operations of Libby Dam were run using historic discharge data for Libby Reservoir (LRMOD; Marotz et al. 1996). Annual data files (inflow, outflow and surface elevation files: *.dat) were entered into the model interface and results compiled in Microsoft Excel for summary analysis. An error in previous reports was found in the 1985 reservoir and river model simulations, a result of very low discharges in the input data. These errors were corrected and are now reflected in this report. Biological conditions resulting from Dam operation strategies and water years will be evaluated and ranked according to modeled biological conditions in each of the reservoirs. Seasonal comparisons will be performed using the following criteria:

Fall = October-November
Winter = December-March
Spring = April- June
Summer = July-September

Statistical Analysis

Model simulations of biological conditions were summarized at the seasonal and annual levels using Microsoft Excel.

Results and Discussion

Modeled primary productivity of Koocanusa Reservoir has increased in the winter, spring, and annual periods since 2000, with many rankings within the top 10 of the 32 water years modeled to date (Table 2-1). Summer primary productivity rankings have ranged from 13-29 since 2000, with most of the top 10 summer rankings occurring in the 1980's. Koocanusa Reservoir used to remain full until power generation increased in late fall/winter due to weather. Now the reservoir is drafted for sturgeon tiered flows (spring release masked by VARQ) and salmon flow augmentation during summer, so the euphotic zone volume is smaller during the most productive months. In addition, primary productivity washout increased due to high discharges from reservoir storage during what would naturally be the low flow period. Summer drawdown for anadromous fish flow augmentation reduces the volume of the warm, productive euphotic zone and increases washout through the turbines.

Winter and spring productivity has been high in recent years due to longer residence time (Table 2-1) as a result of reduced annual drawdown under VARQ flood control. This does not hold true for the fall months. Since water year 2000, water residence time has increased compared to previous historic levels (i.e., water year 1977-1999), but modeled primary productivity has not been high. Most rankings have been between 12-25; however, 2005 was the highest modeled primary productivity for the fall season since 1977 (Table 2-1). The increased winter productivity is likely the result of reduced reservoir drawdown during recent years (shift from standard flood control to VARQ, which drafts less). Dam operations for electrical generation have shifted from 4-year critical year planning to the current situation in which refill is targeted every year (critical year 1) regardless of how many years a drought cycle lasts. Increased spring productivity can be attributed to VARQ operations. Under standard flood control, the reservoir attempts to capture the entire spring freshet while releasing minimal flow during spring runoff. VARQ drafts less (increasing productivity during the initial bloom), captures a smaller percentage of inflow during spring and releases a more normative spring freshet (although washout increases with high seasonal flows). Primary productivity washout during the fall has been low since water year 2000 due to lower fall discharges released from Libby Dam (Table 2-2). Contrary to the fall washout, spring and summer primary productivity washout since 2000 has generally been higher than previous water years due to higher average discharges during the spring and summer months (Table 2-2). Since 2003, modeled zooplankton production has been high, with the lowest seasonal and annual ranking equal to 7 for the winter, spring and annual time periods (Table 2-3), all likely a result of increased reservoir elevations and productivity. Summer and fall zooplankton trends mirror those of primary productivity since water year 1977 with a few slight transpositions of primary productivity rankings, likely due to slight differences in annual dam operations, such as selective withdrawal elevation and physical conditions of the reservoir.

Since phytoplankton (carbon fixed) and zooplankton (births/growth) production are greater during the warm months (late summer and early fall) and the volume of the euphotic zone is largest at full pool, it follows that more will be produced when the reservoir remains at or full pool during the warm months. More plankton is produced and retained to build up when retention times increase. Washout through the dam varies with discharge volume and selective withdrawal of water near the surface (vertical profiles of phytoplankton and zooplankton differ somewhat because zooplankton tend to be lower at the surface than at say 10 meters depth, but the trend is for greater plankton densities near the surface). Even though the MA operations have not been fully implemented, VARQ has reduced reservoir drafting (annual low is about April 15) and improved refill probability. Spring releases for sturgeon and summer releases for salmon have countered the benefits of VARQ to some extent because the reservoir no longer fills as early, nor remains at full pool during summer, as it did shortly after the reservoir first filled in 1974. These generalities will vary annually with changes in primary production and primary production washout. Model simulations indicate that overall, reduced annual draw down and improved refill (VARQ) cancelled out some impacts caused by summer flow augmentation for anadromous fishes.

Table 2-1. Annual water year ranking of LRMOD modeled primary productivity in Koocanusa Reservoir, Montana above Libby Dam for water years 1977-2008. A ranking of 1 equals the highest seasonal primary productivity and 32 equals the lowest.

Water Year	Fall Sum	Fall Rank	Winter Sum	Winter Rank	Spring Sum	Spring Rank	Summer Sum	Summer Rank	Annual Sum	Annual Rank
1977	1670	10	2006	10	2875	27	4387	32	10938	30
1978	1316	32	1607	30	2966	23	5495	9	11383	26
1979	1695	7	1880	17	3169	16	5345	18	12089	16
1980	1596	20	1762	25	3536	6	5593	1	12487	5
1981	1698	6	1908	15	3271	14	5549	2	12426	7
1982	1753	3	1917	14	2755	29	5541	5	11965	18
1983	1729	4	1894	16	3067	19	5506	7	12196	15
1984	1692	8	1973	13	3163	17	5527	6	12355	10
1985	1654	11	1730	28	2971	22	5207	24	11562	24
1986	1561	23	1761	26	3380	9	5547	4	12249	12
1987	1470	29	1785	23	3571	5	5549	2	12374	9
1988	1518	28	1661	29	2713	30	5014	28	10905	31
1989	1374	31	1537	32	2882	26	5274	22	11066	29
1990	1577	22	1792	22	2929	25	5500	8	11799	21
1991	1704	5	1774	24	2635	32	5429	11	11543	25
1992	1534	27	1737	27	3114	18	4987	29	11372	28
1993	1395	30	1581	31	2641	31	5040	26	10657	32
1994	1585	21	1794	21	3339	11	5231	23	11949	19
1995	1617	17	1993	12	3265	15	5432	10	12307	11
1996	1764	2	2039	9	3003	21	5399	12	12205	14
1997	1670	9	1817	20	3019	20	5364	16	11870	20
1998	1629	16	2069	7	3316	13	4628	31	11642	23
1999	1639	14	1822	19	2801	28	5381	14	11643	22
2000	1651	12	1860	18	2937	24	4931	30	11379	27
2001	1550	24	2092	6	3365	10	5028	27	12036	17
2002	1536	25	1994	11	3326	12	5377	15	12233	13
2003	1617	18	2206	3	3906	3	5353	17	13082	3
2004	1603	19	2138	5	3788	4	5324	19	12852	4
2005	1826	1	2281	1	4006	1	5323	20	13435	1
2006	1649	13	2254	2	4004	2	5398	13	13305	2
2007	1633	15	2062	8	3455	8	5306	21	12456	6
2008	1535	26	2167	4	3493	7	5200	25	12396	8

Table 2-2. Annual water year ranking of LRMOD modeled primary productivity washout in Koocanusa Reservoir, Montana above Libby Dam for water years 1977-2008. A ranking of 1 equals the highest primary productivity washout and 32 equals the lowest.

Water Year	Fall Sum	Fall Rank	Winter Sum	Winter Rank	Spring Sum	Spring Rank	Summer Sum	Summer Rank	Annual Sum	Annual Rank
1977	7.05	12	0.28	29	5.47	23	11.18	23	23.98	27
1978	6.25	16	0.93	19	5.08	24	14.48	16	26.74	23
1979	7.68	6	0.98	18	3.46	29	6.49	31	18.61	31
1980	7.36	11	0.86	21	8.61	16	10.88	25	27.71	21
1981	7.03	13	1.23	16	7.52	19	23.81	2	39.59	7
1982	6.12	18	3.27	3	7.82	18	13.79	18	31.00	13
1983	7.50	9	1.93	7	4.73	25	14.86	15	29.02	18
1984	5.86	21	1.55	11	3.79	27	14.04	17	25.24	25
1985	6.60	15	1.38	13	3.23	30	9.24	27	20.45	29
1986	8.77	3	0.88	20	6.77	22	18.26	7	34.68	11
1987	10.77	1	0.28	29	3.59	28	13.05	20	27.69	22
1988	7.73	5	0.35	26	3.20	31	9.07	28	20.35	30
1989	7.59	7	1.34	14	3.10	32	12.91	21	24.94	26
1990	7.86	4	1.67	10	9.34	13	18.01	8	36.88	9
1991	7.38	10	3.94	1	11.17	11	20.02	4	42.51	3
1992	10.05	2	0.62	22	7.44	20	11.03	24	29.14	17
1993	6.98	14	1.71	9	7.04	21	6.68	30	22.41	28
1994	7.59	7	0.37	25	11.32	10	6.01	32	25.29	24
1995	5.30	23	0.34	27	13.95	6	12.44	22	32.03	12
1996	5.67	22	1.87	8	19.09	2	18.59	5	45.22	1
1997	6.20	17	2.08	6	16.60	4	16.17	13	41.05	5
1998	6.03	19	0.41	24	12.69	8	16.81	10	35.94	10
1999	2.93	29	2.19	5	8.31	17	16.55	12	29.98	15
2000	6.00	20	3.69	2	9.26	14	9.91	26	28.86	19
2001	3.27	26	0.19	31	4.27	26	7.37	29	15.10	32
2002	2.88	30	0.31	28	12.09	9	23.86	1	39.14	8
2003	2.50	31	0.56	23	10.63	12	16.66	11	30.35	14
2004	2.99	27	1.13	17	8.76	15	15.33	14	28.21	20
2005	4.57	24	2.51	4	13.85	7	20.22	3	41.15	4
2006	4.46	25	1.32	15	21.62	1	17.80	9	45.20	2
2007	2.99	27	1.47	12	17.95	3	18.34	6	40.75	6
2008	1.89	32	0.00	32	14.71	5	13.30	19	29.90	16

Table 2-3. Seasonal and annual water year average daily zooplankton production and ranking of LRMOD modeled zooplankton production in Koocanusa Reservoir, Montana above Libby Dam for water years 1977-2008. A ranking of 1 equals the highest average zooplankton production and 32 equals the lowest.

Water Year	Fall AVG	Fall Rank	Winter AVG	Winter Rank	Spring AVG	Spring Rank	Summer AVG	Summer Rank	Annual AVG	Annual Rank
1977	3.13	10	1.90	10	3.62	27	5.46	32	3.43	30
1978	2.46	32	1.52	30	3.73	23	6.84	9	3.57	26
1979	3.17	7	1.78	17	3.99	16	6.66	17	3.79	16
1980	2.99	20	1.67	25	4.45	6	6.96	1	3.92	5
1981	3.18	6	1.81	15	4.12	14	6.89	5	3.89	7
1982	3.29	3	1.81	14	3.46	29	6.89	4	3.75	18
1983	3.24	4	1.79	16	3.86	19	6.85	7	3.83	14
1984	3.17	8	1.87	13	3.98	17	6.88	6	3.88	10
1985	3.10	11	1.64	28	3.74	22	6.48	24	3.63	24
1986	2.92	23	1.67	26	4.25	9	6.90	3	3.84	12
1987	2.75	29	1.69	23	4.50	5	6.90	2	3.88	9
1988	2.84	28	1.57	29	3.42	30	6.24	28	3.42	31
1989	2.57	31	1.46	32	3.63	26	6.56	22	3.47	29
1990	2.95	22	1.70	22	3.68	25	6.84	8	3.70	21
1991	3.19	5	1.68	24	3.31	32	6.75	11	3.62	25
1992	2.87	27	1.65	27	3.92	18	6.21	29	3.57	28
1993	2.61	30	1.50	31	3.32	31	6.28	26	3.34	32
1994	2.97	21	1.70	21	4.20	11	6.52	23	3.75	19
1995	3.03	18	1.89	12	4.10	15	6.76	10	3.86	11
1996	3.31	2	1.93	9	3.76	21	6.71	12	3.82	15
1997	3.13	9	1.72	20	3.79	20	6.67	16	3.72	20
1998	3.05	16	1.96	7	4.17	13	5.75	31	3.65	23
1999	3.08	14	1.73	19	3.52	28	6.69	14	3.65	22
2000	3.09	13	1.76	18	3.69	24	6.14	30	3.57	27
2001	2.91	24	1.98	6	4.24	10	6.26	27	3.78	17
2002	2.88	25	1.89	11	4.18	12	6.68	15	3.83	13
2003	3.04	17	2.09	3	4.91	3	6.66	18	4.10	3
2004	3.01	19	2.03	5	4.77	4	6.62	19	4.03	4
2005	3.43	1	2.16	1	5.03	1	6.61	20	4.21	1
2006	3.09	12	2.14	2	5.02	2	6.71	13	4.17	2
2007	3.07	15	1.95	8	4.33	8	6.59	21	3.90	6
2008	2.88	26	2.06	4	4.39	7	6.47	25	3.89	8

CHAPTER 3 – Reservoir Age, Growth and Condition of Fishes

Methods

Koocanusa Reservoir Gill Netting

Gill net series were used to monitor the Koocanusa Reservoir fish community using annual spring and fall sets. Experimental gill nets (38.1 m long by 1.8 m deep with five equal-sized panels of 19-, 25-, 32-, 38-, and 51-mm bar measure) were set overnight and pulled the following day according to standardized sampling methods (Dunnigan et. al 2003). Live game species were released after length measurements were taken. All dead rainbow trout, bull trout, westslope cutthroat trout, and burbot were measured for total length (mm) and weight (g). Scales and otoliths were collected from all dead bull, rainbow and westslope cutthroat trout, and sex and sexual maturity information were recorded. Otoliths were also collected from kokanee.

Fish Condition Indices

Condition of bull trout and kokanee was calculated using relative weight (W_r ; Anderson and Neumann 1996) using the formula: $W_r = ((\text{Observed weight} / \text{standard weight}) * 100)$. Length and weight measurements were expressed in metric units and fish from each species were divided into 100-mm length groups for analysis (e.g., 100-199mm, 200-299mm, etc.). The mean relative weight was calculated for fish greater than 120 mm (Table 3-1).

Age and Growth

Fish used for age and growth analyses were collected during the annual spring and fall gill net series. Scales were collected from each game fish, with the exception of kokanee in the fall. Scales were collected between the dorsal and anal fins above the lateral line (salmonids). Species, length (mm), weight (g), sample date, and location were recorded on each scale envelope prior to scales being placed inside the envelope to dry. Samples were pressed onto acetate slides using a Carver model C press at 200°F at 15,000 PSI for 1 minute. Annuli were distinguished following methods described in DeVries and Frie (1996). Sagittal otoliths (salmonids and burbot) were viewed whole or if necessary, transverse sections were obtained using a Metaserve 2000 grinder/polisher or an Isomet slow speed saw at a thickness varying from 0.25-0.5 mm. Annuli were distinguished as a translucent band followed by an opaque band. Age was estimated as the number of opaque bands (Sharp and Bernard 1988; Hall 1991; Secor et al. 1992; Hining et al. 2000; Ihde and Chittenden 2002). Pectoral fin rays may have also been collected and prepared using methods similar to Cuerrier (1951), Scidmore and Glass (1953), and Zymonas and McMahon (2006). Fin rays were excised proximal to the body and allowed to dry in scale envelopes, labeled with the corresponding species, length, weight, location, and date of collection. Proximal portions of fin rays were set in epoxy and sectioned on the transverse plane at a thickness of 0.25-0.5 mm. Scale impressions, pectoral fin ray sections,

and sectioned otoliths were viewed on a Nikon SMZ-2T dissecting microscope with a MediaCybernetics Model PL-A662 binocular and digital imager. Digital images of annuli on scales, fin rays, and otoliths were digitally recorded and measured. Mean length-at-age was back calculated. Annual growth, mean length at age, and mean length at capture were compared between years. Once age frequencies are completed, survival and mortality estimates were calculated using catch curve analysis.

Table 3-1. List of fish species and their associated standard weight equation intercept, slope, and minimum length (from Hyatt and Hubert 2000). The standard weight equation format is $\text{Log } 10 (Ws) = a + b * (\text{Log } 10 \text{ TL})$ where a = intercept, b = slope, and TL = total length of the fish.

Species	Habitat	Intercept a	Slope b	Minimum Length (mm)
Bull trout		-5.237	3.115	120
Kokanee		-5.062	3.033	120

Statistical Analysis

Mean length at capture and mean length at age were determined using estimates of age from scales and otoliths. Multiple regression analyses of biotic and abiotic conditions may also be used to identify possible combinations of conditions that can predict growth increments of fishes in the Reservoirs. Condition of bull trout, rainbow trout, and westslope cutthroat trout were summarized by year and by 100mm length groups (e.g., 100-199mm, 200-299mm, etc.). A Waller Duncan k-ratio test was used to test for significant differences in mean relative weight between years and between length groups of fishes using SAS (SAS 2006). A $p\text{-value} \leq 0.05$ reflected a significant difference between years and length groups of fishes.

Results and Discussion

Koocanusa Reservoir Gill Netting and Condition

The catch per unit effort of bull trout in the spring gill net series in Koocanusa Reservoir continues to steadily increase, following the trend since the early 1990's. Since 2000, the number of bull trout per net has been above four fish per net, with a maximum near seven bull trout per net in 2000 (Figure 3-1). Similarly, the mean length of bull trout captured in the spring gill net series has increased from near 300mm in the late 1970s to more than 500mm in 2007 (Figure 3-2). The mean length of bull trout captured in the spring gill net series is approaching 600mm. The number of redds counted in the headwaters of Koocanusa Reservoir in British Columbia have steadily increasing since the early 1990's. In 1994, about 100 redds were counted, in 2003, however, over 2600 redds were observed (Figure 3-3). The number of redds has been stable in tributaries above Libby Dam since 2002 with the exception of 2005, when a large boulder fell into the Wigwam River, apparently blocking access to upper portions of the drainage.

Relative weight of bull trout in the spring gill net series has been near 100 since 1976, with most 100mm length groups having averages from 90 to 110 (Table 3-2). Bull trout in the 500 and 600mm length groups had the highest average condition, which was generally greater than 110. In the 1970's and early 1980's, there were few significant differences in relative weight between length groups within years. Beginning in the early 1990's and ending near 2000, there were more significant differences in mean relative weight between length groups within years (Table 3-3). Since 2000, there have been few significant differences in the mean relative weight of bull trout in different 100mm length groups captured in the spring gill net series each year and this trend continued in 2008 (Table 3-3). Generally, longer fish have higher condition values within each year. Within each 100-mm length group, 200 and 300-mm length groups were more variable between years, indicated by more significantly different groupings of relative weight (Table 3-4). Bull trout in the 100, 600, and 700-mm length groups showed no significant differences in mean relative weight between years.

Species composition of the spring gill net series is primarily composed of peamouth, coarsescale sucker, and northern pikeminnow. These three species typically average around 80% of the fish caught from 1977-2007 (Table 3-5), with peamouth representing the dominant species (approximately 65%), followed by coarsescale sucker and northern pikeminnow representing near 10-15% of the fish caught in the spring sinking gill nets. Bull trout have represented from 0 to 9 percent of the fish caught in the spring gill net series. Beginning in the mid-1990's, the percentage of fish caught represented by northern pikeminnow has increased, and now represent about 15% of the total catch in the spring gillnets.

Catch per net of kokanee in the fall gill net series in Koocanusa Reservoir has been highly variable since they were first established in Koocanusa Reservoir in the late 1970's. The number per net has ranged from less than one kokanee per net to a peak of 25 kokanee per net in 2002 (Figure 3-4). Mean length of kokanee has followed a significant declining trend since 1979

($r^2 = 0.59$; $P < 0.0001$), declining from near 450mm in 1980 to a low of near 225mm in 2005. Since 2005, the mean length of kokanee has increased to almost 300mm total length (Figure 3-5). The number of kokanee per net is generally inversely related to the mean length of kokanee in the fall net series, with higher mean length associated with lower catch per unit effort, possibly indicating some density dependence (covariance -155.662 ; Figure 3-6).

Mean relative weight of kokanee in the fall net series has been steady since they were first discovered. With the exception of 100mm length group kokanee in 1986, the average relative weight of kokanee since 1979 has ranged from 85-95 since (Table 3-6). No kokanee in the 300mm or longer length groups have been caught in gill nets since 1987. Despite the higher catch per unit effort of kokanee in some years, there has been no decline in the condition of kokanee. Most of the kokanee captured are similar in length and weight so there are few differences in the mean relative weight between length groups within each year (Table 3-7). Because of the similar size of fish within a year, slight differences in weight between years showed many differences in the mean relative weight between years in the 200 and 300mm kokanee (Table 3-8). Thirteen and ten significantly similar groups were identified from 1979 to 2007 in the 200 and 300-mm kokanee length groups respectively, despite relative weights only ranging from 76-101 in the 200 and 300mm length group. The high number of statistically different groupings is due to tight confidence intervals of the mean relative weight within each 100-mm group.

From 1985-2007, species composition of the fall gill net series was dominated by peamouth (average 53%) and kokanee (average 28%; Table 3-9). Bull trout have made up from 0 to 7 percent of the fish caught during the fall gill net series. Similar to the spring gill net series, pikeminnow now make up a greater percentage of the fish caught in the fall net series, representing greater than 30% of fish caught since 2006 (Table 3-9).

Species composition shifts have been observed in the spring and fall gill net series from Koocanusa Reservoir since the 1980's. In the spring gill net series, the 1980/1990 chi-square test resulted in a value of 0.020 (76.4% similarity), while the 1990/2000 test resulted in a chi-square value of 0.656 (82.6% similarity), indicating a more similar species composition in recent decades. Much of the change in species composition is a result of increases in peamouth and northern pikeminnow abundance and decreases in coarsescale sucker and mountain whitefish abundance in the nets. The fall gill net series is becoming more dissimilar as the decades pass, with a chi-square test value changing from 0.907 to 0.116 (95.1 versus 82.6% similarity) for the 1980/1990 comparison compared to the 1990/2000 comparison (Table 3-10). Much of the dissimilarity in species composition of the fall gill net series through time is due to increases in northern pikeminnow relative abundance from the 1990's to 2000's.

Bull Trout Spring Sinkers

Figure 3-1. Catch per unit effort (# per net) of bull trout during the spring gill net series (sinking nets only) in Koocanusa Reservoir, Montana from 1973-2008.

Bull Trout Spring

Figure 3-2. Mean length (mm, ± 2 SE) of bull trout caught during the spring gill net series in Koocanusa Reservoir, Montana from 1973-2008.

Figure 3-3. Number of bull trout redds counted above Libby Dam in from 1993-2007. The decline in 2005 possibly resulted from a large boulder that rolled into the river and partially blocked access into the headwaters of the drainage by migrating bull trout. Data courtesy of Jim Dunnigan, Montana, Fish, Wildlife and Parks, and Herb Tepper, British Columbia Ministry of Water, Land and Air Protection.

Table 3-2. Mean relative weight of bull trout captured in the spring gill net series by 100mm group from Koocanusa Reservoir, Montana.

	Length Category (100mm group)							
Year	100mm	200mm	300mm	400mm	500mm	600mm	700mm	800mm
1976		92	94	98	94			
1977								
1978		95	101	97	101		110	
1980	98	100	91	86	88			
1981	98	91	88	91	86			
1982		92	95	90	91			
1984		89	96	107	112			
1985		103	94	90	96			
1986		101	94	99	108	113		
1987		90	101	93	100	111		
1988	95	90	91	93	111	98		
1989		89	97	98	101			
1990		92	98	104	121	120		
1991			91	99		119		
1992	87	100	103	96	97	110		
1993	111		99	103	94	110		
1994	93	83	90	100	119	106		
1995		88	93	98	106	125		
1996		94	93	95	100	122		
1997		89	87	91	104	114		
1998	91	97	94	91	112	112	113	
1999	90	86	94	99	100	109	87	105
2000		84	92	95	107	122	102	
2001		94	90	96	105	102	110	101
2002	89	92	93	96	100	107	88	
2003		90	95	91	107	107	85	
2004		99	95	95	100	103	82	84
2005		109	108	98	98	94	92	
2006		94	95		102	103	98	
2007		92	94	93	109	105	106	95
2008		99	93	99	102	107	104	

Table 3-3. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each year, 100mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Year Length group	Group	Group	Year Length group	Group	Group	Year Length group	Group	Group	Group
1973	A		1976	A		1978	A		
100			100			100			
200	94		200	92		200	95		
300	96		300	94		300	101		
			400	98		400	97		
			500	94		500	101		
						600			
						700	110		
1980	A		1981	A		1982	A		
100	98		100	98		100			
200	100		200	91		200	92		
300	91		300	88		300	95		
400	86		400	91		400	90		
500	88		500	86		500	91		
1984	A	B	1985	A		1986	A	B	C
100			100			100			
200		89	200	103		200		**101**	
300		96	300	94		300			94
400	107		400	90		400		**101**	
500	111		500	96		500	**108**		
						600	113		
1987	A		1988	A	B	1989	A		
100			100		95	100			
200	90		200		90	200	89		
300	101		300		91	300	97		
400	93		400		93	400	98		
500	100		500	111		500	101		
600	111		600	**98**					

Table 3-3 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each year, 100-mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Year Length group	Group	Group	Group		Year Length group	Group	Group	Group	Group		Year Length group	Group	Group	Group
1990	A	B	C		1991	A	B				1992	A		
100					100						100	87		
200			92		200						200	100		
300		**98**			300	119					300	103		
400		104			400		99				400	96		
500	121				500						500	97		
600	120				600		91				600	110		
1993	A				1994	A	B	C	D		1995	A	B	C
100	111				100			**93**			100			
200					200				83		200			88
300	99				300			**90**			300			93
400	103				400		**100**				400		**98**	
500	94				500	119					500		106	
600	110				600		106				600	125		
1996	A	B			1997	A	B	C			1998	A	B	
100					100						100		91	
200		94			200			89			200	**97**		
300		93			300			87			300		94	
400		95			400			91			400		91	
500		100			500		104				500	112		
600	122				600	114					600	112		
											700	113		
1999	A	B	C		2000	A	B	C	D		2001	A	B	
100	*****90*****				100						100			
200			86		200				84		200		94	
300	*****94*****				300			**92**			300		90	
400	*****99*****				400		**95**				400	**96**		
500	*****100*****				500		107				500	**105**		
600	109				600	122					600	**102**		
700		**87**			700		**102**				700	110		
800	**105**										800	**101**		

Table 3-3 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each year, 100-mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Year Length group	Group		Year Length group	Group	Group		Year Length group	Group	Group
2002	A		2003	A	B		2004	A	B
100	89		100				100		
200	92		200		90		200	99	
300	93		300	***95***			300	***95***	
400	96		400		91		400	***95***	
500	100		500	107			500	100	
600	107		600	107			600	103	
700	88		700		85		700		82
							800		84
2005	A		2006	A			2007	A	
100			100				100		
200	109		200	94			200	92	
300	108		300	95			300	94	
400	98		400				400	93	
500	98		500	102			500	109	
600	94		600	103			600	105	
700	92		700	98			700	106	
							800	95	
2008	A								
100									
200	99								
300	93								
400	99								
500	102								
600	107								
700	104								

Table 3-4. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group	Group	Group	Group
100mm	A					
1980	98					
1981	98					
1988	95					
1992	87					
1993	111					
1994	93					
1998	91					
1999	90					
2002	89					
200mm	A	B	C	D	E	F
1973		*****94*****				
1976		*****92*****				
1978		*****95*****				
1980	*****99*****					
1981		*****91*****				
1982		*****92*****				
1984			*****89*****			
1985	**103**					
1986	***101***					
1987			*****90*****			
1988			*****90*****			
1989			*****89*****			
1990		*****92*****				
1992	*****100*****					
1994						83
1995			***88***			
1996		*****94*****				
1997			*****88*****			
1998	*****97*****					
1999					**86**	
2000						84
2001		*****94*****				
2002		*****92*****				
2003			*****90*****			
2004	*****99*****					
2005	109					
2006		*****94*****				
2007		*****92*****				
2008	*****99*****					

Table 3-4 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group
300mm	A	B	C	D	E	F	G	H	I	J	K
1973			*****96*****								
1976					*****94*****						
1978		*****101*****									
1980							*****91*****				
1981										***88***	
1982				*****95*****							
1984			*****96*****								
1985					*****94*****						
1986					*****94*****						
1987		***101***									
1988							*****92*****				
1989		*****97*****									
1990		*****98*****									
1991							*****92*****				
1992	***103***										
1993		*****99*****									
1994								*****90*****			
1995						*****93*****					
1996					*****93*****						
1997											87
1998					*****94*****						
1999					*****94*****						
2000						*****92*****					
2001										***90***	
2002						*****93*****					
2003				*****95*****							
2004				*****95*****							
2005	108										
2006			*****95*****								
2007					*****94*****						
2008						*****93*****					

Table 3-4 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group	Group
400mm	A	B	C	D
1976	*****98****			
1978	*****97*****			
1980				86
1981			***91***	
1982			***90***	
1984	107			
1985			***90***	
1986	*****99*****			
1987		*****93*****		
1988		*****93*****		
1989	*****98*****			
1990	104			
1991	*****99*****			
1992	*****97*****			
1993	103			
1994	*****99*****			
1995	*****98*****			
1996	*****95*****			
1997			***91***	
1998			***91***	
1999	*****99*****			
2000	*****95*****			
2001	*****96*****			
2002	*****96*****			
2003			***91***	
2004	*****95*****			
2005	*****98*****			
2007		*****93*****		
2008	*****99*****			

Table 3-4 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group
500mm	A	B	C
1976		***94***	
1978	*****101*****		
1980			88
1981			86
1982			91
1984	*****112*****		
1985	*****96*****		
1986	*****108*****		
1987	*****100*****		
1988	*****111*****		
1989	*****101*****		
1990	121		
1992	*****97*****		
1993		***94***	
1994	***119***		
1995	*****106*****		
1996	*****100*****		
1997	*****104*****		
1998	*****112*****		
1999	*****100*****		
2000	*****107*****		
2001	*****105*****		
2002	*****100*****		
2003	*****107*****		
2004	*****100*****		
2005	*****98*****		
2006	*****102*****		
2007	*****109*****		
2008	*****102*****		

Table 3-4 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group
600mm	A
1986	113
1987	111
1988	98
1990	120
1991	119
1992	110
1993	110
1994	106
1995	125
1996	122
1997	114
1998	112
1999	109
2000	122
2001	102
2002	107
2003	107
2004	103
2005	94
2006	103
2007	105
2008	107

Table 3-4 continued. Comparison of the mean relative weight of bull trout in the spring gill net series in Koocanusa Reservoir. Within each 100-mm group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group
700mm	A
1978	110
1998	113
1999	87
2000	102
2001	110
2002	88
2003	85
2004	82
2005	92
2006	98
2007	106
2008	104

Table 3-5. Species composition (%; sinking nets) of the spring gill net series in Koocanusa Reservoir from 1977-2008. Species abbreviations: CRC peamouth; CSU largescale sucker; DV bull trout; EBT brook trout; FSU longnose sucker; HYB rainbow x cutthroat trout hybrid; KOK kokanee; LING burbot; LMB largemouth bass; MWF mountain whitefish; NP northern pike; NSQ northern pikeminnow; PUMP pumpkinseed; RBT rainbow trout; RSS redside shiner; RSSxCRC redside shiner x peamouth, WCT westslope cutthroat trout; and YEP yellow perch.

Year	Species																	
	CRC	CSU	DV	EBT	FSU	HYB	KOK	LING	LMB	MWF	NP	NSQ	PUMP	RBT	RSS	RSS x CRC	WCT	YEP
1977	2	44	3	0	0	0	0	0	0	16	0	0	0	31	2	0	2	0
1978	2	43	4	0	17	0	0	1	0	14	0	11	0	3	5	0	1	0
1980	13	65	2	0	10	0	0	1	0	2	0	5	0	1	1	0	0	0
1981	18	55	2	0	9	0	0	1	0	4	0	4	0	3	1	0	2	0
1982	37	29	2	0	16	0	0	1	0	3	0	6	0	2	3	0	1	0
1984	41	18	4	0	1	0	1	1	0	18	0	9	0	3	1	0	1	0
1985	46	14	3	0	2	1	0	2	0	19	0	9	0	3	0	0	0	1
1986	60	12	3	0	2	0	0	1	0	9	0	8	0	0	0	0	0	4
1987	47	15	2	0	3	1	1	2	0	4	0	17	0	1	0	0	0	9
1988	65	12	2	0	2	0	2	1	0	2	0	8	0	1	0	0	0	5
1989	66	8	1	0	2	0	2	1	0	1	0	8	0	0	0	0	0	10
1990	82	5	1	0	1	0	2	0	0	0	0	5	0	0	0	0	0	4
1991	74	6	1	0	3	0	2	1	0	1	0	6	0	0	0	0	0	6
1992	81	9	1	0	2	0	0	0	0	1	0	3	0	0	0	0	0	1
1993	72	9	1	0	6	0	4	0	0	0	0	5	0	0	0	0	0	1
1994	76	7	2	0	6	0	0	0	0	0	0	7	0	0	0	0	0	1
1995	63	14	3	0	4	0	2	0	0	1	0	10	0	0	0	0	0	3
1996	56	19	4	0	4	0	2	0	0	2	0	9	0	1	0	0	0	3
1997	54	15	3	0	5	0	2	0	0	1	0	14	0	0	0	0	0	5
1998	76	9	1	0	4	0	1	0	0	1	0	7	0	0	0	0	0	1
1999	57	9	4	0	6	0	5	0	0	1	0	14	0	1	0	0	0	2
2000	66	9	6	0	4	0	1	0	0	1	0	11	0	0	0	0	0	1
2001	74	11	4	0	1	0	0	0	0	0	0	8	0	0	0	0	0	1
2002	62	12	6	0	3	0	1	0	0	1	0	12	0	0	0	0	0	1
2003	55	13	7	0	3	0	2	0	0	1	0	17	0	1	0	0	0	0
2004	63	7	9	0	0	0	1	0	0	1	0	17	0	1	0	0	0	1
2005	54	16	8	0	1	0	5	0	0	0	0	13	0	1	0	0	0	0
2006	71	9	5	0	1	0	1	0	0	1	0	12	0	0	0	0	0	0
2007	66	7	2	0	2	0	2	0	0	1	0	17	0	1	0	0	0	1
2008	55	12	7	0	1	0	1	0	0	1	0	22	0	1	0	0	0	0

Figure 3-4. Catch per unit effort (# per net) of kokanee during the fall gill series (floating nets only) in Kootenai Reservoir, Montana.

Kokanee Fall

Figure 3-5. Mean length (mm, ± 2 SE) of kokanee caught during the fall gill net series in Kootenai Reservoir, Montana.

Figure 3-6. Mean length (bars) and catch per unit effort (red line) of kokanee in the fall gill net series in Koocanusa Reservoir, above Libby Dam, Montana.

Table 3-6. Mean relative weight of kokanee captured in the fall gill net series by 100-mm length group in Koocanusa Reservoir, Montana.

	Length Category (100mm group)				
Year	100mm	200mm	300mm	400mm	500mm
1979			82	97	
1980			101	93	82
1981		95	97		
1982			91	92	85
1983	86		84	93	
1984		91	94	83	
1985	84	93	92	89	
1986	69	101	101	96	
1987		99	91	84	
1988	90	91	86		
1989	94	87	81		
1990		89	87		
1991		101	98		
1992	98	88	88		
1993	85	83	76		
1994		93	86		
1995		93	89		
1996		88	87		
1997		94	95		
1998		86	84		
1999		92	88		
2000		87	89		
2001	96	85	89		
2002		91			
2003		89	88		
2004	93	84	84		
2005		89			
2006		92	80		
2007		93	88		

Table 3-7. Comparison of the mean relative weight of kokanee caught during the fall gill net series in Koocanusa Reservoir. Within each year, 100-mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

1979	A	B			1988	A	B			1998	A	
300		82			100	***90***				200	86	
400	97				200	91				300	84	
					300		86					
1980	A											
300	101				1989	A	B			1999	A	B
400	93				100	94				200	92	
500	82				200	***87***				300		88
					300		81					
1981	A									2000	A	
200	95									200	87	
300	97				1990	A				300	89	
					200	89						
1982	A				300	87				2001	A	
300	91									100	96	
400	92				1991	A				200	85	
500	85				100	101				300	89	
					200	98						
1983	A									2002	A	
100	86				1992	A				200	91	
300	84				100	98						
400	93				200	88				2003	A	
					300	88				200	89	
1984	A	B								300	88	
200	91				1993	A						
300	94				100	85				2004	A	
400		83			200	83				100	93	
					300	76				200	84	
1985	A									300	84	
100	84				1994	A	B					
200	93				200	93				2005	A	
300	92				300		86			200	89	
400	89											
					1995	A	B			2006	A	B
1986	A	B			200	93				200	92	
100		69			300		89			300		80
200	101											
300	101				1996	A				2007	A	B
400	96				200	88				200	93	
					300	87				300		88
1987	A	B	C									
200	99				1997	A						
300		91			200	94						
400			84		300	95						

Table 3-8. Comparison of the mean relative weight of kokanee caught during the fall gill net series in Koocanusa Reservoir. Within each 100-mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group
100mm group	A	B												
1983	**86**													
1985	**84**													
1986		69												
1988	90													
1989	94													
1992	98													
1993	**85**													
2001	96													
2004	93													
200mm group	A	B	C	D	E	F	G	H	I	J	K	L	M	
1981		**95**												
1984				*****91*****										
1985			*****93*****											
1986	101													
1987	**99**													
1988			*****91*****											
1989										*****87*****				
1990						*****89*****								
1991	101													
1992								*****88*****						
1993													83	
1994			*****93*****											
1995			*****93*****											
1996						*****88*****								
1997			**94**											
1998											****86***			
1999			*****92*****											
2000									*****87*****					
2001										****85****				
2002			*****91*****											
2003						*****89*****								
2004												**84**		
2005					*****89*****									
2006			*****92*****											
2007			93											

Table 3-8 continued. Comparison of the mean relative weight of kokanee caught during the fall gill net series in Koocanusa Reservoir. Within each 100-mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length group Year	Group	Group	Group	Group	Group	Group	Group	Group	Group	Group
300mm group	A	B	C	D	E	F	G	H	I	J
1975	*****93*****									
1979								*****82*****		
1980	101									
1981	*****97*****									
1982		*****91*****								
1983							*****84*****			
1984	*****94*****									
1985		*****92*****								
1986	101									
1987		*****91*****								
1988					*****86*****					
1989								*****81*****		
1990				*****87*****						
1991	**98**									
1992				*****88*****						
1993										76
1994				*****86*****						
1995			*****89*****							
1996			*****87*****							
1997	*****95*****									
1998						*****84*****				
1999			*****88*****							
2000			*****89*****							
2001			*****89*****							
2003				*****88*****						
2004						*****84*****				
2006									**80**	
2007				*****88*****						
400mm group	A	B	C	D						
1979	97									
1980	**93**									
1982	**92**									
1983	**93**									
1984				83						
1985		**89**								
1986	96									
1987			**84**							

Table 3-9. Species composition (%; floating nets) of the fall gill net series in Koocanusa Reservoir from 1977-2007. Species abbreviations: CRC peamouth; CSU largescale sucker; DV bull trout; EBT brook trout; FSU longnose sucker; HYB rainbow x cutthroat trout hybrid; KOK kokanee; LING burbot; LMB largemouth bass; MWF mountain whitefish; NP northern pike; NSQ northern pikeminnow; PUMP pumpkinseed; RBT rainbow trout; RSS redside shiner; RSS x CRC redside shiner x peamouth, WCT westslope cutthroat trout; and YEP yellow perch.

	Species																	
Year	CRC	CSU	DV	EBT	FSU	HYB	KOK	LING	LMB	MWF	NP	NSQ	PUMP	RBT	RSS	RSS x CRC	WCT	YEP
1977	10	49	0	0	0	0	0	0	0	3	0	2	0	10	2	0	22	0
1978	10	25	0	0	0	0	0	0	0	3	0	15	0	19	20	0	7	0
1979	32	9	0	0	0	0	1	0	0	6	0	12	0	24	9	0	7	0
1980	38	12	1	0	0	0	1	0	0	3	0	12	0	24	3	0	6	0
1981	24	6	2	0	0	2	2	0	0	10	0	10	0	30	1	0	12	0
1982	47	4	0	0	0	0	22	0	0	3	0	11	0	8	1	0	4	0
1983	44	6	0	0	0	12	1	0	0	2	0	10	0	14	2	0	9	0
1984	38	5	2	0	0	5	29	0	0	2	0	5	0	8	0	0	6	0
1985	14	1	1	0	0	3	67	0	0	1	0	1	0	7	0	0	4	0
1986	65	2	0	0	0	4	14	0	0	2	0	4	0	6	1	0	2	0
1987	79	1	0	0	0	1	12	0	0	0	0	3	0	2	1	0	0	0
1988	43	2	0	0	0	1	47	0	0	0	0	2	0	2	1	0	1	1
1989	65	0	0	0	0	0	30	0	0	0	0	3	0	0	0	0	0	0
1990	52	0	0	0	0	1	38	0	0	1	0	5	0	1	0	0	1	0
1991	52	0	0	0	0	0	38	0	0	1	0	6	0	1	0	0	1	0
1992	68	2	1	0	0	0	21	0	0	1	0	5	0	1	0	0	1	0
1993	77	0	1	0	0	1	8	0	0	1	0	8	0	2	0	0	2	0
1994	58	0	0	0	0	0	24	0	0	1	0	14	0	1	1	0	1	0
1995	17	0	7	0	0	0	54	0	0	2	0	13	0	5	1	0	1	0
1996	64	0	0	0	0	0	17	0	0	0	0	12	0	2	1	0	1	0
1997	71	1	0	0	0	0	11	0	0	1	0	11	0	1	3	0	0	0
1998	70	0	0	0	0	1	12	0	0	1	0	13	0	1	1	0	0	0
1999	64	0	0	0	0	0	22	0	0	0	0	13	0	0	1	0	0	0
2000	54	0	0	0	0	0	31	0	0	0	0	12	0	2	0	0	1	0
2001	60	2	0	0	0	0	13	0	0	2	0	19	0	1	1	0	1	0
2002	41	1	0	0	0	0	42	0	0	0	0	14	0	0	1	0	0	0
2003	50	1	0	0	0	0	28	0	0	1	0	15	0	2	1	0	1	1
2004	29	1	1	0	0	0	42	0	0	2	0	23	0	2	0	0	0	1
2005	35	1	0	0	0	0	36	0	0	0	0	23	0	1	0	0	1	2
2006	47	2	0	0	0	0	15	0	0	1	0	30	0	1	1	0	0	3
2007	45	2	0	0	0	0	12	0	0	1	0	36	0	1	1	0	0	1

Table 3-10. Results of Chi-Square test (Panel A) and percent similarity index (Panel B) performed on the fish species composition (average percent) in the spring and fall gill net series in Koocanusa Reservoir by decade (1980's, 1990's, and 2000's). A Chi-square value of 1 means they are the same, 0 means they are different.

Panel A	Chi-Square Analysis		Decade		
Series	Net Type	Decade	1980	1990	2000
Spring	Sinking thru 2008	1980	***	0.020	0.002
	Sinking thru 2008	1990	***	***	0.656
	Sinking thru 2008	2000	***	***	***
			Decade		
Series	Net Type	Decade	1980	1990	2000
Fall	Floating thru 2007	1980	***	0.907	0.000
	Floating thru 2007	1990	***	***	0.116
	Floating thru 2007	2000	***	***	***

Panel B	Percent Similarity Index		Decade		
Series	Net Type	Decade	1980	1990	2000
Spring	Sinking thru 2008	1980	***	76.41	70.30
	Sinking thru 2008	1990	***	***	89.12
	Sinking thru 2008	2000	***	***	***
			Decade		
Series	Net Type	Decade	1980	1990	2000
Fall	Floating thru 2007	1980	***	95.05	85.94
	Floating thru 2007	1990	***	***	82.56
	Floating thru 2007	2000	***	***	***

CHAPTER 4 – Update Reservoir and River Models

Methods

Dr. Craig Althen compiled the RIVBIO and LRMOD models the models in 2006.

Results and Discussion

This objective was completed in 2006. No further model upgrades were required during the current fiscal period and we currently do not anticipate that additional upgrades will be needed for this project.

CHAPTER 5 – IFIM and RIVBIO Biological and Physical Modeling

Methods

RIVBIO Modeling

Model simulations (RivBio; Marotz and Althen 2005; USACE 2006) of Kootenai River (i.e., benthic biomass) and habitat conditions were modeled using average daily discharge (cfs) data obtained from the US Army Corps of Engineers. RivBio was calibrated using multiple river cross-sections to describe channel morphology in two river reaches downstream from Libby Dam. Inputting the average daily discharge data specific to each river reach allows calculation of river stage and wetted perimeter. The model tracks the duration that river substrate remains inundated as flows and river stage change over time. The recovery and loss of benthic biomass will be calculated using varying time increments of 15, 30, 47, 60, 75, and 90-days. Forty-seven days (unregulated flow recovery time) will be considered the minimum standard recovery time for model simulations (Gersich and Brusven 1981). An error in previous reports was found in the 1985 data reservoir and river model simulations, due to several very low discharges in the input data set. These errors were corrected and are now reflected in this report.

IFIM Modeling

Instream flow incremental methodology (Bovee 1982) models were used to develop habitat utilization curves for various fishes in 13 sections of the mainstem Kootenai River (Miller and Geise 2004; Figure 5-1). These models were used to assess the amount of usable habitat availability for various life stages of fishes (e.g., bull trout and rainbow trout) under different dam operation strategies. Model simulations will evaluate whether recent dam operations provide more usable habitat area for fish compared to prior operational and pre-dam conditions. Habitat use curves for rainbow trout were developed using known fish locations gathered via scuba diving and snorkeling in surveyed reaches of the river under various discharge levels. Bull trout habitat use was collected in the Flathead River drainage (Muhlfeld et al. 2003, 2003a; Muhlfeld and Marotz 2005) and applied to the Kootenai River. Discharges from Libby Dam (post-dam construction) and Kootenai River discharge (pre-dam conditions) was used as a model input for the habitat use function curves (i.e., discharge versus area available) for juvenile and adult rainbow and bull trout. More recent seasonal habitat area (i.e., water years 1977-present) was summarized and compared to pre-dam conditions. Seasons within water years were identified as follows: Fall = October-November, Winter = December-March, Spring = April-June, and Summer = July-September. Seasonal water variability (i.e., absolute value of discharge change in cfs) was used to compare high, medium, and low water variability seasons to pre-dam conditions. High, medium, and low years were assigned by sorting the sum of the absolute daily discharge change, with the top 1/3 = high, middle 1/3 = middle, and bottom 1/3 = low variability for the season. If the average daily discharge was outside of the calibrated IFIM range (i.e., 2000-40000 cfs), the weighted usable habitat area value at 2000 or 40000 cfs was assigned to keep analysis within the intended range of discharges that the models were calibrated.

Figure 5-1. Location of 13 IFIM habitat units used to assess habitat availability in the Kootenai River located in Montana and Idaho, USA.

Results and Discussion

RIVBIO modeling

Daily flow data from 1911-2007 included Libby Dam discharge data from the US Army Corps of Engineers and river gage data compiled by the United States Geologic Survey (Leonia, Idaho USGS 12305000, Kootenai River below Libby Dam USGS 12301933, Kootenai River near Rexford, Montana USGS 12301500, Kootenai River at Worland Bridge, Montana USGS 12301850, Kootenai River at Libby, Montana USGS 12303000). Prior to regulation by Libby Dam, peak daily discharge (cfs) in the Kootenai River approached 120,000 cfs, with an average spring discharge of approximately 65,000 cfs (Figure 5-2). Since construction of Libby Dam, peak discharge of the Kootenai River has been greatly reduced. Since 1975, the maximum annual discharges were highest in 2006 at 55,000 cfs. Other high flow events from Libby Dam occurred in 1981 and 2002, when discharges from Libby Dam peaked at 40,000 cfs (Figure 5-2). During 2002 and 2006, peak discharge included water released over the spillway. Daily variation in discharge increased after dam construction due to power peaking and load following. From 1910-1975 the average annual sum of the daily discharge variation was 272,000 cfs (range 115,000-454,000 cfs) and after dam construction, the annual average was 396,000 cfs (Range 87,000-772,000; Figure 5-3). Since 2000, the average was 167,000 (Range 87,000-244,000 cfs).

Daily discharge (cfs) was used to calculate the average wetted perimeter from water year 1977 to 2007. The model output generated a wetted perimeter versus discharge relationship for each water year (Figure 5-4). Since Libby Dam became operational, average fall (October and November) discharge has decreased significantly over time from 1977 to 2007 (Regression r-square 0.40, $P < 0.001$), with average flows since 2001 near 7,500 cfs (Table 5-1). Spring flows increased significantly during the same time-period (Regression r-square 0.41, $P < 0.001$), with the average spring discharge since 2001 averaging 11,200 cfs. No trend has occurred in the average winter or summer discharges, as both have been variable since water year 1977. Concurrent with the trends in discharge, wetted perimeter has shown a decreasing trend in the fall and an increasing trend in the spring since water year 1977 (Table 5-2). Model estimates of spring and summer benthic biomass in the Kootenai River shows an increasing trend since water year 1977 (Figure 5-5; Table 5-3). Model estimates of benthic biomass vary when the model is set to differing assumptions of recolonization time. Sensitivity analysis of benthic biomass of the Kootenai River indicates that seasonal differences vary little (i.e., generally $\pm < 5\%$) across differing recolonization periods (i.e. 15, 30, 60, 75, and 90-days compared to 47-day assumed time (Tables 5-4 to 5-8). Very low discharges (i.e., < 3000 cfs) affected the productivity of the Kootenai River in water years 1979, 1988, and 1989. However, the intent of the model is to compare differing operation strategies and rank varying operating strategies from productive to unproductive.

Daily minimum, maximum, and optimal target water temperatures for water released from Libby Dam have been developed. Daily minimum water temperatures range from 32°F in from February and March to 50.5°F in July and August (Figure 5-6). Maximum water temperatures range from 40 to 58°F and the optimum temperature range is from 36 to 58°F (Figure 5-6; data from Greg Hoffman, USACE, from Helms, year unknown). The minimum

water temperature targets for the selective withdrawal gates at Libby Dam were exceeded frequently from the 1970s to the mid 1980s and from the mid 1990s to 2007. The recommended daily minimum temperature targets are typically exceeded in May and June with the maximum average monthly deviation of -4.28°F occurring in May 2001 (Table 5-9). Deviations during early spring typically occur because thermal stratification is just beginning in the reservoir and water can not be withdrawn within about 25 ft from the surface to avoid turbine cavitation, so warm water near the surface may not be accessible in some years. In 2005 and 2006, the minimum temperature targets were also exceeded in the fall and early winter months by up to an average of -2.69°F (Table 5-9). Daily maximum temperature targets have been sporadically exceeded in almost every month of the year since 1974. The average daily maximum temperature targets were exceeded by a maximum of 5.95°F in July 1975, but since 1977, most of the average daily maximum temperature targets have been exceeded by less than 2°F (Table 5-10).

The potential effects of four different dam operating strategies on sediment transport, fishes growth, river stage, and flow have been evaluated on the Green River below Flaming Gorge Reservoir in Utah. Operational scenarios included year-round high fluctuations, seasonally adjusted high fluctuations, seasonally adjusted moderate fluctuations, and seasonally adjusted steady flows (Hlohowskyj and Hayse 1995; Williams, et al. 1995). Williams et al. (1995) found that none of the hydropower operation strategies would differ significantly in terms of sediment transport, with the exception of dry water years, when the total sediment load is small compared to even moderately wet years. Seasonally adjusted steady flows and seasonally adjusted flows with moderate fluctuations could result in increased growth, higher fish condition indices, and higher over-winter survival if coordinated with reductions in fish stocking efforts. These operational changes could also result in increased food production and spawning habitat availability (Hlohowskyj and Hayse 1995). Model simulations of the Kootenai River indicate that more recent operations provide more physical habitat and more productive habitat conditions in the spring and summer months compared to historical operations, which may translate to better fish condition, survival, and growth.

Figure 5-2. Peak discharge of the Kootenai River near Libby Dam for water years 1911-2008. Data from the United States Geological Survey and the United States Army Corps of Engineers data.

Daily Discharge Variability of the Kootenai River, Montana

Figure 5-3. Sum of the absolute average daily discharge variation (cfs) in the Kootenai River below Libby Dam, Montana from water year 1911-2008.

Figure 5-4. Relationship of wetted perimeter versus discharge (kcfs) for the Kootenai River below Libby Dam for water year 1981. The relationship generated is a composite of multiple river transects (Marotz and Althen 2005). Multiple river transects were used to calibrate the RIVBIO model.

Table 5-1. Average seasonal outflow (kcfs) from Libby Dam into the Kootenai River from water year 1977 to 2008. A ranking of 1 equals the highest average outflow and 32 equals the lowest.

Water Year	Fall Average (kcfs)	Fall Rank	Winter Average (kcfs)	Winter Rank	Spring Average (kcfs)	Spring Rank	Summer Average (kcfs)	Summer Rank	Annual Average (kcfs)	Annual Rank
1977	15.02	12	11.26	23	5.48	24	8.75	14	9.82	18
1978	13.76	15	7.86	25	4.66	15	11.35	26	8.93	28
1979	16.59	5	11.78	28	3.42	31	5.44	13	8.90	29
1980	15.74	10	8.86	19	6.58	25	8.17	23	9.27	24
1981	14.51	14	14.35	20	6.49	2	16.40	8	12.93	4
1982	12.83	20	14.79	15	8.34	22	9.56	6	11.53	10
1983	16.14	8	14.72	24	4.82	17	10.67	7	11.47	11
1984	12.40	21	12.14	27	3.75	16	10.85	11	9.77	19
1985	13.74	16	12.57	31	3.12	28	7.66	10	9.17	27
1986	18.71	3	9.93	22	6.05	5	13.89	16	11.43	12
1987	22.69	1	7.52	29	3.24	19	10.13	30	9.65	20
1988	16.50	6	11.87	32	3.00	26	7.93	12	9.44	22
1989	8.16	9	3.13	30	10.46	18	17.09	18	9.32	25
1990	16.76	4	14.29	13	8.59	12	12.86	9	12.92	5
1991	14.70	13	19.69	10	10.69	4	15.27	1	15.50	2
1992	22.65	2	7.14	18	7.03	21	9.53	31	10.31	16
1993	15.03	11	9.03	21	6.22	30	5.95	20	8.56	31
1994	16.46	7	9.49	11	9.78	32	4.95	19	9.58	21
1995	11.63	23	8.62	6	12.57	23	9.52	24	10.33	17
1996	12.36	22	16.72	1	18.51	7	13.67	4	15.67	1
1997	13.40	18	14.94	4	14.92	14	11.98	5	13.93	3
1998	13.18	19	9.00	8	11.13	10	13.21	21	11.29	14
1999	6.44	29	16.83	17	7.11	11	13.05	3	11.72	9
2000	13.46	17	17.56	14	8.40	27	7.88	2	12.15	8
2001	7.51	26	7.37	26	4.02	29	6.05	32	6.23	32
2002	6.15	30	9.72	9	10.86	1	16.59	17	11.14	15
2003	5.30	32	7.64	12	9.27	8	13.62	29	9.16	26
2004	6.69	28	7.71	16	7.60	13	12.07	28	8.61	30
2005	9.84	25	8.45	7	11.87	3	15.93	25	11.42	13
2006	10.03	24	8.87	2	17.84	9	13.32	22	12.42	6
2007	7.22	27	10.29	3	17.28	6	13.77	15	12.40	7
2008	5.92	31	7.78	5	13.04	20	10.09	27	9.36	23

Table 5-2. Summary of average daily wetted perimeter (feet) by season and water year in the Kootenai River below Libby Dam, Montana. A ranking of 1 equals the highest average wetted perimeter and 32 equals the lowest.

Water Year	Fall Average	Fall Rank	Winter Average	Winter Rank	Spring Average	Spring Rank	Summer Average	Summer Rank	Annual Average	Annual Rank
1977	475.33	10	437.88	15	351.55	27	435.14	24	421.93	24
1978	467.04	17	418.11	27	356.71	26	455.93	15	420.51	25
1979	484.12	4	446.79	13	338.50	28	384.47	31	410.32	29
1980	482.79	5	407.14	31	366.43	24	414.05	28	411.38	27
1981	471.96	13	462.69	9	360.23	25	476.80	3	442.25	15
1982	458.74	20	471.97	5	438.00	12	446.65	20	454.91	7
1983	478.42	9	470.55	7	407.27	19	452.19	18	451.46	11
1984	457.21	21	450.31	11	371.06	23	453.66	16	432.55	22
1985	471.00	14	456.29	10	308.80	32	421.39	27	413.18	26
1986	492.82	3	436.06	18	380.98	21	469.44	6	440.23	16
1987	503.97	2	407.39	30	316.25	31	449.21	19	411.35	28
1988	480.73	8	437.86	16	324.71	30	386.71	30	403.92	31
1989	475.05	11	404.41	32	327.56	29	424.99	26	402.24	32
1990	481.05	7	465.93	8	430.93	14	463.56	12	459.13	4
1991	466.39	18	493.82	1	450.14	7	476.79	4	474.05	2
1992	505.40	1	409.36	29	417.57	18	437.25	23	434.49	21
1993	472.90	12	410.03	28	379.76	22	381.53	32	405.81	30
1994	481.69	6	433.33	20	440.19	11	408.06	29	436.75	18
1995	453.40	22	431.24	21	455.79	6	444.18	21	444.33	14
1996	452.50	23	479.10	4	487.16	1	469.99	5	474.36	1
1997	467.29	16	471.47	6	471.87	3	462.91	14	468.71	3
1998	466.18	19	437.06	17	446.19	9	468.24	10	452.06	10
1999	428.78	27	479.27	3	417.98	17	467.59	11	452.61	9
2000	469.06	15	481.41	2	424.98	15	443.60	22	455.75	6
2001	437.40	26	429.41	22	398.84	20	427.79	25	422.72	23
2002	428.71	28	447.62	12	441.59	10	478.13	2	450.65	12
2003	417.69	31	421.59	26	431.06	13	468.36	8	435.09	19
2004	422.02	30	426.59	24	424.55	16	463.52	13	434.63	20
2005	446.43	24	426.50	25	446.62	8	480.15	1	448.37	13
2006	444.94	25	434.25	19	466.96	4	468.34	9	452.78	8
2007	427.16	29	444.91	14	485.15	2	468.86	7	458.01	5
2008	417.40	32	427.37	23	456.44	5	452.46	17	439.28	17

Figure 5-5. Seasonal modeled benthic biomass summary of the Kootenai River below Libby Dam from water year 1977 to 2008. Model simulations assumed a 47-day recovery period. Low discharges (<4000cfs) in water years 1979, 1988, and 1989 are the reason for low biomass totals in those water years.

Table 5-3. RIVBIO modeled seasonal and annual benthic biomass and seasonal and annual ranking in the Kootenai River below Libby Dam. Model simulations assume a 47-day recovery period. A ranking of 1 equals the highest benthic biomass and 32 equals the lowest.

Water Year	Fall Sum	Fall Rank	Winter Sum	Winter Rank	Spring Sum	Spring Rank	Summer Sum	Summer Rank	Annual Sum	Annual Rank
1977	27565	9	47382	29	33539	29	62030	29	170516	29
1978	26235	24	47218	30	35023	26	67048	21	175524	25
1979	28889	4	52031	10	34203	27	49995	32	165118	31
1980	26605	18	48103	28	33885	28	64782	27	173374	27
1981	26265	23	51358	13	35189	25	72698	13	185509	21
1982	25445	30	51012	15	44753	12	66373	22	187583	19
1983	26872	16	53895	4	43349	19	68884	18	192999	14
1984	26287	22	51293	14	38507	23	66004	23	182091	24
1985	26413	20	52813	8	32758	30	59587	30	171571	28
1986	28168	6	49519	22	37349	24	71346	15	186382	20
1987	29923	1	46740	31	32703	31	64719	28	174084	26
1988	29505	3	50057	19	32482	32	51283	31	163326	32
1989	24471	32	36210	32	40786	21	68317	20	169784	30
1990	26071	28	51580	11	43904	16	71216	16	192772	15
1991	26748	17	56837	1	45267	11	72856	12	201708	5
1992	29582	2	48309	27	40532	22	65277	25	183699	23
1993	27066	11	48606	26	43575	18	65022	26	184269	22
1994	27737	8	52192	9	46006	7	65984	24	191919	16
1995	25228	31	48775	24	47019	5	69443	17	190465	17
1996	26233	25	54796	3	48396	2	74288	7	203713	2
1997	27267	10	53422	5	46467	6	73928	8	201085	7
1998	27742	7	48696	25	45790	9	73563	10	195791	12
1999	26989	12	53188	6	43589	17	73191	11	196957	10
2000	28590	5	56063	2	43959	15	72023	14	200635	8
2001	26974	13	50021	21	43312	20	68335	19	188642	18
2002	26925	15	52998	7	45519	10	77634	2	203076	3
2003	26370	21	49185	23	44469	14	75501	6	195524	13
2004	25613	29	50304	18	44484	13	75562	5	195963	11
2005	26946	14	50386	17	45798	8	78085	1	201215	6
2006	26603	19	50802	16	47753	4	76685	3	201842	4
2007	26142	26	51517	12	49747	1	76657	4	204063	1
2008	26122	27	50031	20	48238	3	73915	9	198305	9

Table 5-4. Percent difference in the seasonal and annual modeled benthic biomass of the Kootenai River below Libby Dam with a recovery period of 15-days as compared to a baseline value of 47-days.

Water Year	Fall % Difference	Winter % Difference	Spring % Difference	Summer % Difference	Annual % Difference
1977	4.94	5.97	6.12	9.18	7.00
1978	4.03	1.34	8.90	5.23	4.74
1979	3.20	2.05	5.11	7.10	4.41
1980	7.36	1.51	9.43	3.17	4.57
1981	6.32	6.97	9.82	3.37	6.01
1982	4.66	9.26	2.83	4.43	5.39
1983	8.14	4.21	0.55	3.71	3.75
1984	4.52	4.76	5.03	5.46	5.03
1985	6.25	0.28	9.04	2.53	4.93
1986	6.65	4.62	9.22	3.11	5.27
1987	4.46	2.00	3.42	6.47	4.35
1988	2.47	3.06	0.00	7.67	3.79
1989	1.93	0.85	7.04	6.44	4.74
1990	5.25	6.41	4.32	3.01	4.52
1991	3.28	3.50	3.87	2.73	3.27
1992	3.34	1.24	6.49	2.04	3.02
1993	5.02	2.65	2.45	0.83	2.31
1994	5.51	0.61	3.90	0.17	1.96
1995	3.96	3.36	4.63	3.20	3.70
1996	6.02	4.01	6.90	1.34	3.98
1997	3.62	4.89	7.31	1.32	3.96
1998	1.98	3.23	4.96	2.68	3.25
1999	0.00	5.79	2.85	2.94	3.29
2000	1.46	2.63	4.53	0.53	2.12
2001	0.96	2.25	0.04	1.33	1.23
2002	0.01	1.69	5.04	0.96	1.94
2003	0.02	2.20	5.07	1.12	2.14
2004	2.38	1.85	3.75	0.31	1.76
2005	2.66	1.24	5.18	0.82	2.17
2006	3.58	2.29	6.15	0.05	2.53
2007	0.87	2.44	4.19	0.57	1.96
2008	0.13	1.28	2.41	0.05	0.94

Table 5-5. Percent difference in the seasonal and annual modeled benthic biomass of the Kootenai River below Libby Dam with a recovery period of 30-days as compared to a baseline value of 47-days.

Water Year	Fall % Difference	Winter % Difference	Spring % Difference	Summer % Difference	Annual % Difference
1977	2.20	2.80	1.95	3.77	2.89
1978	0.69	0.21	4.06	1.99	1.73
1979	1.37	0.67	1.26	2.54	1.48
1980	3.34	0.48	3.80	1.20	1.84
1981	2.83	3.50	5.01	1.61	2.95
1982	1.41	5.08	1.37	1.51	2.43
1983	3.46	2.27	0.08	1.62	1.71
1984	1.29	2.50	2.05	2.60	2.27
1985	6.25	0.28	9.04	2.53	4.93
1986	2.75	2.37	4.52	1.25	2.43
1987	2.42	0.40	0.86	3.29	1.91
1988	1.35	1.47	0.00	3.36	1.75
1989	0.49	0.16	3.49	1.94	1.73
1990	1.51	2.59	1.33	1.65	1.81
1991	1.08	1.82	1.75	1.14	1.46
1992	1.37	0.58	2.77	0.60	1.20
1993	2.24	1.32	0.73	0.20	0.92
1994	3.01	0.39	2.05	0.05	1.05
1995	0.72	1.00	2.51	1.48	1.51
1996	3.10	2.03	3.43	0.49	1.94
1997	1.20	2.60	3.22	0.43	1.75
1998	0.82	0.99	2.35	1.20	1.36
1999	0.00	2.69	0.78	1.71	1.53
2000	0.41	1.45	1.59	0.46	0.97
2001	0.23	0.99	0.01	0.71	0.56
2002	0.00	0.86	2.33	0.71	1.02
2003	0.00	0.85	2.27	0.68	0.99
2004	1.00	0.84	1.89	0.23	0.86
2005	1.09	0.62	2.46	0.55	1.08
2006	1.46	1.19	3.29	0.01	1.27
2007	0.16	1.20	1.81	0.31	0.88
2008	0.00	0.00	0.00	0.00	0.00

Table 5-6. Percent difference in the seasonal and annual modeled benthic biomass of the Kootenai River below Libby Dam with a recovery period of 60-days as compared to a baseline value of 47-days.

Water Year	Fall % Difference	Winter % Difference	Spring % Difference	Summer % Difference	Annual % Difference
1977	-1.55	-2.19	-0.61	-2.55	-1.90
1978	-0.19	-0.06	-2.20	-1.25	-0.96
1979	-0.63	-0.62	-0.37	-0.91	-0.66
1980	-2.52	-0.24	-1.43	-1.31	-1.22
1981	-0.85	-1.60	-2.44	-1.92	-1.78
1982	-0.36	-2.16	-0.87	-0.80	-1.13
1983	-1.35	-2.28	-0.02	-0.87	-1.14
1984	-0.38	-1.52	-0.72	-2.35	-1.49
1985	-1.02	-0.01	-2.78	-0.87	-1.39
1986	-1.51	-0.89	-2.02	-1.60	-1.48
1987	-1.70	-0.11	-0.25	-2.47	-1.29
1988	-1.00	-0.99	0.00	-1.59	-0.98
1989	-0.64	-0.04	-2.71	-0.76	-1.06
1990	-0.61	-1.42	-0.41	-1.11	-0.96
1991	-0.56	-1.37	-1.00	-0.84	-0.99
1992	-0.72	-0.24	-1.87	-0.19	-0.66
1993	-0.85	-0.28	-0.22	-0.05	-0.27
1994	-2.09	-0.34	-1.41	-0.09	-0.76
1995	-0.20	-0.38	-1.94	-0.98	-0.96
1996	-1.45	-1.43	-1.98	-0.42	-1.19
1997	-0.41	-2.23	-2.14	-0.31	-1.26
1998	-0.50	-0.29	-1.41	-1.00	-0.85
1999	0.00	-1.72	-0.24	-1.19	-0.96
2000	-0.16	-0.84	-0.53	-0.59	-0.59
2001	-0.07	-0.54	0.00	-0.54	-0.35
2002	0.00	-0.50	-1.31	-0.87	-0.76
2003	0.00	-0.30	-0.89	-0.83	-0.60
2004	-0.33	-0.65	-0.86	-0.55	-0.61
2005	-0.43	-0.49	-1.51	-0.54	-0.73
2006	-0.58	-0.73	-2.39	-0.13	-0.87
2007	-0.05	-0.62	-1.19	-0.24	-0.54
2008	-0.03	-1.41	-4.01	-0.20	-1.41

Table 5-7. Percent difference in the seasonal and annual modeled benthic biomass of the Kootenai River below Libby Dam with a recovery period of 75-days as compared to a baseline value of 47-days.

Water Year	Fall % Difference	Winter % Difference	Spring % Difference	Summer % Difference	Annual % Difference
1977	-2.75	-4.57	-1.57	-5.31	-3.95
1978	-0.31	-0.09	-3.77	-3.04	-1.98
1979	-1.11	-1.43	-0.60	-1.48	-1.22
1980	-4.88	-0.50	-2.34	-3.14	-2.52
1981	-1.37	-2.96	-4.12	-4.49	-3.56
1982	-0.57	-3.24	-1.56	-1.37	-1.82
1983	-2.23	-4.32	-0.04	-1.74	-2.14
1984	-0.61	-2.89	-1.17	-4.95	-2.94
1985	-1.02	-0.01	-2.78	-0.87	-1.39
1986	-2.77	-1.45	-3.37	-3.94	-2.99
1987	-3.40	-0.18	-0.40	-5.15	-2.62
1988	-2.00	-2.04	0.00	-2.69	-1.83
1989	-2.16	-0.07	-5.91	-1.21	-2.23
1990	-1.12	-2.68	-0.81	-2.31	-1.90
1991	-1.06	-2.92	-1.75	-1.73	-1.98
1992	-1.15	-0.31	-4.05	-0.31	-1.27
1993	-1.50	-0.45	-0.36	-0.08	-0.45
1994	-4.15	-0.84	-2.63	-0.35	-1.58
1995	-0.31	-0.63	-3.62	-2.02	-1.83
1996	-2.38	-2.96	-3.58	-1.01	-2.32
1997	-0.74	-4.19	-3.55	-0.89	-2.36
1998	-0.99	-0.49	-2.56	-2.38	-1.76
1999	0.00	-3.18	-0.38	-2.47	-1.86
2000	-0.30	-1.55	-0.85	-1.39	-1.16
2001	-0.11	-0.93	0.00	-1.15	-0.68
2002	0.00	-0.93	-2.35	-2.15	-1.59
2003	0.00	-0.49	-1.46	-1.98	-1.22
2004	-0.54	-1.34	-1.44	-1.46	-1.31
2005	-0.71	-1.04	-2.68	-1.52	-1.55
2006	-0.95	-1.42	-4.36	-0.68	-1.77
2007	-0.07	-1.25	-2.52	-0.49	-1.13
2008	-0.04	-1.70	-5.53	-0.52	-1.97

Table 5-8. Percent difference in the seasonal and annual modeled benthic biomass of the Kootenai River below Libby Dam with a recovery period of 90-days as compared to a baseline value of 47-days.

Water Year	Fall % Difference	Winter % Difference	Spring % Difference	Summer % Difference	Annual % Difference
1977	-3.44	-6.27	-2.46	-7.90	-5.65
1978	-0.37	-0.11	-4.74	-5.06	-2.96
1979	-1.45	-1.88	-0.72	-1.80	-1.54
1980	-7.54	-0.79	-2.86	-5.15	-3.86
1981	-1.69	-3.95	-5.13	-7.22	-5.14
1982	-0.69	-3.87	-2.01	-1.60	-2.19
1983	-2.75	-5.36	-0.07	-2.51	-2.79
1984	-0.79	-3.70	-1.42	-7.25	-4.08
1985	-1.02	-0.01	-2.78	-0.87	-1.39
1986	-3.68	-1.77	-4.18	-6.57	-4.38
1987	-4.63	-0.21	-0.48	-7.63	-3.78
1988	-2.86	-2.93	0.00	-3.36	-2.47
1989	-4.28	-0.08	-8.83	-1.66	-3.42
1990	-1.54	-3.57	-1.03	-3.41	-2.66
1991	-1.39	-4.42	-2.22	-2.62	-2.87
1992	-1.44	-0.34	-6.37	-0.38	-1.86
1993	-2.18	-0.54	-0.43	-0.10	-0.60
1994	-5.62	-1.56	-3.46	-0.62	-2.28
1995	-0.37	-0.77	-4.73	-2.99	-2.50
1996	-2.93	-4.32	-4.77	-1.66	-3.28
1997	-0.90	-5.56	-4.43	-1.66	-3.23
1998	-1.36	-0.61	-3.31	-3.91	-2.59
1999	0.00	-4.26	-0.46	-3.62	-2.60
2000	-0.50	-2.13	-1.04	-2.26	-1.70
2001	-0.13	-1.17	0.00	-1.74	-0.96
2002	0.00	-1.29	-3.02	-3.60	-2.39
2003	0.00	-0.60	-1.79	-3.25	-1.81
2004	-0.66	-1.92	-1.78	-2.57	-1.97
2005	-0.87	-1.50	-3.42	-2.78	-2.35
2006	-1.17	-1.98	-5.66	-1.59	-2.60
2007	-0.09	-1.83	-3.88	-0.70	-1.68
2008	-0.04	-1.88	-6.66	-1.08	-2.50

Kootenai River Selective Withdrawal Targets

Figure 5-6. Daily water temperature targets of water released from Libby Dam into the Kootenai River. Data courtesy of Greg Hoffman, United States Army Corps of Engineers, Libby Dam office.

Table 5-9. Average monthly water temperature (°F) deviation of water released from Libby Dam compared to daily minimum target water temperatures from 1974-2008. Water temperature data obtained from USGS gage 12301933 and the United States Army Corps of Engineers.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974					-0.04	-0.76						
1975					-1.20	-2.15		-2.30	-0.50			
1976						-3.70	-3.85	-1.40				
1977					-2.84	-4.20						
1978					-0.50							
1979					-0.12							
1980					-0.48							
1981					-0.10	-0.69						
1982					-0.94	-2.10			-1.48			
1983					-0.50							
1984					-1.25							
1985					-0.30	-0.10						
1986	-0.70				-0.78							
1987												
1988												
1989												
1990						-1.10						
1991												
1992												
1993												
1994												
1995					-1.90	-0.80						
1996												
1997					-1.20	-0.58						
1998					-0.60							
1999					-1.67	-3.19						
2000					-0.30							
2001					-4.28	-6.34						
2002					-4.18	-2.01	-0.13					
2003					-2.06	-0.51	-0.54					
2004					-2.12	-0.43						
2005					-2.95	-0.71	-0.06			-0.57	-0.60	
2006					-0.66	-0.43				-2.69	-1.52	-0.28
2007					-0.44							
2008					-2.96	-2.71	-0.87					

Table 5-10. Average monthly water temperature deviation (°F) of water released from Libby Dam compared to daily maximum target water temperatures from 1974-2008. Water temperature data obtained from USGS gage 12301933 and the United States Army Corps of Engineers.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974								1.54	1.95			
1975							5.95	2.80				
1976												5.20
1977								2.50				
1978												
1979								1.90	0.56	0.14		
1980												
1981												
1982						1.70						0.80
1983	1.78	1.60	1.90	1.39					0.10			
1984			0.70									
1985							2.80	0.10				
1986							1.00	1.00	2.00		1.40	2.69
1987	0.15	0.38		0.10			1.00	1.50				
1988							1.00	1.11	1.13			
1989	0.60											
1990												
1991												
1992							2.00	1.00				
1993					0.10			0.79				
1994												
1995												
1996												
1997								1.39	0.84			
1998		0.10			0.40		0.33	1.00				
1999							1.87	0.90				
2000								1.00	0.50			
2001								1.44	0.99	0.40		
2002								1.13	1.58			
2003							0.30	1.42	1.37			
2004							1.32	1.37	0.35			
2005				0.89	1.04			1.12				
2006							0.74	0.24	1.53			
2007								0.47	0.45			
2008							0.55	0.70	0.75			

IFIM Modeling

Model simulations of weighted usable habitat for juvenile bull trout indicated that both during the day and night, less habitat area is available during the fall and winter seasons due to greatly increased discharges compared to pre-dam conditions (i.e., 140-294%; Tables 5-11 and 5-12). However, more habitat area is available during the spring season, resulting from greatly reduced discharges compared to pre-dam conditions (i.e., 20-40%; Table 5-12). Average seasonal discharge during the summer season is very close to pre-dam conditions and as a result, habitat area values are very close to pre-dam conditions for juvenile bull trout (98-113%). Daytime and nighttime habitat area curves were different for juvenile bull trout, but both showed that more habitat area was available at lower discharges compared to higher discharges (Figures 5-7 and 5-8).

IFIM model simulations of habitat area for adult bull trout in the Kootenai River indicate that low, medium, and high variability fall and winter seasons provide less habitat area for adult bull trout than pre-dam conditions (Tables 5-11 and 5-12). Less area is available during the fall and winter months due to increased seasonal average discharge compared to pre-dam conditions. Habitat area for adult bull trout is greater post dam during all variability strata during spring due to greatly reduced discharges that are 20-40% of the historical seasonal average (Tables 5-11 and 5-12). Similar to juvenile bull trout, habitat area for adult bull trout was greater at lower discharges (Figure 5-9).

Habitat area trends for adult and juvenile rainbow trout were similar to those exhibited for juvenile and adult bull trout (Tables 5-11 and 5-12). Less habitat area during the fall and winter months, more habitat area during the spring months, and very similar habitat area during the summer months compared to pre-dam conditions regardless of seasonal variability. Juvenile and adult rainbow trout curves were nearly identical due to very similar habitat use in the Kootenai River (Figure 5-10).

Table 5-11. Summary of IFIM model simulations (average daily area (m²)) by species, life stage, and season in the Kootenai River downstream of Libby Dam from water year 1911 to 2008. The pre-dam period was from water year 1911 to 1976 and is considered the baseline for comparison. Seasons were identified as the following Fall = October-November; Winter = December-March, Spring = April-June, and Summer = July-September.

Species	Life Stage Diel period	Strata (seasonal variability)	Fall	Winter	Spring	Summer
Bull trout	Adult	Post-Dam Low	1560628	1387141	1511124	1495882
		Post-Dam Medium	1235977	1330420	1406771	1487081
		Post-Dam High	1233388	1410603	1409243	1442002
		Pre-Dam	1639868	1507677	1030852	1437735
Bull trout	Juvenile Day	Post-Dam Low	1508662	1334953	1570235	1349825
		Post-Dam Medium	1073066	1261039	1379946	1395631
		Post-Dam High	1103232	1345964	1377930	1319808
		Pre-Dam	1640144	1592438	955642	1325891
Bull trout	Juvenile Night	Post-Dam Low	739696	713243	996468	598541
		Post-Dam Medium	493400	675939	769018	695880
		Post-Dam High	540120	721342	782812	622562
		Pre-Dam	861678	1059261	511962	613260
Rainbow trout	Adult	Post-Dam Low	1015632	877648	1073116	848883
		Post-Dam Medium	647898	818912	914329	897602
		Post-Dam High	674998	877147	896757	831845
		Pre-Dam	1121760	1089119	590070	842504
Rainbow trout	Juvenile	Post-Dam Low	1055590	923413	1182175	862521
		Post-Dam Medium	662322	864605	974474	934702
		Post-Dam High	700039	932931	960031	852967
		Pre-Dam	1184445	1208571	652150	863830
Avg. Discharge (cfs)		Post-Dam Low	8872	11158	5135	11168
		Post-Dam Medium	15455	12084	10153	10058
		Post-Dam High	15133	10308	10048	11720
		Pre-Dam	6344	4110	25623	12877

Table 5-12. Summary of IFIM model simulations (average daily percent of the habitat area compared to pre-dam conditions) by species, life stage, and season in the Kootenai River downstream of Libby Dam from water year 1911 to 2008. The pre-dam period was from water year 1911 to 1976 and is considered the baseline for comparison. Seasons were identified as the following Fall = October-November; Winter = December-March, Spring = April-June, and Summer = July-September.

Species	Life Stage Diel period	Strata (seasonal variability)	Fall	Winter	Spring	Summer
Bull trout	Adult	Post-Dam Low	95	92	147	104
		Post-Dam Medium	75	88	136	103
		Post-Dam High	75	94	137	100
		Pre-Dam	100	100	100	100
Bull trout	Juvenile Day	Post-Dam Low	92	84	164	102
		Post-Dam Medium	65	79	144	105
		Post-Dam High	67	85	144	100
		Pre-Dam	100	100	100	100
Bull trout	Juvenile Night	Post-Dam Low	86	67	195	98
		Post-Dam Medium	57	64	150	113
		Post-Dam High	63	68	153	102
		Pre-Dam	100	100	100	100
Rainbow trout	Adult	Post-Dam Low	91	81	182	101
		Post-Dam Medium	58	75	155	107
		Post-Dam High	60	81	152	99
		Pre-Dam	100	100	100	100
Rainbow trout	Juvenile	Post-Dam Low	89	76	181	100
		Post-Dam Medium	56	72	149	108
		Post-Dam High	59	77	147	99
		Pre-Dam	100	100	100	100
Avg. Discharge (cfs)		Post-Dam Low	140	271	20	87
		Post-Dam Medium	244	294	40	78
		Post-Dam High	239	251	39	91
		Pre-Dam	100	100	100	100

Figure 5-7. Juvenile bull trout day and night weighted usable area (m²) in the Kootenai River from water year 1977 to 2008.

Figure 5-8. Juvenile bull trout composite average day and night weighted usable area (m²) in the Kootenai River from water year 1977 to 2008.

Figure 5-9. Adult bull trout weighted usable area (m²) in the Kootenai River from water year 1977 to 2008.

Figure 5-10. Juvenile and adult rainbow trout weighted usable area (m²) in the Kootenai River from water year 1977 to 2008.

CHAPTER 6 – Cohort Survival Mainstem Kootenai and Flathead Rivers

Methods

Mainstem Kootenai River Electrofishing

Electrofishing was performed at night, using two boats with boom-mounted electrodes to sample the both banks of the river. Each boat included one driver and two netters, and was equipped with a 5,000-watt generator and either a Coffelt Mark 22 or Mark 15 VVP rectifying unit. Straight DC outputs were maintained at 3-5 amps and 200-300 volts. All fish sampled were netted and placed in holding tanks in each boat until fish could be transferred to larger holding cages in the river at the fish working station. Captured fish were anesthetized using an aqueous buffered solution of tricaine methanesulfonate (MS-222), identified, measured for total length (mm) and weight (g), and inspected for PIT tags, marks, and injuries. During population estimates, all fishes were marked with a fin clip that is easily recognizable during recapture sampling. Recapture sampling occurred about one week after the last fish were marked, depending on water conditions and weather. Population estimates were calculated using modified Petersen and partial log-likelihood estimators using Fisheries Analysis Plus software (Fisheries Analysis + 2004).

Fish population monitoring in the Kootenai River was accomplished using population estimates from three sections of the Kootenai River (Figure 6-1). River sections included: the Flower-Pipe section between Flower Creek and Pipe Creek (rm 204.0 to 201.0; fall estimate); the Reregulation Dam section between Johnson Draw (rm 214.8) and Lowery Gulch (i.e., Osprey Landing access; spring estimate) on the Kootenai River (rm 213.3); and from Libby Dam to the Fisher River confluence with the Kootenai River (rm 221.7 to 218.2; bull trout estimate in the spring).

Figure 6-1. Location of population estimate reaches in the Kootenai River below Libby Dam, Montana. Photo courtesy of the United States Geological Survey.

Statistical Analysis

Annual population estimates in the Kootenai River were analyzed using the Fisheries Analysis Plus software (2004; Montana Fish, Wildlife, and Parks, Fisheries Information Services, 1400 South 19th Avenue, Bozeman, MT 59718). Mark-recapture (single mark and single recapture run; larger rivers) methods were used to estimate the numbers of fishes within specific reaches of the Kootenai River (Dunnigan et al. 2003). The partial log-likelihood estimator was used in Fisheries Analysis + Software (Fisheries Analysis + 2004) for population estimation with three recaptured fish within each 25mm length group needed for a valid estimate within the length group. If the minimum of three recaptured fishes was not met, two or more length groups were lumped in order to meet the minimum recapture criteria.

Mortality rates will be calculated following methods described in (Van Den Avyle 1993). The following equation(s) will be used to estimate annual mortality depending of data availability:

$$N_t = N_0 e^{-Zt}$$

or

$$N_t = N_0 e^{-Ft} e^{-Mt}$$

N_t = number alive at time t

N_0 = number alive initially at time t_0

Z = instantaneous mortality rate

t = time elapsed since t_0

F = fishing mortality

M = natural mortality

N_t = number alive at time t

N_0 = number alive initially at time t_0

Z = instantaneous mortality rate

t = time elapsed since t_0

Results and Discussion

Rainbow and Cutthroat Trout

The number of *Oncorhynchus* spp. in the Flower-Pipe section of the Kootenai River has remained stable in the last few years. The highest population estimate (813 per 1000 feet) occurred in the fall of 2006 after the summer spill event (Figure 6-2 and Table 6-1). The increase in the estimate was largely due to increased estimate of rainbow and cutthroat trout from 150-199mm total length. The estimate decreased in the fall of 2007, to 547 fish per 1000 feet in 2007, identical to the average since the early 1990's. There appears to be little recruitment of fish in the Flower-Pipe section to large size groups (i.e., larger than 400mm).

The population estimate of rainbow and westslope cutthroat trout in the Rereg section of the Kootenai River remained stable from 2001-2006 (range 150-250 fish per thousand feet; Figure 6-3 and Table 6-2). In the spring of 2007, the estimate increased to 432 fish per 1000 feet but decreased in the spring of 2008 to 343 fish per 1000 feet, still above the average since 2001

(246 per 1000ft). This increase in 2007 was due to estimates of 100-199mm fishes, similar to the Flower-Pipe section of the Kootenai River. Similar to the Flower-Pipe section, there appears to be little recruitment of fishes to lengths longer than 400mm.

Bull Trout

The bull trout estimate below Libby Dam in the spring of 2004 and 2005 was near 950 fish in the 3 miles downstream of Libby Dam (Figure 6-4). The estimate dropped in 2006 to near 175 fish but increased in 2007 to 417 fish. The length range of captured bull trout has remained steady since 2004, ranging from approximately 350-900mm total length (Figure 6-5), but less fish were captured from 2005 to 2007 compared to 2004. More shorter bull trout (i.e., $\leq$ 350mm) were captured in 2007 during the population estimate than in previous years, and this trend continued in 2008, with 9 being captured in 2008. The number of fish handled during the population estimate has ranged from 53 fish in 2005 to 306 fish in 2004 (Table 6-3). The number of fish handled in 2 successive years has been less than 15 fish each year and the percentage of fish handled in successive years was near 5% from 2004 to 2007, but increased to 11% in 2008 (range 3.8-11.6; Table 6-4). The low percentage of bull trout recaptured from one year to the next may be a reflection of the origin of the fish. Although entrainment of bull trout through Libby Dam was shown by Skaar et al. (1996), the affect on the population number downstream of Libby Dam has been unknown. Genetic analysis of bull trout collected below Libby Dam in 2006 identified approximately 50% as having natal origin above Libby Dam (Ardren et al. 2007). A large percentage of these bull trout may migrate downstream over Kootenai Falls with the majority of these fish not returning to the upstream reaches of the Kootenai River above Kootenai Falls. This may reflect the low percentages of bull trout observed during successive population estimates. Dunnigan et al. (2003) observed that 38% of radio tagged bull trout near Libby Dam migrated downstream over Kootenai Falls. With the apparent high number of bull trout being entrained through Libby Dam, redd counts have not increased significantly in any of the tributaries downstream of Libby Dam except O'Brien Creek, which makes the total redds appear to be increasing (Figure 6-6). O'Brien Creek has increased from nearly 20 redds in the early 1990's to near 80 redds in 2007.

Flower-Pipe Oncorhynchus spp. Population Estimate

Figure 6-2. Population estimate of rainbow trout and cutthroat trout, as the number of fish per 1000 feet ($\pm$ SD), in the Flower-Pipe (1973-2007) section of the Kootenai River below Libby Dam, Montana.

Table 6-1. Population estimate ($\pm$ SD) of *Oncorhynchus* spp. by length group in the Flower-Pipe section of the Kootenai River from 1973-2007. An asterisk (*) indicates a lumped estimate.

Length Group (mm)	Year						
	1973	1974	1975	1977	1978	1979	1980
0-24	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
25-49	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
50-74	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
75-99	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
100-124	0 $\pm$ 0	5 $\pm$ 0.8	3 $\pm$ 0.4	1 $\pm$ 0.1	0 $\pm$ 0	0 $\pm$ 0	1 $\pm$ 0.1
125-149	0 $\pm$ 0	10 $\pm$ 1.7	1 $\pm$ 0.2	1 $\pm$ 0.1	4 $\pm$ 0.9	0 $\pm$ 0	2 $\pm$ 0.5
150-174	0 $\pm$ 0.1	12 $\pm$ 2.2	1 $\pm$ 0.2	4 $\pm$ 0.7	4 $\pm$ 0.9	0 $\pm$ 0.1	3 $\pm$ 0.6
175-199	1 $\pm$ 0.3	5 $\pm$ 0.8	2 $\pm$ 0.4	4 $\pm$ 0.6	4 $\pm$ 0.8	1 $\pm$ 0.2	3 $\pm$ 0.5
200-224	2 $\pm$ 0.5	5 $\pm$ 0.8	2 $\pm$ 0.3	3 $\pm$ 0.4	7 $\pm$ 1.3	5 $\pm$ 0.7	5 $\pm$ 0.8
225-249	3 $\pm$ 0.7	4 $\pm$ 0.6	5 $\pm$ 0.7	6 $\pm$ 0.8	14 $\pm$ 2.7	13 $\pm$ 1.8	13 $\pm$ 2.0
250-274	7 $\pm$ 1.2	12 $\pm$ 1.6	20 $\pm$ 2.2	10 $\pm$ 1.2	24 $\pm$ 4.2	22 $\pm$ 2.6	40 $\pm$ 5.3
275-299	13 $\pm$ 2.0	14 $\pm$ 1.6	24 $\pm$ 2.2	7 $\pm$ 0.7	34 $\pm$ 5.4	20 $\pm$ 2.0	31 $\pm$ 3.7
300-324	9 $\pm$ 1.5	10 $\pm$ 1.0	17 $\pm$ 1.5	8 $\pm$ 0.8	22 $\pm$ 3.3	9 $\pm$ 0.8	13 $\pm$ 1.5
325-349	* 13 $\pm$ 5.3	7 $\pm$ 0.8	5 $\pm$ 0.5	8 $\pm$ 0.8	9 $\pm$ 1.4	3 $\pm$ 0.3	4 $\pm$ 0.6
350-374		4 $\pm$ 0.5	3 $\pm$ 0.4	2 $\pm$ 0.3	2 $\pm$ 0.4	5 $\pm$ 0.6	5 $\pm$ 0.9
375-399		3 $\pm$ 0.5	2 $\pm$ 0.3	3 $\pm$ 0.4	0 $\pm$ 0.1	4 $\pm$ 0.7	* 10 $\pm$ 3.6
400-424		1 $\pm$ 0.2	* 6 $\pm$ 2	2 $\pm$ 0.4	2 $\pm$ 0.5	2 $\pm$ 0.5	
425-449		* 3 $\pm$ 1.0		2 $\pm$ 0.5	* 5 $\pm$ 2.1	* 3 $\pm$ 0.9	
450+				* 10 $\pm$ 3.5			
Total	49 $\pm$ 6	95 $\pm$ 4.2	92 $\pm$ 4.2	70 $\pm$ 4.2	130 $\pm$ 4.2	88 $\pm$ 4.2	129 $\pm$ 8

Table 6-1 continued. Population estimate ($\pm$ SD) of *Oncorhynchus* spp. by length group in the Flower-Pipe section of the Kootenai River from 1973-2007. An asterisk (*) indicates a lumped estimate.

Length Group (mm)	Year						
	1981	1985	1986	1987	1988	1989	1990
0-24	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
25-49	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
50-74	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
75-99	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
100-124	1 $\pm$ 0.2	2 $\pm$ 0.3	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
125-149	1 $\pm$ 0.2	2 $\pm$ 0.4	0 $\pm$ 0	1 $\pm$ 0.4	1 $\pm$ 0.3	4 $\pm$ 1.3	0 $\pm$ 0
150-174	3 $\pm$ 0.5	59 $\pm$ 9.1	34 $\pm$ 7	4 $\pm$ 1.3	9 $\pm$ 1.8	54 $\pm$ 14.9	79 $\pm$ 17.3
175-199	11 $\pm$ 1.8	122 $\pm$ 16.8	69 $\pm$ 12.9	19 $\pm$ 5.1	53 $\pm$ 9.8	111 $\pm$ 27.3	134 $\pm$ 25.6
200-224	37 $\pm$ 5.1	79 $\pm$ 9.6	70 $\pm$ 11	38 $\pm$ 9.3	57 $\pm$ 9.2	140 $\pm$ 30.3	73 $\pm$ 11.4
225-249	62 $\pm$ 7.2	36 $\pm$ 4.2	60 $\pm$ 8.1	35 $\pm$ 7.1	48 $\pm$ 6.7	43 $\pm$ 9	20 $\pm$ 2.8
250-274	54 $\pm$ 5.5	29 $\pm$ 3.9	29 $\pm$ 3.9	18 $\pm$ 3.3	14 $\pm$ 1.8	18 $\pm$ 4.6	15 $\pm$ 2.2
275-299	18 $\pm$ 1.9	39 $\pm$ 7.2	24 $\pm$ 4.2	15 $\pm$ 2.9	12 $\pm$ 1.6	* 17 $\pm$ 9.2	15 $\pm$ 3.1
300-324	12 $\pm$ 1.6	*46 $\pm$ 14.3	10 $\pm$ 2.5	16 $\pm$ 3.9	11 $\pm$ 1.9		* 7 $\pm$ 2.0
325-349	6 $\pm$ 1.2		* 10 $\pm$ 3.7	* 15 $\pm$ 6.2	* 8 $\pm$ 2.4		
350-374	* 9 $\pm$ 3.1						
375-399							
400-424							
425-449							
450-474							
Total	214 $\pm$ 11.4	415 $\pm$ 27.3	306 $\pm$ 21.4	161 $\pm$ 15.4	213 $\pm$ 15.6	387 $\pm$ 45.5	343 $\pm$ 33.3

Table 6-1 continued. Population estimate ($\pm$ SD) of *Oncorhynchus* spp. by length group in the Flower-Pipe section of the Kootenai River from 1973-2007. An asterisk (*) indicates a lumped estimate.

Length Group (mm)	Year						
	1991	1993	1994	1995	1997	1999	2001
0-24	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
25-49	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
50-74	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
75-99	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	3 $\pm$ 0.3	0 $\pm$ 0	0 $\pm$ 0
100-124	4 $\pm$ 1	6 $\pm$ 0.6	0 $\pm$ 0	3 $\pm$ 0.3	1 $\pm$ 0.1	30 $\pm$ 2.3	27 $\pm$ 3.5
125-149	26 $\pm$ 7	86 $\pm$ 8.4	46 $\pm$ 6.9	10 $\pm$ 0.9	19 $\pm$ 1.6	92 $\pm$ 6.9	87 $\pm$ 11.1
150-174	91 $\pm$ 22.5	169 $\pm$ 15.2	94 $\pm$ 13.8	30 $\pm$ 2.6	110 $\pm$ 8.3	108 $\pm$ 7.4	99 $\pm$ 12.3
175-199	142 $\pm$ 30.4	164 $\pm$ 12.7	80 $\pm$ 10.8	110 $\pm$ 8.6	242 $\pm$ 15.7	55 $\pm$ 3.3	69 $\pm$ 7.9
200-224	131 $\pm$ 23.7	87 $\pm$ 5.7	61 $\pm$ 7.4	197 $\pm$ 13.4	207 $\pm$ 11.6	35 $\pm$ 1.9	58 $\pm$ 6
225-249	70 $\pm$ 12.6	41 $\pm$ 2.5	25 $\pm$ 2.9	152 $\pm$ 9.1	80 $\pm$ 4.5	29 $\pm$ 1.5	33 $\pm$ 3.2
250-274	21 $\pm$ 5.1	18 $\pm$ 1.3	12 $\pm$ 1.4	64 $\pm$ 3.7	30 $\pm$ 2.1	37 $\pm$ 2.3	19 $\pm$ 1.9
275-299	23 $\pm$ 8.2	10 $\pm$ 1.1	14 $\pm$ 2.0	17 $\pm$ 1.1	20 $\pm$ 2.0	30 $\pm$ 2.5	13 $\pm$ 1.6
300-324	* 38 $\pm$ 22.4	4 $\pm$ 0.7	13 $\pm$ 2.5	15 $\pm$ 1.4	18 $\pm$ 2.6	19 $\pm$ 2.2	9 $\pm$ 1.4
325-349		5 $\pm$ 1	* 12 $\pm$ 3.6	13 $\pm$ 1.5	* 20 $\pm$ 4.8	7 $\pm$ 1.2	* 15 $\pm$ 4.1
350-374		4 $\pm$ 1		6 $\pm$ 0.9		* 10 $\pm$ 2.7	
375-399		2 $\pm$ 0.7		3 $\pm$ 0.5			
400-424		* 2 $\pm$ 1		* 0 $\pm$ 0.2			
425-449							
450-474							
Total	547 $\pm$ 52.8	598 $\pm$ 22.6	356 $\pm$ 21.1	620 $\pm$ 19.1	751 $\pm$ 22.6	450 $\pm$ 12.3	429 $\pm$ 20.5

Table 6-1 continued. Population estimate ($\pm$ SD) of *Oncorhynchus* spp. by length group in the Flower-Pipe section of the Kootenai River from 1973-2007. An asterisk (*) indicates a lumped estimate.

Length Group (mm)	Year					
	2002	2003	2004	2005	2006	2007
0-24	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
25-49	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
50-74	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
75-99	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0
100-124	0 $\pm$ 0	2 $\pm$ 0.3	2 $\pm$ 0.3	1 $\pm$ 0.2	5 $\pm$ 0.5	3 $\pm$ 0.5
125-149	33 $\pm$ 4.1	14 $\pm$ 2.8	2 $\pm$ 0.3	6 $\pm$ 1	55 $\pm$ 5.6	12 $\pm$ 2.4
150-174	252 $\pm$ 31.2	36 $\pm$ 7	23 $\pm$ 3.3	47 $\pm$ 7.7	162 $\pm$ 15.4	50 $\pm$ 9.2
175-199	264 $\pm$ 30.8	126 $\pm$ 22	34 $\pm$ 4.3	135 $\pm$ 20.1	269 $\pm$ 22.6	119 $\pm$ 19
200-224	143 $\pm$ 15.5	108 $\pm$ 16.4	69 $\pm$ 7.3	137 $\pm$ 17.9	171 $\pm$ 12.7	155 $\pm$ 20
225-249	46 $\pm$ 4.8	58 $\pm$ 7.5	86 $\pm$ 7.5	65 $\pm$ 7.5	54 $\pm$ 4	103 $\pm$ 11.5
250-274	18 $\pm$ 2	46 $\pm$ 5.9	53 $\pm$ 4.7	31 $\pm$ 3.4	32 $\pm$ 2.9	49 $\pm$ 6.7
275-299	9 $\pm$ 1.2	26 $\pm$ 4.3	20 $\pm$ 2.4	26 $\pm$ 3.4	19 $\pm$ 2.4	* 57 $\pm$ 15.4
300-324	4 $\pm$ 0.7	11 $\pm$ 2.5	12 $\pm$ 2.2	19 $\pm$ 3.4	16 $\pm$ 2.9	
325-349	2 $\pm$ 0.3	* 8 $\pm$ 3.2	* 16 $\pm$ 5.2	* 14 $\pm$ 3.8	* 29 $\pm$ 11.7	
350-374	* 5 $\pm$ 1.3					
375-399						
400-424						
425-449						
450-474						
Total	774 $\pm$ 47	434 $\pm$ 30.5	317 $\pm$ 14.1	481 $\pm$ 29.8	813 $\pm$ 33.4	547 $\pm$ 35.6

Figure 6-3. Population estimate ($\pm$ SD) of *Oncorhynchus* spp. in the Rereg section of the Kootenai River below Libby Dam, Montana from 2001-2008.

Table 6-2. Population estimate ($\pm$ SD) by length group of fish in the Rereg section of the Kootenai River from 2001-2007. No estimate was completed in 2002 due to high flows after the mark run. An asterisk (*) indicates a lumped estimate for that length group and all longer length groups. No estimate was completed in 2002 because of high flows after the mark run.

Length Group (mm)	Year							
	2001	2002	2003	2004	2005	2006	2007	2008
0-24	0 $\pm$ 0		0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.0 $\pm$ 0.0
25-49	0 $\pm$ 0		0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.0 $\pm$ 0.0
50-74	0 $\pm$ 0		0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.0 $\pm$ 0.0
75-99	0 $\pm$ 0		0 $\pm$ 0	1 $\pm$ 0.2	0 $\pm$ 0	0 $\pm$ 0	0 $\pm$ 0	0.0 $\pm$ 0.0
100-124	4 $\pm$ 1.1		8 $\pm$ 1.3	19 $\pm$ 3.1	0 $\pm$ 0	15 $\pm$ 3.4	26 $\pm$ 3.3	4.0 $\pm$ 1.1
125-149	36 $\pm$ 11.2		1 $\pm$ 0.2	18 $\pm$ 2.9	3 $\pm$ 0.5	16 $\pm$ 3.8	24 $\pm$ 3.1	5.0 $\pm$ 1.2
150-174	38 $\pm$ 12.1		35 $\pm$ 5.5	8 $\pm$ 1.3	4 $\pm$ 0.8	16 $\pm$ 3.7	79 $\pm$ 10	37.0 $\pm$ 8.7
175-199	49 $\pm$ 15.8		40 $\pm$ 6.1	17 $\pm$ 2.2	14 $\pm$ 2.4	37 $\pm$ 8.0	99 $\pm$ 11.4	46.0 $\pm$ 9.8
200-224	23 $\pm$ 7.2		50 $\pm$ 6.8	25 $\pm$ 2.8	20 $\pm$ 3.0	55 $\pm$ 10.5	80 $\pm$ 8.2	59.0 $\pm$ 10.8
225-249	20 $\pm$ 6.1		22 $\pm$ 2.8	16 $\pm$ 1.7	27 $\pm$ 3.5	37 $\pm$ 6	36 $\pm$ 3.3	56.0 $\pm$ 8.5
250-274	2 $\pm$ 0.6		8 $\pm$ 1	10 $\pm$ 1.2	25 $\pm$ 3.1	25 $\pm$ 3.5	26 $\pm$ 2.4	41.0 $\pm$ 5.4
275-299	4 $\pm$ 1.0		4 $\pm$ 0.5	7 $\pm$ 1.1	19 $\pm$ 2.9	18 $\pm$ 2.4	19 $\pm$ 2.1	44.0 $\pm$ 6.5
300-324	10 $\pm$ 2.6		2 $\pm$ 0.4	10 $\pm$ 2.1	17 $\pm$ 3.7	19 $\pm$ 3.1	17 $\pm$ 2.4	27.0 $\pm$ 5.6
325-349	10 $\pm$ 2.5		2 $\pm$ 0.3	* 14 $\pm$ 5.1	* 31 $\pm$ 13.5	* 16 $\pm$ 4.1	16 $\pm$ 3	* 23.0 $\pm$ 8.4
350-374	5 $\pm$ 1.4		* 7 $\pm$ 2.7				* 10 $\pm$ 3.2	
375-399	3 $\pm$ 1.0							
400-424	* 4 $\pm$ 1.8							
Total	208 $\pm$ 25.1		179 $\pm$ 11.5	145 $\pm$ 8.3	160 $\pm$ 15.5	254 $\pm$ 17.2	432 $\pm$ 19.1	343 $\pm$ 23.2

Figure 6-4. Bull trout population estimate ($\pm 95\%$ CI) from Libby Dam to the Fisher River confluence, below Libby Dam, Montana from 2004-2008. Data courtesy of Jim Dunnigan, Montana Fish, Wildlife and Parks.

Figure 6-5. Length frequency of bull trout below Libby Dam captured during annual population estimates collected from 2004 (upper panel, $N = 344$) and 2005 (lower panel, $N = 56$), 2006 (panel C, $N = 71$), and 2007 (panel D, $N = 91$).

Figure 6-5 continued. Length frequency of bull trout below Libby Dam captured during annual population estimates collected from 2006 (upper panel, $N = 71$) and 2007 (lower panel, $N = 91$).

Figure 6-5 continued. Length frequency of bull trout below Libby Dam captured during the annual population estimate collected in 2008 ($N = 117$).

Table 6-3. Summary of recaptured bull trout during the spring population estimate below Libby Dam on the Kootenai River, Montana. Fish handled in multiple years are counted under more than one category.

Year	Number Bull Trout Handled (including recaptures)
2004	306
2005	53
2006	71
2007	92
2008	117
Years Handled	Number of Fish
2004 and 2005	14
2004 and 2006	10
2004 and 2007	5
2004 and 2008	4
2005 and 2006	2
2005 and 2007	2
2005 and 2008	0
2006 and 2007	5
2006 and 2008	2
2007 and 2008	10
2004, 2005 and 2006	1
2004, 2005 and 2007	1
2004, 2005 and 2008	0
2004, 2006, and 2007	2
2004, 2006, and 2008	1
2004, 2007, and 2008	1
2005, 2006 and 2007	0
2005, 2006, and 2008	0
2005, 2007 and 2008	0
2006, 2007 and 2008	1
2004, 2005, 2006 and 2007	0
2004, 2005, 2006, and 2008	0
2004, 2005, 2007, and 2008	0
2004, 2006, 2007, and 2008	1
2005, 2006, 2007, and 2008	0
2004, 2005, 2006, 2007, and 2008	0

Table 6-4. Percentage of bull trout recaptured from one year to the next year during the spring bull trout population estimate below Libby Dam on the Kootenai River, Montana.

Years	Percentage	Number
2004 to 2005	5.1	14
2005 to 2006	3.8	2
2006 to 2007	7.6	5
2007 to 2008	11.63	10

Figure 6-6. Redd counts in tributaries downstream of Libby Dam, Montana from 1995-2008.

CHAPTER 7 – Radio Telemetry

Methods

Radio Telemetry

Fish sampling procedures, surgical procedures, radio tag implantation, and acquisition of fish locations followed methods described in Dunnigan et al. 2003, Muhlfeld et al. 2003, Muhlfeld and Marotz 2005, Summerfelt and Smith 1990, Winter 1983, and Winter 2000.

Rainbow and bull trout were captured for radio telemetry using nighttime electrofishing techniques mentioned previously or hook and line sampling. Fishes were anesthetized using an aqueous non-buffered solution of MS-222. Once the fish lost equilibrium (Figure 7-1), they were examined for marks (fin clips), other tags (e.g., radio, PIT, floy), and injuries (e.g., spinal damage, predation injuries and hook scars), and then measured for total length (mm) and weight (g). Only fish that appeared healthy were implanted with a radio tag. Fish were placed on their back in a trough with enough solution of MS-222 to cover their gills but not enter the body cavity. Surgeries were performed with cleaned and disinfected scalpels, sterile scalpel blades, and forceps. A ½ to 1.5-inch incision was made anterior to the pelvic girdle and lateral to the midline. A non-coring, 14-gauge x 4-inch hypodermic needle was inserted into the body cavity posterior to the pelvic girdle. The radio tag antenna was fed through the needle, the needle was then removed, and then the radio tag was inserted into the body cavity. Incisions were closed with four or five interrupted sutures (4-0 non-absorbable silk) disinfected with iodine (Figure 7-2). Nitrile or latex gloves were worn by the staff performing the surgeries. Fish were allowed to recover for 15-30 minutes in fresh water following surgery and watched for any symptoms indicating they should not be released (e.g., inability to recover equilibrium, continued hemorrhaging).

Figure 7-1. Photograph of a bull trout anesthetized with MS-222 that had lost equilibrium and was not responsive to external stimuli prior to surgical implantation of a radio transmitter.

Figure 7-2. Photograph of a rainbow trout following surgical implantation of a radio tag into the body cavity and application of an iodine disinfectant to prevent possible infections.

Radio tags (Table 7-1) were purchased from Lotek Wireless Incorporated of New Market, Ontario. A Lotek Model SRX-400 telemetry receiver was used for mobile monitoring from boats, vehicles, and fixed-wing aircraft using a single or double tuned loop antenna, as appropriate. Fish movement and possible visual observations were indicative of post-tagging survival and tag retention. Fishes were tracked weekly or biweekly depending discharge and other work duties. Fish locations were recorded with a handheld GPS unit, the tag number, signal strength, location notes, time, and depth / mortality sensors if appropriate depending on the type of radio tag. Fish movements ($\text{m}\cdot\text{day}^{-1}$) will be calculated and compared between stable increasing, and decreasing flow periods for rainbow and bull trout. Discharge between locations will be used to determine discharge regime.

Table 7-1. Table of radio tags surgically implanted in fishes in the Kootenai River in 2007 and 2008. Radio tags were manufactured by Lotek Wireless, Inc., Newmarket, Ontario, Canada.

Year	Tag Model	# Tags	Tag Weight in Air (grams)	Frequencies Used (kHz)	Burst Rate (Seconds)	Individual ID Codes	Life (days)	Notes
2007	NTC-4-2L	6	2.1	148.680 148.800	7.0, 7.1, 7.2, 7.3, 7.4, and 7.5	23 to 28	210	
2007	MCFT-3FM	6	10	148.680 148.800	5 and 5.5	11 to 16	423	
2007	MCFT-3L	6	26	148.680 148.800	5 and 5.5	17 to 22	1095	
2008	NTC-4-2L	9	2.1	148.320 148.460 148.780	5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7, and 5.8	23 to 31	201	12 hours on 12 hours off
2008	NTC-6-1	9	2.8	148.320 148.460 148.780	7.0, 7.1, 7.2, 7.3, 7.4, 7.5, 7.6, 7.7, and 7.8	32 to 40	219	
2008	SR-PM11-25	3	11	148.560 148.890	7.0	4, 7 and 8	613	Depth / Mortality
2008	SR-PM-16-25	5	18	148.560 148.890	5.5	9 to 13	1095	Depth / Mortality

Radio tags will also be placed in 2 sections of the Kootenai River in which Instream Flow Incremental Methodology was completed to validate previous habitat quality models (Hoffman et. al 2002, Miller and Geise 2004; Figures 7-3 and 7-4). The two sections are located near Libby, Montana. Run 45 is located near river mile 204.0, 1.8 to 3.6km downstream of Highway 37 in Libby and Pools 24, 27, and 28 are located near river mile 209.9, 6.2 to 9.8km upstream of the Highway 37 Bridge. The proximity of fish locations to higher quality habitat based on previous work will be visually assessed (i.e., fish are in or near higher quality habitat or in lower quality habitat) at the incremental discharges (Table 7-2).

Figure 7-3. Location of IFIM Run 45 in relation to Libby, Montana (indicated by the red dot). The IFIM section is indicated by the pink to red shaded area northwest of Libby, Montana.

Figure 7-4. Location of IFIM Pools 24, 27, and 28 in relation to Libby, Montana (indicated by the red dot). The IFIM sections are indicated by the pink to red shaded area northeast of Libby, Montana.

Table 7-2. Incremental discharges (cfs) of the Kootenai River that Instream Flow Incremental Methodology was completed in four habitat units that will be verified using radio telemetry.

Habitat Unit Discharge (cfs)			
Run 45	Pool 24	Pool 27	Pool 28
2000	2000	2000	2000
4702	5200	4030	4480
10000	10000	9000	9000
13435	15291	12567	12500
18000	18000	16000	16000
20601	23770	23751	21460
25000	30000	25000	25000
30000	35000	30000	30000
35000	40000	35000	35000
40000		40000	40000

Statistical Analysis

Radio telemetry data analysis was performed using ArcGIS 9 software, ArcMap 9.2 and Hawth's Tools extension. Fish movements ($\text{m}\cdot\text{day}^{-1}$) were compared between flow regimes (i.e., increased flow between locations, decreased flows, or stable flows). Movement data will be stratified by species and tag size if differences in movement between sizes of fish are present. Depth data (m) will be compared between daytime (sunrise to sunset) and nighttime (sunset to sunrise) periods to assess if there are differences in habitat use and movement during different periods of the day.

Validation of IFIM work will be completed by comparing fish locations to the preferred habitats (Hoffman et. al 2002; Miller and Geise 2004) at incremental discharges within each habitat section. Point locations of fish will be visually compared to the proximity of habitat quality (low to high) at the incremental discharges of the Kootenai River. These fish will also be used in movement analysis during increasing, decreasing, and stable flows in the Kootenai River to assess if there are any differences between sections of the river.

Stepwise logistic regression analysis (SAS 9.1) was used to investigate variables and combinations of variables that may affect each fishes movement downstream of Libby Dam. A $p\text{-value} \leq 0.05$ will be used to include variables in the model. Variables used included season (Fall, Winter, Spring, Summer), flow regime (stable, increase, decrease), water temperature, change in discharge, and combinations of these variables.

Results and Discussion

Radio Tagging

Thirty-seven fish were implanted with radio tags from April 26, 2007 to June 30, 2007 including 18 bull trout and 19 rainbow trout (Table 7-3). Five radio tags were redeployed after fish were harvested by anglers ($N=2$), shed tag located ($N=1$), or fish found dead ($N=2$). Another tag was found on the stream bottom with no antenna attached and could not be redeployed. Radio tagged bull trout radio tagged ranged from 267-801mm and rainbow trout from 260-433mm (Table 7-4). Only one fish had a radio tag percentage of body weight greater than 2 percent (Table 7-4; following recommendations of Winter 2000). Three tags were located in Idaho, after initially being released in Montana. Two of these fish were originally tagged near Libby Dam, and another was tagged near Troy, Montana.

Table 7-3. Summary of fish lengths and weight surgically implanted with radio tags in the Kootenai River in 2007 and 2008. Species abbreviations used: RBT = rainbow trout and DV = bull trout.

TAG ID#	Freq. (kHz)	Date Tagged (mm/dd/yyyy)	Species	Length (mm)	Weight (g)	% Body Weight	Comments
7	148.890	4/17/2008	DV	440	728	1.51	Sensor tag
8	148.890	4/16/2008	DV	490	1333	0.83	Sensor tag
9	148.560	4/16/2008	DV	633	2652	0.68	Sensor tag
10	148.560	4/16/2008	DV	571	2516	0.72	Sensor, mortality, Copeland, Idaho
11	148.890	4/17/2008	DV	613	2314	0.78	Sensor tag
13	148.890	4/17/2008	DV	629	2416	0.75	Sensor tag
11	148.680	5/8/2007	RBT	415	818	1.22	
12	148.680	5/8/2007	RBT	433	711	1.41	
13	148.680	10/24/2007	RBT	408	490	2.04	Shed, recovered 3/3/2008
13	148.680	4/16/2008	DV	497	1754	0.57	Redeployed tag
14	148.800	5/8/2007	DV	582	2301	0.43	
15	148.800	5/8/2007	DV	638	2532	0.39	Not located after 8/2/2007
16	148.800	6/21/2007	RBT	373	502	1.99	
17	148.680	5/8/2007	DV	644	2646	0.98	Likely mortality, near Ball Creek, Idaho
18	148.680	2/4/2008	DV	655			Mortality Dunn Creek, redeployed
18	148.680	2/25/2008	DV	617			Redeployed tag
19	148.680	5/8/2007	DV	732	3663	0.71	Mortality???, Lake Ck eddy
20	148.800	1/8/2008	DV	801			
21	148.800	10/24/2007	DV	760	3536	0.74	Angler mortality, redeployed
21	148.800	1/8/2008	DV	790			Redeployed tag, mortality, Copeland, ID
22	148.800	2/4/2008	DV	652			Dam to Alexander Creek
23	148.680	6/15/2007	RBT	292	216	0.97	Never located after release
24	148.680	6/15/2007	RBT	331	316	0.66	Tag expired November 2007
25	148.680	6/15/2007	DV	267	154	1.36	Not located after 8/15/2007
26	148.800	4/26/2007	RBT	320	271	0.77	Angler harvest 6/17/2007
26	148.800	6/21/2007	RBT	333	289	0.73	Redeployed tag
27	148.800	4/26/2007	RBT	264	167	1.26	Angler harvest 7/25/2007
27	148.800	8/2/2007	RBT	326	289	0.73	Redeployed tag
28	148.800	6/15/2007	RBT	318	226	0.93	Tag recovered, no antenna
24	148.320	6/25/2008	RBT	260	164	1.28	IFIM
25	148.320	6/24/2008	RBT	302	251	0.84	IFIM
27	148.460	6/25/2008	RBT	265	175	1.20	IFIM
28	148.460	6/24/2008	RBT	313	265	0.79	IFIM
33	148.320	6/25/2008	RBT	280	185	1.51	IFIM
34	148.320	6/24/2008	RBT	313	232	1.21	IFIM
36	148.460	6/25/2008	RBT	331	351	0.80	IFIM
37	148.460	6/24/2008	RBT	361	378	0.74	IFIM

Table 7-4. Statistics of radio tagged fishes in the Kootenai River active from July 2007 to June 2008. Percent body weight (BW) was calculated as: (Tag weight in air * 100) / (Fish weight in air). Species abbreviations used: RBT = rainbow trout and DV = bull trout.

Fiscal Year Tagged	Species	Tag Size	Length Range (mm)	AVG % BW	Range % BW	Number of Tags
2006-2007	RBT	Small	264-333	0.88	0.66-1.26	5
		Medium	373-433	1.54	1.22-1.99	3
		Large	NA	NA	NA	0
2007-2008	RBT	Small	260-361	1.00	0.73-1.51	10
		Medium	408	2.04	NA	1
		Large	NA	NA	NA	0
2006-2007	DV	Small	267	1.36	NA	1
		Medium	582-638	0.41	0.39-0.43	2
		Large	644-732	0.85	0.71-0.98	2
2007-2008	DV	Small	NA	NA	NA	0
		Medium	440-497	0.97	0.57-1.51	3
		Large	571-801	0.73	0.68-0.78	10

Movement

Bull trout

There were no differences in movement ($\text{m}\cdot\text{day}^{-1}$) of bull trout during stable, increasing, and decreasing discharges in the Kootenai River as tag size increased (Figure 7-5). Movement per day was higher during increasing (18g tags) and decreasing discharges (26g tag), but movements were not different from other tag sizes and flow regimes. Movement per day of bull trout during stable periods of discharge was less variable than during increasing and decreasing periods of discharge. Additionally, there were no significant differences in movement as bull trout size increased (i.e., surrogate tag size), a result of several large movements by larger fish within the area between Libby Dam and Dunn Creek

Seasonal movement of bull trout indicated no significant differences in movement as fish size increased, although larger bull trout typically had higher movements per day than smaller fish (Figure 7-6). The high variability of the larger fish movements resulted in no statistical differences in seasonal movements. Movement per day during the spring and summer were higher than fall and winter movements, and were not associated with spawning movements. Similar to results of Muhlfeld et al. (2005), adult bull in our study appeared to have two movement patterns, fish that moved downstream and fish that remained near the tagging and release location.

Rainbow trout

Movement per day of rainbow trout during stable, increasing, and decreasing discharges resulted in few significant differences. The only difference between tag sizes was 2.8 and 10g tags during decreasing discharges (Figure 7-7). Seasonal movements per day of rainbow trout indicated that rainbow trout with 2.1g tags moved more during the spring than during the fall and summer periods (Figure 7-8), possibly due to spawning activity, but this trend was not seen for larger rainbow trout. Larger rainbow trout (10g tags) moved more during the fall than smaller rainbow trout (2.1g tags).

Figure 7-5. Movement ($\text{m} \cdot \text{day}^{-1}$) of bull trout during periods of stable ($\pm 500\text{cfs}$), increasing ($> +500\text{cfs}$), and decreasing ($< -500\text{cfs}$) discharge in the Kootenai River, downstream of Libby Dam, Montana by tag size.

Figure 7-6. Seasonal movement ($\text{m} \cdot \text{day}^{-1}$) of bull trout in the Kootenai River, downstream of Libby Dam by tag size.

Figure 7-7. Movement ($\text{m}\cdot\text{day}^{-1}$) of rainbow trout during periods of stable ($\pm 500\text{cfs}$), increasing ($>+500\text{cfs}$), and decreasing ($<-500\text{cfs}$) discharge in the Kootenai River, downstream of Libby Dam, Montana by tag size.

Figure 7-8. Seasonal movement ($\text{m}\cdot\text{day}^{-1}$) of rainbow trout in the Kootenai River, downstream of Libby Dam by tag size.

Regression Analysis and Individual Fish Movement Descriptions

Regression analysis did lend insight into variables explaining fish movement. Water temperature was the most frequent significant variable in explaining movement followed by change in flow * season and change in flow * flow regime (Table 7-5). Additional analysis after more locations are gathered may provide additional insight but to date results are limited.

Table 7-5. Stepwise logistic regression analysis for rainbow and bull trout movement downstream of Libby Dam, Montana from April 2007 to June 2008. Variables with an asterisk were significant ($p \leq 0.05$) in explaining fish movement. Several fish were excluded from analysis due to small sample sizes.

Tag Number	Species	Length (mm)	Dates Deployed	Variable							
				DeltaQ	Water Temperature	Flow Regime	Season	DeltaQ * Flow Regime	DeltaQ * Season	Flow Regime * Season	DeltaQ * Flow Regime * Season
7	DV	440	4/17/2008								
8	DV	490	4/16/2008		*						
9	DV	633	4/16/2008								
112	DV	613	4/17/2008		*						
133	DV	629	4/17/2008								
11	RBT	415	5/8/2007								
12	RBT	433	5/8/2007	*	*	*	*	*	*	*	
131	RBT	408	10/24/2007								
14	DV	582	5/8/2007						*	*	
15	DV	638	5/8/2007								
16	RBT	373	6/21/2007		*			*			
182	DV	617	2/25/2008								
19	DV	732	5/8/2007								
211	DV	760	10/24/2007								
212	DV	790	1/8/2008						*		*
22	DV	652	2/4/2008		*						
241	RBT	331	6/15/2007					*			
251	DV	267	6/15/2007								
261	RBT	320	4/26/2007								
262	RBT	333	6/21/2007		*						
271	RBT	264	4/26/2007								
272	RBT	326	8/2/2007								
281	RBT	318	6/15/2007								

Radio Tag 7 sensor

Radio tag 7 was deployed April 17, 2007 in a bull trout (L 440mm, W 728g) at Dunn Creek, approximately 3.5km below Libby Dam. After being released, the fish crossed the Kootenai River several times between the east and west banks between Dunn Creek and Alexander Creek island until late May. At the end of May or early June, the fish moved approximately 500m downstream to the head end of the Blackwell side channel where it remained until the end of June. Between June 26 and June 30, the fish moved back upstream 1km to the east bank above Dunn Creek. Water depths used by fish #7 ranged from 3.3 to 8.7m, with an overall mean depth of 5.1m, a daytime mean of 5.1m and a nighttime mean of 4.8m.

Radio Tag 8 sensor

Tag 8 was put in a bull trout (L 490mm, W 1333g) on April 16, 2008 and released 1.2km below Libby Dam. The fish moved towards the right bank for 2 weeks post release and then moved upstream towards Libby Dam. The fish remained above the David Thompson bridge from May to near the end of June. The fish moved 0.5km downstream of the David Thompson bridge between June 24 and June 26 and then returned above the bridge between June 27 and June 30. Fish #8 used water depths ranging from 2.1 to 7.8m, with an overall mean water depth of 5.3m, a daytime mean of 5.0m, and a nighttime mean of 6.5m.

Radio Tag 9 sensor

Radio Tag 9 was deployed on April 16, 2008 in a bull trout (L 633mm, W 2652g) and was released 1.2km below Libby Dam. The fish remained near the release site from April 21st to May 8th. Between May 6th and May 8th, the fish moved 0.6km downstream and has not been located since that time, even from several aerial flights covering the entire Kootenai River from Libby Dam to Kootenay Lake, in British Columbia, Canada. Water depths used ranged from 2.6 to 3.9m, with an overall mean 3.0m. The location and fate of the tag remains unknown to date.

Radio Tag 10 sensor

Radio tag 10 was released 1.2km below Libby Dam on April 16, 2008 in a bull trout (L 571mm, W 2516g). After being released, the fish was found but we could not code the tag out. Between April 21 and April 24, 2008 the fish moved up to Libby Dam, on the west side of the stilling basin and then moved 2km downstream by April 27th. The fish was not located until May 28th from a plane 4km upstream of Copeland, Idaho. A mortality signal was given by the tag. We attempted to find the dead fish / shed tag on June 23 but the tag was not found. Water depths averaged 3.1m (range 2.1-3.9m) with the identical daytime average. No nighttime water depths were taken prior to the tag going missing and then being located near Copeland, ID.

Radio Tag 11 sensor

Radio tag 11 sensor was released on April 17, 2008. The tag was placed in a bull trout (L 613mm, W 2314g) and released 3.5km below Libby Dam at the Dunn Creek boat ramp. The fish

remained near the east bank, 300m downstream of the Dunn Creek boat ramp until May 19, 2008. The fish moved upstream 100 yards and then back downstream to the previous location. The tag gave a mortality signal on June 4, 2008 and slowly moved downstream 350m to some slower, deeper water. We continued to get a mortality signal June 7, but on June 9, the mortality signal ceased. The fish moved upstream between June 11 and June 17 indicating the fish was not dead. The fish continued to move in the same general vicinity through the end of June. Water depths occupied by the fish averaged 4.3m (range 3-5.4m), with average daytime and nighttime depths of 4.1 and 4.8m.

Radio Tag 13 sensor

Radio Tag 13 was deployed on April 17, 2008 in a bull trout (L 629mm, W 2416g) and was released at the Dunn Creek boat ramp 3.5km below Libby Dam. The fish initially moved upstream slightly (200m) and across the river and in early May, moved downstream and back across the river near the Dunn Creek ramp. In early June, the fish moved to the lower end of the Alexander Creek side channel, where it remained until the end of June, with the exception of one location, 500m upstream above the Alexander Creek island. The fish returned to the lower end of the side channel after that movement. Between June 27 and June 30, the fish moved 1.7km upstream near the dredge cut access area 1.4km below Libby Dam. Average water depth used by this fish was 3.4m overall (range 2.4-4.5m), with a daytime average of 3.3m and a nighttime average of 3.7m.

Radio Tag 11

Tag 11 was implanted on May 8, 2007 in a rainbow trout (L 415mm, W 818g) and the fish was released below the dredge cut boat ramp on the east bank below Libby Dam. On May 14 and 17, the fish was detected along the west bank approximately 0.75 km downstream of the release site. By June 1, the fish had moved upstream 1.5 km, to within 200 meters of the David Thompson Bridge and remained near the east bank until August 2. A Montana Fish, Wildlife, & Parks technician caught and released this fish on July 2 while angling in the area of the detections; all sutures were intact and the surgical incision had completely healed. From August 2 through September 6, the fish was consistently located about 3.75 km downstream of the previous location in the Blackwell Flats side channel. After September 6, the tag was not detected again, and the fish was presumed to have moved downstream or died. It has not been found during aerial flights along the Kootenai River

Radio Tag 12

Tag 12 was implanted on May 8, 2007 in a rainbow trout (L 433mm, W 711g), and the fish was released below the dredge cut boat ramp on the east bank. On May 14, the fish was detected 0.7 km downstream against the west bank just above the Alexander Creek campground. The fish showed minimal movement within this area early during tracking and was detected in the same spot through December 2007. On January 3, 2008 the tag was not found and was not found until April 27, 2008 approximately 9km downstream approximately 3km above the Osprey Landing boat ramp. The tag is likely a shed tag on the bottom, it has not moved as of

June 26, 2008 and no rainbow trout has been seen in the area of the tag location. We will attempt to recover the tag during lower flows in the fall/winter of 2008.

Radio Tag 13_1 and 13_2

Tag 13_1 was implanted on October 24, 2007 in a rainbow trout (L 408mm, W 490g), and the fish was released above the Rereg boat ramp at the bottom of the side channel along the south bank. On October 31, the fish was detected in the main channel at the upper end of the lower-most island above the Rereg boat ramp, 0.55 km above the release sight. It remained in that area until it was detected on November 19, 0.4 km downstream of the previous location. By November 27, the fish had moved 0.95 km upstream into the side channel about 2/3 of the way up the island and was detected in this area through December. The shed tag was recovered on March 3, 2008 near previous locations in the side channel above the Osprey Landing river access.

Radio tag 13_2 was redeployed in a bull trout (L 497mm, W 1754g) on April 17, 2008 and released at the 1.2km below Libby Dam. By April 24, 2008, the fish moved downstream to the confluence of the Fisher River approximately 5.6km below Libby Dam. The tag was located upstream of the Osprey Landing access on April 27, 2008 (an additional 6.5km downstream), but has not been found since that date, even during aerial flights from Libby Dam to Kootenay Lake, British Columbia. The fate of the tag and fish is unknown but is believed to be a mortality.

Radio Tag 14

Tag 14 was implanted on May 8, 2007 in a bull trout (L 582mm, W 2301g), and the fish was released below the dredge cut boat ramp on the east bank. On May 17, the fish was detected downstream of the release site approximately 0.3km along the west bank of the main channel. The fish then crossed the river from the west bank to east bank and moved downstream 0.2km between May 17 and May 25 and then moved upstream 1.7km towards Libby Dam. Between June 1 and early September, the fish located between the release site and Libby Dam, with several 0.5 to 1km movements up and downstream. Between September 6 and September 17, the fish moved approximately 2.5km downstream to the Alexander Creek side channel. From September 17, 2007 through June 30, 2008, the fish has been located in the Alexander Creek side channel, 2.5km below Libby Dam. Several bull trout have been seen near the tag locations but no positive identifications or visual observations have been made of this fish. There are many large boulders and woody debris providing cover for fish in the side channel.

Radio Tag 15

Tag 15 was implanted on May 8, 2007 in a bull trout (L 638mm, W 2532g), and the fish was released below the dredge cut boat ramp on the east bank. From May 17 until July 6, the fish was located 0.9 km downstream of the release site across the channel from Alexander Creek. There was one upstream movement (0.2km) between June 21 and June 29 but the fish returned to the previous location between June 29th and July 6, 2007. From July 11 through August 2, the fish was consistently located 2.2 km upstream of the previous location, above the David

Thompson Bridge near the base of the dam. Since August 2, the fish has not been found and the location and fate of this tag is unknown. The tag has not been found during aerial flights from

Radio Tag 16

Tag 16 was implanted on June 21, 2007 in a rainbow trout (L 373mm, W 502g), and the fish was released 0.15km above Dunn Creek on the east bank. On June 29, the fish was detected in the main channel, 1.4 km above the release near the dredge cuts 1.2km below Libby Dam. Between August 27 and September 6th, the fish was detected in the main channel immediately below the dredge cut boat ramp, until October 9th. Between October 9 and 24, #16 had moved upstream 0.9km and then an additional 0.2km upstream by 10/31. The fish has been located at that location since from October 31, 2007 until June 30, 2008. It is likely a shed tag or the result of a dead fish, there have been no movements of the tag. At low flows, the bottom is visible and no fish have been seen at the location.

Radio Tag 17

Tag 17 was implanted on May 8, 2007 in a bull trout (L 644mm, W 2646g), and the fish was released below the dredge cut boat ramp. This fish not located after the release date until May 28, 2008 near Ball Creek, Idaho downstream of Bonners Ferry, Idaho approximately 125km downstream of the release site. It is believed to be a shed tag, that we will try to recover at lower flows.

Radio Tag 18_1 and 18_2

Tag 18_1 was put in a bull trout (L 655mm, W not available) on February 4, 2008 and released 0.2km downstream of the confluence of Dunn Creek and the Kootenai River. The fish was located 2 days later 0.1km downstream near the Dunn Creek boat ramp, but was found on February 14, 2008 dead 0.5km below the last known location.

Tag 18_2 was redeployed in a bull trout (L 617mm, W not available) on February 25, 2008. The fish was released across the main channel from Alexander Creek. From the release date through the end of April, the fish moved steadily upstream 1.0km near the gravel bar above the dredge cut boat launches. The fish then moved back downstream into the dredge cuts and from early April until early June, made movements from the dredge cuts back into the main channel weekly. In early June, the fish moved out of the dredge cuts and moved 0.8 km upstream towards the USGS trolley cable that crosses the Kootenai River below Libby Dam. By mid June, the fish was moving every week or two weeks between the dredge cuts and the main channel. Between June 11 and June 17, the fish had moved to the David Thompson Bridge 1.4 km upstream but then moved back downstream 1.4km to the dredge cuts where it remained until the end of June.

Radio Tag 19

Tag 19 was implanted on May 8, 2007 in a bull trout (L 732mm, W 3663g), and the fish was released below the dredge cut boat ramp. The fish was located just above the release site on

May 14 and was detected progressively moving upstream toward the dam (total 1.35 km) until June 29, when it appeared to settle near the dam through August 2. On August 15, the fish was not detected between the dam and the Fisher River confluence. On August 17, #19 was located 55 km downstream, below Kootenai Falls and across from the Lake Creek confluence in an eddy. It has remained in this location through June 2008.

Radio Tag 20

Tag 20 was implanted in a bull trout (L 801mm, W not available) on January 8, 2008 and released above Lake Creek on the south bank. The fish had moved downstream 3.5km by January 24, and the fish remained in this location until February 6, 2008. The fish has not been located by boat or by plane since that date.

Radio Tag 21_1 and 21_2

Tag 21_1 was implanted on October 24, 2007 in a bull trout (L 760mm, W 3536g), and the fish was released in the side channel below Alexander Creek. From the release date until November 27, the fish was detected in the side channel below Alexander Creek with some detectable movement (maximum 0.5 km) up and downstream within the side channel and the fish was located in the main channel once. On December 10, a dead bull trout was observed near #21's location, but was not recovered due to high flows. On December 12, the previously observed dead fish was collected and was #21. The bull trout had a hook with a northern pikeminnow head stuck in its mouth and three to four feet of monofilament fishing line with a swivel attached. The line and swivel were wrapped around some woody debris, likely leading to the fishes death. All sutures were still intact, but the incision had not completely healed. No signs of infection were noticeable.

Tag 21_2 was released on January 8, 2008 in a bull trout (L 790mm, W not available) below the mouth of Lake Creek 0.2km. The fish remained near the release site through the end of January and then moved upstream 1.8km to just above the rock island above O'Brien Creek, where it remained until early April. We handled the fish during some electrofishing efforts near O'Brien Creek, all incision appeared to be healed and no infections were present. After being handled on April 3, the fish moved upstream 1km where it stayed until the end of May. In early May, the fish crossed the river to the north bank and moved upstream and downstream while moving slowly downstream until early June. On June 19, 2008, we could not find this fish, but on June 23, we located the fish 23.5km downstream of Bonners Ferry, Idaho. The fish had sustained some trauma, several abrasions and cuts were present on the head, but the fish was still alive and trying to swim on it's back. We sacrificed the fish and recovered the tag.

Radio Tag 22

Radio tag 22 was put in a bull trout (L 652mm, W not available) on February 4, 2008 and released at the Alexander Creek campground. The fish moved downstream into the Alexander Creek side channel where it remained until the middle of April. In the middle of April the fish moved upstream 1.2 km near the boat accesses 1.2 km below Libby Dam. The fish remained in that vicinity until the end of May when it moved upstream to the David Thompson Bridge. The

fish moved between the boat launch area and the David Thompson Bridge about every week to week and a half until the end of June.

Radio Tag 23

Tag 23 was implanted on June 15, 2007 in a rainbow trout (L 292mm, W 216g), and the fish was released at the top of the island above the Rereg boat ramp. This fish was not detected after being released.

Radio Tag 24

Tag 24 was implanted on June 15, 2007 in a rainbow trout (L 331mm, W 316g) and released at the downstream end of the island near the Blackwell Flats boat ramp. On June 21, the fish was located slightly below the release site in deeper water. From June 29 through December, the fish was consistently detected upstream of the release site at the upper end of the side channel above Blackwell Flats along the west bank where it remained until the tag expired in early January 2008. The tag was last located on January 8, 2008.

Radio Tag 24 IFIM

Tag 24IFIM was placed in a rainbow trout (L 260mm, W 164g) and released in the Flower-Pipe section of the Kootenai River 4.4km downstream of the Highway 37 Bridge in Libby, Montana. The fish remained at this location until the end of this reporting period.

Radio Tag 25

Tag 25 was implanted on June 15, 2007 in a bull trout (L 267mm, W 154g), and the fish was released at the upper end of the island above the Rereg boat ramp. The fish was detected near the release site from June 15 through August 15. During this time, the tag signal strength was weak, sometimes coding only within 30 meters. After August 15, the fish was no longer detected as has not been found.

Tag 25 IFIM

Tag 25IFIM was released at the base of the island below Rainy Creek in a rainbow trout (L 302mm, W 251g) on June 24, 2008. After being released, the fish moved upstream slightly over the next week 0.15 km along the south edge of the island. Only two locations of this fish were made prior to the end of this reporting period.

Radio Tag 26

Tag 26-1 was implanted on April 26, 2007 in a rainbow trout (L 320mm, W 271g), and the fish was released below the Rereg boat ramp. Between April 26 and May 2, the fish remained approximately 0.35 km downstream of the release before crossing the river prior to May 21. Between May 25 and June 5, the fish made two larger movements, one 0.55 km upstream to the downstream end of the gravel bar below the Osprey Landing access and then

returned to the previous location 0.55 km downstream. Between June 5 and June 17, an angler harvested the fish and returned the radio tag to the Libby field station. The tag was later redeployed.

Tag 26-2 was implanted on June 21, 2007 in a rainbow trout (L 333mm, W 289g), and the fish was released 0.6km downstream from the Osprey Landing boat ramp. On June 29, the fish was detected 0.5 km downstream of the release site but by July 5, the fish had returned to a location near the release location. From July 5 until November 8, the fish was consistently located near the release site on the south bank and in the side channel with slight movements within a 0.2 km range up and down stream. The signal from the tag was weak and barely audible on November 14, 2007 and was not found after that date.

Radio Tag 27

Tag 27-1 was implanted on April 26, 2007 in a rainbow trout (L 264mm, W 167g), and the fish was released slightly upstream of the Rereg boat ramp at the base of the island. Between April 26 through May 21, the fish moved from the tagging location, 1.8 km downstream to below the Osprey Landing boat ramp. From May 21 through July 20 the fish was located downstream of the boat ramp, but frequently moved across the channel and also up and downstream. On July 25, an angler from Whitefish, Montana harvested the fish and returned the entire fish (L 270mm, W 204g) to the Montana, Fish, Wildlife and Parks Kalispell office. The tag was later redeployed.

Tag 27-2 was implanted on August 2, 2007 in a rainbow trout (L 326mm, W 289g), and the fish was released at the upstream end of the island about 400 meters above the Rereg boat ramp. Between August 27 and September 5, the fish moved 0.85 km downstream from near the release site to an eddy along the north bank 0.8km upstream of the Osprey Landing boat ramp. After November 19, the fish was not found and the tag is believed to have expired.

Tag 27 IFIM

Tag 27IFIM was released on June 25, 2008 in a rainbow trout (L 265mm, 175g) downstream of Libby near a for sale sign. The fish was located only once after release before the reporting period ended.

Radio Tag 28

Tag 28 was implanted on June 15, 2007 in a rainbow trout (L318 W226), and the fish was released 100 meters above Alexander Creek on the west bank. We had a difficult time locating the tag on sampling dates after releasing the fish. One June 21, the tag was located 1.1km upstream of the release location 0.2 km upstream of the USGS trolley cable. We could not get a strong signal at that location and could not get a stronger signal from that location in any direction. On July 6, the tag location was triangulated 0.7 km downstream at the head of the island directly below the dredge cut boat ramps. The tag location appeared to be in just a few inches of water. As flows were reduced, it became apparent that the tag had been shed and was then located on dry land. On October 12, the shed tag was recovered with no antenna attached.

Tag 28 IFIM

Tag 28IFIM was released on June 24, 2008 in a rainbow trout (L 313mm, 265g) below the large island below Rainy Creek. The fish was not located on 6/26, but was found 0.2 km upstream on June 30, 2008. That was the last location for this reporting period.

Tag 33 IFIM

Radio tag 33IFIM was released on June 25, 2008 in a rainbow trout (L 280mm, W185g) downstream of Libby, Montana in the Flower-Pipe section of the Kootenai River near a house on the south bank with a chain-link fence around it. Over the next five days the fish moved downstream approximately 0.2km before the end of this reporting period.

Tag 34 IFIM

Tag 34IFIM was released in a rainbow trout near the Libby Dam RV Park, upstream of Libby, Montana. The rainbow trout (L 313mm, W 232g) was released on June 24, 2008 0.3 km across the river from the RV Park. The fish made two incremental upstream movements prior to the reporting period of 0.12 and 0.05 km to some calmer water with a seam near a point bar.

Tag 36 IFIM

Tag 36IFIM was released approximately 3km downstream of the highway 37 bridge in Libby Montana on the south bank. The rainbow trout (331mm, 351g) remained on that bank but moved downstream from June 25 to June 26. Between June 26 and June 30, 2008 the fish moved an additional 0.4 km downstream and across the river to a location with a riffle and an eddy nearby. The fish was located 2 times after being released before the end of this reporting period.

Tag 37 IFIM

A rainbow trout (L 361mm, W 378g) had tag 37IFIM surgically implanted on June 24, 2008 0.2 km upstream of Rainy Creek. Over the next 6 days, the fish made two downstream movements (0.12 and 0.11 km) that crossed from the east bank to the west bank directly across from the confluence with Rainy Creek. The three locations prior to June 30, were the only locations of this fish prior to the reporting period for this report.

Sensor Tags

Six depth sensing radio tags were deployed in the spring of 2008, in an attempt to characterize daytime and nighttime movements and water depth use. Initially only daytime work was completed, but nighttime work started in June 2008. Two radio tags disappeared. One was found near Copeland, Idaho and the other is still missing. The number of daytime depths ranged from 20 to 21 per tag and nighttime depths ranged from 5 to 6 per tag at the of this report (Table 7-6). There were no significant differences (i.e., at $p \leq 0.05$) in daytime versus nighttime water depths for any of the tagged fish or for the combined day and nighttime depths (Figures 7-9 to 7-14). However, radio tags 8, 11, and the overall results were close to being significant, with deeper water depths at night than during the day (p-value range from 0.067 to 0.077). It was previously thought that bull trout in the Kootenai River moved into shallower water depths at night to feed on a regular basis, but the preliminary results do not indicate that during the spring season. The average nighttime depths were deeper than during the day for 3 of 4 fish, and there were no significant differences. Muhlfeld et al. (2003a, 2003) found that subadult bull trout made diel movements into shallow margins at night. Nighttime and daytime work will continue for the life of the tags to assess any additional seasonal differences in water depths used during the day and night.

Table 7-6. Summary of depths recorded for five radio-tagged bull trout in the Kootenai River, downstream of Libby Dam, Montana.

Tag #	Day	Night
7	21	5
8	20	6
11	21	5
13	21	5
Total	91	21

Bull Trout - Day vs Night Depths with 95% CI

Figure 7-9. Daytime versus nighttime water depths (meters; $\pm 95\%$ CI) used by bull trout below Libby Dam, near Libby, Montana.

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Day Depth (m)	21	108.70	5.18	1.32
Night Depth (m)	5	23.80	4.76	1.16

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.69952015	1.00	0.70	0.54	0.469	4.26
Within Groups	30.9900952	24.00	1.29			
Total	31.6896154	25.00				

Figure 7-10. Results of day versus nighttime water depth (m) ANOVA for radio tag 7 in the Kootenai River, downstream of Libby Dam.

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	20	99.10	4.96	3.57
Column 2	6	39.10	6.52	2.23

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	11.2560128	1.00	11.26	3.42	0.077	4.26
Within Groups	78.9178333	24.00	3.29			
Total	90.1738462	25.00				

Figure 7-11. Results of day versus nighttime water depth (m) ANOVA for radio tag 8 in the Kootenai River, downstream of Libby Dam. Column 1 represents day data and column 2 represents night data.

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	21	86.70	4.13	0.60
Column 2	5	24.10	4.82	0.15

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	1.93068132	1.00	1.93	3.67	0.067	4.26
Within Groups	12.6108571	24.00	0.53			
Total	14.5415385	25.00				

Figure 7-12. Results of day versus nighttime water depth (m) ANOVA for radio tag 11 in the Kootenai River, downstream of Libby Dam. Column 1 represents day data and column 2 represents night data.

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Column 1	21	70.20	3.34	0.37
Column 2	5	18.40	3.68	0.44

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	0.45903297	1.00	0.46	1.19	0.285	4.26
Within Groups	9.21942857	24.00	0.38			
Total	9.67846154	25.00				

Figure 7-13. Results of day versus nighttime water depth (m) ANOVA for radio tag 13 in the Kootenai River, downstream of Libby Dam. Column 1 represents day data and column 2 represents night data.

Anova: Single Factor

SUMMARY

<i>Groups</i>	<i>Count</i>	<i>Sum</i>	<i>Average</i>	<i>Variance</i>
Day Depth (m)	83	364.70	4.39	1.92
Night Depth (m)	21	105.40	5.02	2.06

ANOVA

<i>Source of Variation</i>	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>P-value</i>	<i>F crit</i>
Between Groups	6.54822725	1.00	6.55	3.36	0.070	3.93
Within Groups	198.519369	102.00	1.95			
Total	205.067596	103.00				

Figure 7-14. Results of day versus nighttime water depth (m) ANOVA for four radio tagged bull trout in the Kootenai River, downstream of Libby Dam.

IFIM Validation

Eight radio tags were implanted in rainbow trout in two sections of the Kootenai River near Libby, Montana with IFIM habitat work completed (Hoffman et. al 2002; Miller and Geise 2004). Shortly after releasing fish, only five of the eight rainbow trout remained in the habitat units allowing locations within the IFIM sections. Only a few locations for each fish could be made prior to the end of this reporting period, but preliminary results will be discussed for each fish.

Radio Tag 25 was released at the lower end of the Rainy Creek Island while flows were at 20500cfs. Following release, the fish moved upstream in two increments. Location 1 was recorded at 20500cfs and this point was near the higher quality habitat predicted by the IFIM model at 16000cfs (Figure 7-15). Location 1 was further from quality habitat predicted by the 23751cfs model compared to the 16000cfs model (Figures 7-15 and 7-16). Location two was recorded at 17000 cfs and was in higher quality habitat at the 16000cfs than the 23751 habitat model. Location two was also very close to the higher quality habitat predicted by the 23751cfs discharge, but was slightly towards the main part of the channel (Figure 7-16). Habitat use by fish number 25 at 20500 and 17000cfs was better predicted by the 16000 cfs model than by the 23751 habitat model indicated by the higher location values compared to the habitat unit maximum values (Table 7-7).

Radio tag 27 was released downstream of Libby in the upper 3rd of the Run 45. We only made one location of this fish in the FIIM habitat unit and it was near high quality habitat. After that location, the fish moved upstream 2.3km to the Highway 37 Bridge out of the habitat unit. The only location of this fish (at 20500cfs) was just inside of the predicted highest quality habitat at 20601cfs (Figure 7-17; Table 7-7). No further comparisons of habitat use were made for this fish.

Radio tag 28 was released at 20500cfs, in high quality habitat in Pool 28 (Figure 7-18; (Table 7-7). The second location for this fish was located 0.2km upstream and was located again in high quality habitat compared to the 16000cfs model. Similar to fish number 25, the higher discharge model of 21460 resulted in lower habitat quality values compared to the 16000cfs model.

Radio Tag 33 was released downstream of Libby in Run 45. The fish was released in lower quality habitat and moved downstream from the release location. The fish was relocated in lower quality habitat on each of the two sample dates (i.e., locations 1 and 2 at 20500 and 17000cfs respectively). Both locations did not match well with the habitat models at 18000 and 20601cfs (Figures 7-20 and 7-21; Table 7-7). The GIS layer predicted the highest quality habitat on shore. The distances from the GIS layer to the stream bank were approximately the same distance from shore to the fishes locations, possibly indicating the fish was in higher quality habitat than indicated by the models.

Radio tag 36 was first located in medium quality habitat at 20500cfs, which did not change at the IFIM discharge levels of 18000 and 20601cfs. The fish moved downstream 0.35km out of the habitat unit (Figures 7-22 and 7-23; Table 7-7). Similar to the other fish, the lower discharge model, predicted the fish to be in higher quality habitat. We will continue to monitor these fish until the radio tags expire in 2009 assessing movements in relation to changes in discharge and if the fish is located within one of the IFIM units, we will assess habitat quality at the current discharge at the time the fish is located.

The IFIM validation results presented in this report will be expanded in future reports. Fish used for this work has been released less than a week at the time of this report, and may not have been acting normal following implantation of the radio tags.

Figure 7-15. Locations of radio tag 25 in Pool 27. Locations 0 (release site) and 1 were at 20500 cfs and location 2 was at 17000 cfs. The IFIM flow area is 16000 cfs. The dark blue area represents higher quality habitat.

Figure 7-16. Locations of radio tag 25 in Pool 27. Locations 0 (release site) and 1 were at 20500 cfs and location 2 was at 17000 cfs. The IFIM flow area is 23751 cfs. The dark blue area represents higher quality habitat.

Figure 7-17. Locations of radio tag 27 in Run 45. Location 1 was at 20500 cfs and the IFIM flow area is 20601 cfs. The dark blue area represents higher quality habitat.

Figure 7-18. Locations of radio tag 28 in Pool 28. Location 0 (release site) was taken at 20500 cfs and location 2 was recorded at 17000 cfs. The IFIM flow area is 16000 cfs. The dark blue area represents higher quality habitat.

Figure 7-19. Locations of radio tag 28 in Pool 28. Location 0 (release site) was taken at 20500 cfs and location 2 was recorded at 17000 cfs. The IFIM flow area is 21460 cfs. The dark blue area represents higher quality habitat.

Figure 7-20. Locations of radio tag 33 in Run 45. Location 1 was recorded at 20500 cfs and location 2 at 17000 cfs. The IFIM flow area is 18000 cfs. The dark blue area represents higher quality habitat.

Figure 7-21. Locations of radio tag 33 in Run 45. Location 1 was recorded at 20500 cfs and location 2 at 17000 cfs. The IFIM flow area is 20601 cfs. The dark blue area represents higher quality habitat.

Figure 7-22. Locations of radio tag 36 in Run 45. Location 1 was recorded at 20500 cfs and location 2 at 17000 cfs. The IFIM flow area is 18000 cfs. The dark blue area represents higher quality habitat.

Figure 7-23. Locations of radio tag 36 in Run 45. Location 1 was recorded at 20500 cfs and location 2 at 17000 cfs. The IFIM flow area is 20601 cfs. The dark blue area represents higher quality habitat.

Table 7-7. Habitat value of radio tagged fish location in two sections of the Kootenai River below Libby Dam, Montana. Locations were mapped and the habitat value within a 2m by 2m cell were obtained from grids in the GIS based habitat units.

Radio Tag #	Habitat Unit	Discharge (cfs)	Location Number	IFIM Model Discharge (cfs)	Habitat Unit Maximum Value	Location Value	Notes
25	Pool 27	20500	0	16000	0.877626	0.015209	Release location
25	Pool 27	20500	1	16000	0.877626	0.036405	
25	Pool 27	17000	2	16000	0.877626	0.556345	
25	Pool 27	20500	0	23751	0.769333	0.000001	Release location
25	Pool 27	20500	1	23751	0.769333	0.000950	
25	Pool 27	17000	2	23751	0.769333	0.055606	
27	Run 45	20500	1	20601	0.544581	0	Model on shore, ~0.3-0.4 nearby
28	Pool 28	20500	0	16000	0.971272	0.410462	Release location
28	Pool 28	17000	2	16000	0.971272	0.533956	
28	Pool 28	20500	0	21460	0.910813	0.065485	Release location
28	Pool 28	17000	2	21460	0.910813	0.119065	
33	Run 45	20500	1	18000	0.575947	0.000000	Model on shore, ~0.27 nearby
33	Run 45	17000	2	18000	0.575947	0.000000	Model on shore, ~0.27 nearby
33	Run 45	20500	1	20601	0.544581	0.000000	Model on shore, ~0.08 nearby
33	Run 45	17000	2	20601	0.544581	0.000000	Model on shore, ~0.08 nearby
36	Run 45	20500	1	18000	0.575947	0.028388	
36	Run 45	17000	2	18000	0.575947	NA	Out of habitat unit
36	Run 45	20500	1	20601	0.544581	0.004697	
36	Run 45	17000	2	20601	0.544581	NA	Out of habitat unit

CHAPTER 8 – Tributary Conditions and Impacts on Survival

Methods

Survival and Mortality Estimates

Additional fish sampling will be required to better estimate age frequencies during the years of interest. Survival and mortality rates will be calculated using age data from scale and otolith samples and length frequencies from each tributary (i.e., catch curve analyses). A sample of fish will be aged in each section of the river for years in which population estimate data are available. Linear regressions will be used on the descending limb of the age Log_e transformed age frequency. Cohort survival and mortality will also be followed through time in relation to environmental variables (e.g., flow variation, temperature, minimum and maximum discharge) and fish population parameters (e.g., number per mile, per thousand feet, or per square meter).

Temperature and discharge data will be collected from a United States Forest Service staff gage and Aquarod located approximately 200 yards upstream of the remote PIT tag station located on Quartz Creek. Additionally, temperature loggers will be placed at several locations throughout the Quartz Creek drainage. Immigration and emigration patterns of bull trout will be assessed (Downs et al. 2006 and Downs and Jakuboski 2006) to better understand how biotic and abiotic factors influence migration patterns, stream usage by adult bull trout, and to better understand the population dynamics of bull trout in the Kootenai River system.

PIT tagging, tributary population estimates, and remote PIT tag stations

Backpack electrofishing in tributary streams was conducted during the summer months when tributaries were at or near low flow conditions. Elapsed time electrofishing was recorded to calculate fish catch per unit effort of fishes (i.e., fish per hour) that was used for comparisons between years in reaches that are sampled annually. All fish were processed for length (mm), weight (g), collection of scales if applicable, inspected for injuries and marks, and tagged using methods identical to those used in large rivers mentioned above. Fish will be PIT tagged (2 x 12 mm FDX tags and 3 x 20 mm HDX tags, 134.2 kHz) during electrofishing efforts in Quartz Creek, the mainstem Kootenai and Flathead Rivers, and selected tributaries. This tagging will occur in conjunction with the installation of at least one remote PIT tag monitoring station. This PIT tag monitoring equipment is produced by Biomark, Incorporated, of Boise, Idaho (Figure 8-1, courtesy Muhlfeld et al. 2004). PIT tags will be injected into the dorsal sinus or body cavity following conventional procedures (Figure 8-2; PIT Tag Steering Committee 1999). All adult bull trout captured while electrofishing will be released to minimize handling stress prior to spawning if they do not have a PIT tag. If adult bull trout have a PIT tag, they will be scanned and an approximate length will be taken. Other fishes will receive PIT tags if fish and tag sizes are compatible and conditions are suitable for tag injection (e.g., water temperatures). Tag identification numbers are stored in the PIT tag reader but were also recorded on corresponding

data sheet and scale envelope. Depletion methods will be used to estimate fish abundance within the juvenile monitoring section of Quartz Creek and additional sites when possible. A block net will be placed at the downstream boundary of the electrofishing reach prior to sampling. Electrofishing will proceed from the upstream boundary towards the downstream boundary using two backpack electrofishing units, DC current, two netters, and one fish carrier equipped with one or two 5 gallon buckets. After fish are collected during the first pass, all fish will be anesthetized with MS-222 and measured for total length (mm) and weight (g), species identification, and other notes such as PIT tag information, fin clips, etc. Once fish from the first pass are measured, the fish from the 1st pass will be allowed to recover in a live cage while the second pass is completed. After electrofishing is completed and all fishes have been measured, the probability of capture (P) using the following formula:

$$P = C1 - C2 / C1$$

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

Based on captures made during the first two passes, if P was < 0.7, a third pass was conducted. A capture efficiency of 70% (i.e., P < 0.7) between consecutive passes will be required to end additional sampling (Dunnigan et al. 2003). Population estimates were performed for fish > 75 mm, in order to make juvenile fish estimates consistent with historic data collected prior to 1997.

Figure 8-1. The left panel shows a previously installed PIT tag detection unit in the Flathead River Basin in Langford Creek, showing the in-stream antenna, solar panel, transceiver, and battery boxes. The right panel shows a detailed view of the detection antenna encompassing Langford Creek discharge (Photographs courtesy of Muhlfeld et al. 2004).

Figure 8-2. Location of PIT tag injection sites (within red ovals) for fishes in the Kootenai River basin for use with remote PIT tag interrogation systems and for use in growth survival, and movement monitoring. All fish are marked with an adipose clip.

Statistical Analysis

Juvenile bull trout population estimates will be performed using the multi-pass maximum likelihood estimator in Fisheries Analysis Plus software (Fisheries Analysis + 2004). Annual survival and mortality rates will be calculated in various tributaries of the Kootenai River for bull trout, rainbow trout, and westslope cutthroat trout when appropriate length frequency data and age data is available. Annual mortality will be calculated using methods mentioned previously in Chapter 6 of this report using data from electrofishing and estimates of age from scales. Minimum survival estimates for emigrating juvenile bull trout (juvenile fish to adult fish) will also be calculated if returning juvenile fish return to a natal tributary using methods described in using the following formula (from Downs and Jakubowski 2006):

$$S = N_{t+1} / N_t$$

where N_t = number of fish alive at time t
 N_{t+1} = number of fish alive at time $t+1$

Results and Discussion

Quartz Creek Discharge Data

Discharge data for Quartz Creek was provided by the United States Forest Service (USFS). The gauge and Aquarod are placed at Forest Service Road 601 Bridge approximately 1.6 km (1 mi) from the confluence with the Kootenai River. Peak discharge of Quartz Creek since water year 2001 was 686cfs on April 16, 2002 based on USFS calibration data (Figures 8-3 and 8-4; Table 8-1). Minimum discharge since water year 2000 was approximately 2.29 cfs in September 2003 (Table 8-1). Peak discharge has decreased each water year from 2002 to 2005 with several years having high winter discharges, likely results of rain on snow events. A severe drought occurred in water year 2001 with the peak discharge of 92 cfs occurring in May (Table 8-1). High discharges in Quartz Creek have not occurred since 2002 and have not allowed recalibration of the staff gage at high discharges (i.e., >500 cfs) since 2002. The staff gage is recalibrated yearly at lower discharges due to channel scouring and fill. In May 2008, discharge of Quartz Creek near Kootenai River Road peaked at greater than 700 cfs (approximate based on previous calibration data), the highest since water year 2002.

Figure 8-3. Quartz Creek gauge height versus discharge from water year 2001 to 2006. Data courtesy of the United States Forest Service, Canoe Gulch office, Libby Montana.

Table 8-1. Minimum and maximum discharge of Quartz Creek, a tributary of the Kootenai River below Libby Dam and above Kootenai Falls.

Water Year	Minimum Discharge (cfs)	Maximum Discharge (cfs)
2001	10	92
2002	10	686
2003	2	401
2004	18	227
2005	17	217
2006	15	265

Figure 8-4. Quartz Creek discharge from water year 2001-2006. Data courtesy of the United States Forest Service, Canoe Gulch Office.

Figure 8-5. Approximate discharge (cfs) of Quartz Creek from July 2007 to June 2008. Discharge was approximated using previous staff gage calibration data at the Forest Service Road 601 Bridge.

Quartz Creek remote PIT tag station

The Quartz Creek remote PIT tag station was installed on August 21-22, 2007 approximately 0.5 river miles upstream of the confluence with the Kootenai River. The legal description of the site is: SW ¼ SW ¼ SE ¼ S13 R32W T31N with coordinates (DD MM.MMM) N 48 26.598 W 115 37.903 (NAD83 / WGS84) on property of the United States Forest Service, Kootenai National Forest. Bankfull width of the channel was 9-10 meters with a maximum depth of 0.6 meters at the PIT tag station installation site (Figure 8-6). The station consists of 4-antennas and seal plates, a thermoelectric generator, PIT tag reader, and associated electronics, propane fuel tanks, and duck-billed anchors (Figures 8-7 to 8-9). The antenna and reader system was manufactured and purchased from Biomark, Inc. (Boise, Idaho, USA 208-275-0011) following Montana Fish, Wildlife & Parks specifications. The reader model used was a Digital Angel FS1001M multiplexing transceiver. The Model 5060 Thermoelectric Generator was purchased from Global Thermoelectric (Calgary, Alberta, Canada 1-403-236-5556; Figure 8-9). The generator uses approximately 1.5 gallons of liquid propane per day and is more efficient at colder temperatures. The generator produces electricity using the temperature differential between the unit and the ambient temperature.

Of 166 fish collected in Quartz Creek in 2007, 68 fish were PIT tagged during the four sampling dates (Table 8-2). Tagged fish included 17 bull trout, 39 rainbow trout, 11 westslope cutthroat trout, and 1 westslope cutthroat trout x rainbow trout hybrid (based on external characteristics). Most of the fish collected were less than 200 mm total length with a few fish greater than 300 mm (Figures 8-10 to 8-12). There is a species composition shift for salmonids in Quartz Creek from headwater to the confluence with the Kootenai River. The West Fork of Quartz Creek contains bull trout and cutthroat trout, while lower sections have bull trout, cutthroat trout, and rainbow trout, with rainbow trout dominating the late summer catch in lower sections of Quartz Creek (Figures 8-10 to 8-12).

Twenty-four fish were detected at the PIT tag station from August 2007 to June 2008, 16 from Quartz Creek electrofishing efforts, and 8 from previous tagging efforts in the mainstem Kootenai River (Table 8-3). Of the 24 fish detected, 13 were bull trout (8 adult, 5 juvenile) and the remaining fish were rainbow trout tagged in Quartz Creek (Tables 8-3 and 8-4). The 24 fish detected at the station resulted in 49,728 PIT tag records from August 22, 2007 until June 30, 2008. Early in the operation, the reader memory filled up because we did not have the reader unique setting on delay. The reader would read the PIT tags 2 to 5 times every second if a fish was holding in the field, which occurred commonly. We later set the delay to 5 minutes, which reduced the number of detections, however, it does not affect multiple readings if the fish were to move between antennas. Two bull trout were not detected at the station again after being detected moving upstream, possible indicating spawning mortality (Table 8-4). Three bull trout made upstream and downstream movements, ranging from 8 to 28 days between detections at the station (Table 8-4). Movement direction was not determined for three adult bull trout. These fish were tagged in 2004 ($N=2$) and 2006 ($N=1$) and had older PIT tags. Lower read ranges of these tags or tag orientation as the fish passed through the station could have caused us to miss these fish at other antennas. We detected all other bull trout at multiple antennas. All bull,

cutthroat, and rainbow trout in Quartz Creek are being tagged with the TX1411SST 134.2 kHz PIT tags produced by Digital Angel Corporation to maximize efficiency of the PIT tag station. The station was turned off and electronics removed on January 4, 2008 to protect the unit during the coldest winter months. The unit was restarted on February 22, 2008. A high spring flow event caused by above normal snow pack and 90+ degree days occurred in May 2008, causing the PIT tag station to blow out on the night of May 18th or May 19th. The 20-foot antennas became dislodged from the anchors and were moved downstream. One antenna was located about 100 yards downstream in some woody debris and boulders. The other 20-foot antenna was never recovered, but was sighted near Bonners Ferry, Idaho on May 20th or 21st. We flew in an airplane to locate the antenna but were unsuccessful.

Based on previous genetic work by Ardren et. al 2007, genetic assignments were available for 4 adult bull trout, 3 were assigned to the Wigwam River and one from the West Fisher (Table 8-4). The most prevalent second choice for genetic assignment was the West Fisher (75%) followed by O'Brien Creek (25%). It appears that many of the bull trout located directly downstream of Libby Dam are entrained fish from Koocanusa Reservoir, and some of these fish stray to other tributaries to spawn.

Monitoring of juvenile bull trout has occurred in the West Fork of Quartz Creek since 1997, typically when discharge is near the minimum discharge for the year. Juvenile bull trout estimates in the West Fork of Quartz Creek have ranged from slightly lower than 6 per m² to greater than 10-m² (Figure 8-13). Lengths of bull trout collected have ranged from 3-47cm during electrofishing effort in the juvenile section since 1997 (Figure 8-14). Age-0, Age-1, Age-2, and Age-3 bull trout were recognizable when the length frequencies were combined from 1997-2006 (Figure 8-15). The combined length frequency histogram was used to estimate the ages of juvenile bull trout (i.e., during months of July / August). Length ranges at age were estimated as Age-0 30-69mm, Age-1 70-119mm, Age-2 120-189mm, Age-3 190-269mm, and Age-4 270-350mm to calculate annual survival estimates. Only the age-2 to age-3 survival estimate was valid (i.e., <100 percent; Table 8-5). More fish of the older age classes were captured than younger age classes for many of the years, making survival estimates greater than 100 percent. Of the 17 juvenile bull trout tagged during this report period, five were detected at the PIT tag station, resulting in a 29.4 percent emigration rate. Length of fish emigrating from Quartz Creek ranged from 125-246mm at the time of tagging. Percentages of fish emigrating at age (at tagging) were 20, 60, and 20 percent for ages 1, 2, and 3 fish respectively, however the sample size was small ($N = 5$). These percentages were similar to those reported by Fraley and Sheppard (1989) and Ratliff et al. (1996), that showed the majority of fish migrating out of natal tributaries at Age-2. More juvenile bull trout will be tagged in Quartz Creek in the next year to increase sample size to characterize juvenile migration patterns and percentage of emigrating juvenile bull trout returning as adults to spawn.

Figure 8-6. Quartz Creek channel profiles prior to installation of the remote PIT tag station in August 2007. The site was installed upstream and downstream of XS1 upstream cross section due to the flatter channel profile.

Figure 8-7. Photograph of sill plate installation in Quartz Creek, a tributary to the Kootenai River, Montana.

Figure 8-8. Upper panel: remote PIT tag station consisting of a 4-antenna array located in Quartz Creek, a tributary to the Kootenai River, Montana. Photograph is looking upstream. Lower panel: diagram of antenna layout in relation to stream flow.

Figure 8-9. Thermoelectric generator, propane tanks, and reader equipment located at Quartz Creek, a tributary to the Kootenai River, Montana.

Table 8-2. Summary of Quartz Creek electrofishing in 2007. Number of fish PIT tagged is in parentheses. ** Twenty to thirty age-0 *Oncorhynchus spp.* were not dip-netted because they fell through the dip net mesh.

Date	Species	Number Caught (# tagged)	Hours Electrofished	Catch per unit effort (#/hour)	Notes Location
6/14/2007	DV	13	0.7175	18.118	Kootenai River road to PIT tag station
	RBT	6 (5)	0.7175	8.362**	
	BKT	1	0.7175	1.394	
7/17/2007	DV	62 (14)	NA	NA	500 foot section at the West Fork Quartz Creek bridge crossing
	WCT	29 (11)	NA	NA	
8/28/2007	DV	4 (1)	1.5094	2.650	Kootenai River Road to FSR601 bridge
	RBT	46 (32)	1.5094	30.475	
	RBT x WCT	1 (1)	1.5094	0.662	
3/24/2008	DV	2 (2)	NA	NA	
	RBT	2 (2)	NA	NA

Figure 8-10. Length frequency of fishes collected in Quartz Creek on June 14, 2007 downstream of the PIT tag station from 100m upstream of Kootenai River Road to the PIT tag station (length approximately 600m).

Figure 8-11. Length frequency of fishes collected in the West Fork of Quartz Creek on July 17, 2007 approximately 7.5km (4.5 miles) above the remote PIT tag station (section length approximately 175m).

Figure 8-12. Length frequency of fishes collected in Quartz Creek on August 28, 2007 directly adjacent (above and below) the remote PIT tag station, section length approximately 700m.

Table 8-3. Summary of fish detected at the Quartz Creek PIT tag station from August 21, 2007 until June 30, 2008.

PIT Tag Code	Date Range	Days Detected	Antenna Number Detections				Total # Detections	Notes
			3	4	5	6		
3D9.257C5AB763	8/22/2007 – 3/12/2008	44	3434	110	849	128	4521	Rainbow trout tagged 6/14/2007 in Quartz Creek 131mm
3D9.257C5B0652	9/2/2007	1	8		3		11	Bull trout tagged 10/4/2006 Flower-Pipe section 635mm
3D9.257C6BF6ED	8/30/2007- 9/1/2007	2	44	4478	9		4531	Rainbow trout tagged 8/28/2007 in Quartz Creek 152mm
3D9.257C6C2E1D	8/30/2007	1	19				19	Rainbow trout tagged 8/28/2007 in Quartz Creek 176mm
3D9.257C6C2F44	8/30/2007 – 2/26/2008	4	585		10		595	Rainbow trout tagged 8/28/2007 in Quartz Creek 162mm
3D9.257C6C3871	8/28/2007 – 9/1/2007	3	1659		184	4339	6182	Rainbow trout tagged 8/28/2007 in Quartz Creek 150mm
3D9.257C6C5C07	8/28/2007 – 8/29/2007	2	293		106	353	752	Rainbow trout tagged 8/28/2007 in Quartz Creek 170mm
3D9.257C6C74EA	8/30/2007 – 8/31/2007	2	6		4		10	Rainbow trout tagged 8/28/2007 in Quartz Creek 165mm
3D9.257C6C1083	9/11/2007 – 9/20/2007	3	21		3		24	Bull trout tagged 4/10/2007 in Kootenai River - Rereg section 690mm
3D9.1BF1C4CD8F	9/12/2007	1	2				2	Bull trout tagged 4/15/2004 in Kootenai River - Dam to Fisher River 765mm
3D9.257C6C5688	9/12/2007 – 10/10/2007	2	3		3		6	Bull trout tagged 3/24/2007 in Kootenai River - Dam to Fisher River 600mm
3D9.257C6C3280	9/17/2007	1	2		2		4	Bull trout tagged 5/9/2007 Kootenai River - Dam to Fisher River 767mm
3D9.257C6C171A	9/18/2007 – 10/18/2007	3	4		8		12	Bull trout tagged 5/2/2007 in Kootenai River - Dam to Fisher River 740mm
3D9.1BF1C68186	9/18/2007	1	1				1	Bull trout tagged 4/19/2006 in Kootenai River - Dam to Fisher River 780mm
3D9.257C6C07B9	9/20/2007	1	1		1		2	Bull trout tagged 7/17/2007 in Quartz Creek 180mm
3D9.1BF1C69C64	9/26/2007	1			1		1	Bull trout tagged 4/22/2004 in Kootenai River - Dam to Fisher River 538mm
3D9.257C6C4255	9/28/2007 – 11/1/2007	3	44		3		47	Bull trout tagged 8/28/2007 in Quartz Creek 246mm
3D9.257C6C15D4	9/30/2007 – 3/28/2007	130	32226	199	409	29	32863	Rainbow trout tagged 8/28/2007 in Quartz Creek 180mm
3D9.257C6C5BA0	4/9/2008	1	1		1		2	Bull trout tagged 7/17/2007 in Quartz Creek 155mm
3D9.257C6C3C58	4/16/2008	1		1	1	4	6	Bull trout tagged 7/17/2007 in Quartz Creek 151mm
3D9.257C6C1DE0	4/16/2008 – 5/12/2008	11	8	39	6	80	133	Rainbow trout tagged 3/24/2008 in Quartz Creek 185mm
3D9.257C6BF EFE	5/5/2008	1			1		1	Bull trout tagged 3/24/2008 in Quartz Creek 125mm
3D9.257C6C2B65	5/9/2008	1	1				1	Rainbow trout tagged 8/28/2007 in Quartz Creek 183mm
3D9.257C5A48F1	5/14/2008	1	1		1		2	Rainbow trout tagged 6/14/2007 in Quartz Creek 337mm
Grand Total			38363	4827	1605	4933	49728	

Table 8-4. Summary of bull trout detections and movement direction at the remote PIT tag station in Quartz Creek, a tributary to the Kootenai River, Montana from July 2007 to June 2008.

PIT tag Code	Unidentified movement direction	Upstream movement	Downstream movement	Days between detections	Adult / Juvenile	Genetics Assignment (1 st and 2 nd choice locations)
3D9.257C5B0652		9/2/2007			Adult	NA
3D9.257C6C1083		9/11/2007	9/19/2007	8	Adult	NA
3D9.1BF1C4CD8F	9/12/2007				Adult	NA
3D9.257C6C5688		9/12/2007	10/10/2007	28	Adult	NA
3D9.257C6C3280		9/17/2007			Adult	Wigwam, West Fisher
3D9.257C6C171A		10/10/2007	10/18/2007	8	Adult	West Fisher, Obrien
3D9.1BF1C68186	9/18/2007				Adult	Wigwam, West Fisher
3D9.257C6C07B9			9/20/2007		Juvenile, 180mm	
3D9.1BF1C69C64	9/26/2007				Adult	Wigwam, West Fisher
3D9.257C6C4255			11/1/2007		Juvenile, 246mm	
3D9.257C6C5BA0			4/9/2008		Juvenile, 155mm	
3D9.257C6C3C58			4/16/2008		Juvenile, 151mm	
3D9.257C6BFEFE	5/5/2008				Juvenile, 125mm

Figure 8-13. Juvenile bull trout estimate ($\#/m^2$) in the West Fork of Quartz Creek, a tributary to the Kootenai River, Montana.

Figure 8-14. Length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007.

Figure 8-14 continued. Length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007.

Figure 8-14 continued. Length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007.

Figure 8-14 continued. Length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007.

Figure 8-14 continued. Length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007.

1997- 2007 Juvenile Bull Trout

Figure 8-15. Combined length frequency of juvenile bull trout collected during annual electrofishing surveys from 1997-2007. Surveys were during July and August.

Table 8-5. Annual survival of juvenile bull trout in the West Fork of Quartz Creek from 1997-2007. Data collected during the juvenile estimates, ages estimated from the combined length frequency of juvenile bull trout collected from 1997-2007 (Figure 8-15). Ages were estimated from the combined length frequency histogram as Age-0 30-69mm, Age-1 70-119mm, Age-2 120-189mm, Age-3 190-269mm, and Age-4 270-350mm.

Year Class Annual Survival (%)	Age 0 to Age 1	Age 1 to Age 2	Age 2 to Age 3
1997			
1998			13.79
1999			4.44
2000			11.32
2001			11.43
2002			
2003			2.70
2004			4.17
2005			
2006			
2007			

CHAPTER 9 – Mainstem River Age, Growth, and Condition

Methods

Age and Growth

Fish scales were collected during population estimates from 10 randomly selected fish per centimeter group per species. Scales were collected between the dorsal and anal fins above the lateral line. Species, length, weight, sample date, and location were recorded on each scale envelope prior to scales being placed inside an envelope to dry. Scale samples will be pressed onto acetate slides using a Carver model C press at 200 °F at 15,000 PSI for 1 minute. Annuli will be distinguished following methods described in DeVries and Frie (1996) and Weisberg and Frie (1987). Sagittal otoliths (salmonids) are collected when possible (i.e., mortality) and viewed whole or if necessary, transverse sections are made using a Metaserve 2000 grinder/polisher or an Isomet slow speed saw at a thickness of 0.5 mm. Annuli were distinguished as a translucent band followed by an opaque band. Age was and will be estimated as the number of opaque bands (Sharp and Bernard 1988; Hall 1991; Secor et al. 1992; Hining et al. 2000; Ihde and Chittenden 2002). Pectoral fin rays will be collected if mortalities occur and prepared using methods similar to Cuerrier (1951) and Scidmore and Glass (1953). Pectoral or pelvic fin rays will be excised proximal to the body and allowed to dry in scale envelopes, labeled with the corresponding length, weight, species, location, and date of collection. Proximal portions of fin rays will be set in epoxy and sectioned on the transverse plane at a thickness from 0.25-0.5 mm. Scale impressions, pectoral fin ray sections, and otoliths will be viewed on a Nikon SMZ-2T dissecting microscope with a MediaCybernetics Model PL-A662 binocular and digital imager. Images of annuli on scales, fin rays, and otoliths will be digitally recorded and measured. Back-calculated mean length at age will be related to environmental variables including flow variation, dam operation strategy, and other environmental conditions (DeVries and Frie 1996). Once age analysis is completed, estimated ages will be applied to the length frequency histogram, and survival and mortality estimates will be calculated using methods previously mentioned in this report.

Fish Condition Indices

Condition of fish was calculated using relative weight (W_r ; Anderson and Neumann 1996) for rainbow, westslope cutthroat, and bull trout using the formula: $W_r = ((\text{Observed weight} / \text{standard weight}) * 100; \text{Table 9-1})$.

Table 9-1. List of fish species and their associated standard weight equation intercept and slope and minimum length. The standard weight equation format is $\text{Log}_{10}(W_s) = a + b(\text{Log}_{10} \text{ TL})$ where a = intercept, b = slope, and TL = total length of the fish.

Species	Habitat	Intercept a	Slope b	Minimum Length (mm)	Reference
Bull trout		-5.237	3.115	120	Hyatt and Hubert 2000
Rainbow trout	Lotic	-5.023	3.024	120	Simpkins and Hubert 1996
Cutthroat trout	Lotic	-5.189	3.099	130	Kruse and Hubert 1997

Statistical Analysis

Condition of bull trout, rainbow trout, and westslope cutthroat trout were summarized by year and by 100mm length groups (e.g, 100-199mm, 200-299mm, etc.). A Waller Duncan k-ratio test was used to test for significant differences in mean relative weight between years and between length groups of fishes using SAS (SAS 2006). A p-value ≤ 0.05 reflects significant differences between years or length groups of fishes.

Results and Discussion

Condition

Mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River of has generally been in the 80's and 90's since 1972, with a few averages in the 70's and lower 100's (Table 9-2). Since 1990, mean relative weight of shorter rainbow trout has generally been higher than that of longer rainbow trout (Table 9-3). Within each 100mm length group, no trends were evident because of interannual variability (Table 9-4). Since the early 1980's, 100mm length group rainbow trout have shown higher average relative weight than rainbow trout from 1974-1982 (Table 9-4). Rainbow trout from 300 to 399mm have shown lower relative weight on average than rainbow trout in the 1970's (Table 9-4).

Rainbow trout in the Rereg section of the Kootenai River have generally had mean relative weights in the 80's (Table 9-5). No trends have been evident in the Rereg section since 2001, as condition has been steady both within years and between length groups (Table 9-6 and 9-7).

Mean relative weight of westslope cutthroat trout in the Flower-Pipe section of the Kootenai River have ranged between 77 and 110 from 1972-2007, with most averages in the 80's (Table 9-8). Early historical data in the Flower-Pipe section showed increases in mean relative weight with increasing length, but like rainbow trout, most of the recent data shows decreasing average relative weight as length increases (Table 9-8). Cutthroat trout in the Rereg section of

the Kootenai River are less than 400mm total length and have mean relative weights ranging from 79-93 since 2001 (Table 9-9).

Mean relative weight of bull trout in the 3 miles below Libby Dam typically have average relative weights greater than 95 with most 100mm length groups having averages greater than 100 (Table 9-10). The general trend is that as the length increases, bull trout are in better condition from the Dam to the Fisher River confluence. This trend continued in 2008. Relative weight of bull trout captured in Rereg and Flower-Pipe sections are captured during other population estimates but typically have average relative weights greater than 90, similar to the 3 miles downstream of Libby Dam (Table 9-10). There were few significant differences in the average relative weight within each of the 100mm length groups between years (Table 9-11) and no trend in condition was evident. Significant differences occurred in 2004 between several 100mm length groups, with a trend of increasing condition as length increased (Table 9-12) but fewer significant differences have occurred since 2004. In the spring of 2008, a sample of bull trout were collected via nighttime electrofishing near Troy, Montana near O'Brien Creek. Bull trout downstream of Kootenai Falls had lower condition indices than those located directly downstream of Libby Dam (Figure 9-1; Table 9-13), however only the 600 and 700mm groups were significantly different (Table 9-13). A larger sample size downstream of Kootenai Falls will be collected in 2009 to make a better comparison between condition of bull trout above and below Kootenai Falls. With the entrainment of fish (i.e., primarily kokanee) at Libby Dam, it bull trout directly downstream of Libby Dam may have a higher condition than bull trout downstream of Kootenai Falls due to the seasonally high energy available.

Table 9-2. Mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River by 100mm length group from 1973-2007.

	Length Group					
Year	100mm	200mm	300mm	400mm	500mm	600mm
1972	106	97	99	107		
1973	102	98	100	98		
1974	89	90	94	96	105	
1975	95	94	93	92	95	96
1977	89	94	102	106	104	107
1978	81	98	101	100	77	
1979	89	88	91	91	89	
1980	85	93	93	93	91	
1981	88	90	88	88		
1982	87	88	87	90		
1983	118	103	96	77		
1985						
1986	100	96	91	53		
1987	98	99	91			
1988	93	91	88		81	
1989	96	94	85	91	88	
1990	99	94	87	82		
1991	106	102	90			
1993	102	96	87	89		
1994	98	97	89	100		
1995	100	97	89	82		
1997						
1999						
2001						
2002						
2003	98	95	90	90		
2004	102	99	92	86		
2005	99	96	88	101		
2006	96	92	86			
2007	93	91	85			

Table 9-3. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each year, 100mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Year	Group	Group	Year	Group	Group	Group	Year	Group	Group	Group
1972	A		1973	A			1974	A	B	
100	106		100	102			100		89	
200	97		200	98			200		90	
300	99		300	100			300		94	
400	107		400	98			400	****96****		
							500	105		
1975	A		1977	A	B	C	1978	A	B	
100	95		100			89	100		81	
200	94		200		****94****		200	98		
300	93		300	****102****			300	101		
400	92		400	106			400	100		
500	95		500	****104****			500		77	
600	96		600	107						
1979	A		1980	A	B		1981	A		
100	89		100		85		100	88		
200	88		200	93			200	90		
300	91		300	93			300	88		
400	91		400	93			400	88		
500	89		500	****91****						
1982	A		1983	A	B	C	1986	A	B	
100	87		100	118			100	100		
200	88		200		103		200	96		
300	87		300		96		300	91		
400	90		400			77	400		53	
1987	A	B	1988	A			1989	A		
100	98		100	93			100	96		
200	99		200	91			200	94		
300		91	300	88			300	85		
			400				400	91		
			500	81			500	88		

Table 9-3 continued. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each year, 100mm length groups with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Year	Group	Group	Group	Year	Group	Group	Group	Year	Group	Group	Group
1990	A	B	C	1991	A	B	C	1993	A	B	C
100	99			100	106			100	102		
200	***94***			200		102		200		96	
300		***87***		300			90	300			87
400			82	400				400			89
1994	A	B		1995	A	B		2003	A	B	
100	***98***			100	100			100	98		
200	***97***			200	97			200	***95***		
300		91		300	***89***			300		90	
400	100			400		82		400		90	
2004	A	B	C	2005	A	B		2006	A	B	C
100	102			100	***99***			100	96		
200	***99***			200	***96***			200		92	
300		***92***		300		88		300			86
400			86	400	101			400			
2007	A	B	C								
100	93										
200		91									
300			85								
400											

Table 9-4. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$). Example: 1972 has statistically the same average relative weight as 1973, 1991, 1993, and 2004.

100mm group	A	B	C	D	E	F	G	H	I
1972		106							
1973		****102****							
1974							****89****		
1975					****95****				
1977							****89****		
1978									81
1979							****89****		
1980								****85****	
1981							****88****		
1982								87	
1983	118								
1986			****100****						
1987			*****98*****						
1988						****93****			
1989				*****96*****					
1990			*****99*****						
1991		106							
1993		****102****							
1994			*****98*****						
1995				100					
2003			*****98*****						
2004		****102****							
2005			*****99*****						
2006				*****96*****					
2007						****93****			

Table 9-4 continued. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

200mm group	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1972				****97****										
1973		****98****												
1974												****90****		
1975						****94****								
1977					*****94*****									
1978		*****98*****												
1979													****88****	
1980							****93****							
1981										****90****				
1982														88
1983	103													
1986			*****96*****											
1987		****99****												
1988										*****91*****				
1989						****94****								
1990							****94****							
1991	102													
1993			*****96*****											
1994			*****97*****											
1995			****97****											
2003					*****95*****									
2004		99												
2005				*****96*****										
2006								****92****						
2007									****91****					

Table 9-4 continued. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

300mm group	A	B	C	D	E	F	G	H	I	J	K	L
1972		***99***										
1973	***100***											
1974				***94***								
1975					93							
1977	102											
1978	***101***											
1979					*****91*****							
1980					93							
1981									*****88*****			
1982										*****87*****		
1983			***96***									
1986					*****91*****							
1987					*****91*****							
1988								*****88*****				
1989											***85***	
1990										*****87*****		
1991						*****90*****						
1993										*****87*****		
1994					*****89*****							
1995						*****89*****						
2003						*****90*****						
2004					***92***							
2005										*****88*****		
2006											***86***	
2007												85

Table 9-4 continued. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

400mm group	A	B	C	D	E	F	G	H
1972	107							
1973	*****98*****							
1974	*****96*****							
1975		*****92*****						
1977	***106***							
1978	*****100*****							
1979			*****91*****					
1980		*****93*****						
1981			*****88*****					
1982			*****90*****					
1983							77	
1986								53
1989			*****91*****					
1990						***82***		
1993			*****89*****					
1994	*****100*****							
1995					*****82*****			
2003			*****90*****					
2004				*****86*****				
2005	*****101*****							

Table 9-4 continued. Comparison of the mean relative weight of rainbow trout in the Flower-Pipe section of the Kootenai River below Libby Dam. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$).

500mm group	A	B
1974	105	
1975	*****95*****	
1977	104	
1978		77
1979	*****89*****	
1980	*****91*****	
1988	*****81*****	
1989	*****88*****	

Table 9-5. Mean relative weight of rainbow trout in the Rereg section of the Kootenai River by 100mm length group from 2001-2008.

	Length Group							
Year	100mm	200mm	300mm	400mm	500mm	600mm	700mm	800mm
2001	74	77	82	85			148	
2002	81	79	87	77				
2003								
2004	86	84	84	82				
2005	84	84	83	91	125			
2006	82	82	81	78				53
2007	79	80	81	76	92			
2008	81	82	81					

Table 9-6. Comparison of the mean relative weight of rainbow trout in the Rereg section of the Kootenai River below Libby Dam. Within each 100mm length group, years with the same letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$). Example 100mm group: 1975 has statistically the same average as 1973, 1974, and 1980.

Length Group Year	Group	Group	Group	Group	Group
100mm group	A	B	C	D	E
2001					74
2002			*****81*****		
2004	86				
2005		84			
2006		*****82*****			
2007				79	
2008		*****81*****			
200mm group	A	B	C	D	
2001				77	
2002			79		
2004	84				
2005	84				
2006		82			
2007			80		
2008		82			
300mm group	A	B	C		
2001		*****82*****			
2002	87				
2004		84			
2005		*****83*****			
2006			81		
2007			81		
2008			81		
400mm group	A				
2001	85				
2002	77				
2004	82				
2005	91				
2006	78				
2007	76				

Table 9-7. Comparison of the mean relative weight of rainbow trout in the Rereg section of the Kootenai River below Libby Dam. Within each year, 100mm length groups that have an overlapping letter grouping (e.g., A, B, or C) were the same using a Waller-Duncan sign ratio test ($P \leq 0.05$). Example 2002: 100mm group is the same as the 200, 300, and 400mm groups.

YEAR Length group	Group	Group	Group	YEAR Length group	Group	Group
2001	A	B	C	2002	A	B
100mm			74	100mm		81
200mm		*****77*****		200mm		79
300mm		*****82*****		300mm	87	
400mm		85		400mm		77
700mm	148					
2004	A	B		2005	A	B
100mm	88			100mm		84
200mm	84			200mm		84
300mm	84			300mm		83
400mm	88			400mm		91
				500mm	125	
2006	A	B		2007	A	
100mm	82			100mm	79	
200mm	82			200mm	80	
300mm	81			300mm	81	
400mm	78			400mm	76	
800mm		53		500mm	92	
2008	A					
100mm	81					
200mm	82					
300mm	81					

Table 9-8. Mean relative weight of westslope cutthroat trout in the Flower-Pipe section of the Kootenai River by 100mm length group from 1972-2007.

	Length Group				
Year	100	200	300	400	500
1972	82	95	89	98	
1973		93	94		108
1975	96	89	87	80	
1977	87	96	103	110	
1983		96	86		
1986		101	86		
1987		92			
1988		98	87		
1990	95	88	89		
1993	97	94	89		
1994	95	96	94		
1995		94	89		
2003	77	91	90		
2004	101	95	87		
2005	92	88	86	79	86
2006	92	87	84	84	
2007	87	87	84		

Table 9-9. Mean relative weight of westslope cutthroat trout in the Rereg section of the Kootenai River by 100mm length group from 2001-2007.

	Length Group		
Year	100	200	300
2001			79
2004		84	86
2005		83	84
2006		83	81
2007	81	76	92
2008		79	79

Table 9-10. Mean relative weight of bull trout located in the Kootenai River, Montana by 100mm length group from 1972-2007.

	Length Group								
River Section Year	100	200	300	400	500	600	700	800	900
Dam-Fisher									
2004			95	93	101	106	109	114	
2005			99	98	111	118	121	121	99
2006				117	107	113	118	114	
2007			94	101	106	104	111	110	
2008		93	88	106	106	108	109	105	123
Rereg									
2001				107					
2002			95			101	82		
2003						98	103		
2004		88		84	105	113		84	
2005		91	106				114		
2006		97	99			110	88		
2007		91	101			106			
2008		92		103					
Flower-Pipe									
1972	117								
1974	96	96	107	114					
1982				104					
1987		119							
1993	92	109		108					
1994				120					
2003		99	91			95	85		
2004	107	106	96		100	107	87		
2005			96	106	98		106		
2006		96		85		110			
2007			85			114			

Table 9-11. Comparison of the mean relative weight of bull trout in the Kootenai River population estimate below Libby Dam. Years within 100mm groups with a different group (e.g., A, B, or C) were statistically different using a Waller-Duncan sign ratio test ($P \leq 0.05$).

Length Group Year	Group	Group	Group
200mm	A		
2008	93		
300mm	A		
2004	94		
2005	99		
2007	94		
2008	88		
400mm	A	B	
2004		93	
2005		98	
2006	117		
2007	*****101*****		
2008	*****106*****		
500mm	A		
2004	101		
2005	111		
2006	107		
2007	106		
2008	106		
600mm	A	B	C
2004			106
2005	118		
2006	*****113*****		
2007			104
2008		*****108*****	
700mm	A	B	C
2004			109
2005	121		
2006	*****118*****		
2007		*****111*****	
2008			109
800mm	A	B	
2004	*****114*****		
2005	121		
2006	*****114*****		
2007	*****110*****		
2008		105	

Table 9-12. Comparison of the mean relative weight of bull trout in the Kootenai River population estimate below Libby Dam. Length groups within years with a different group (e.g., A, B, C, or D) were statistically different using a Waller-Duncan sign ratio test ($P \leq 0.05$).

YEAR Length group	Group	Group	Group	Group
2004	A	B	C	D
300mm				95
400mm				93
500mm			101	
600mm		*****106*****		
700mm	*****109*****			
800mm	114			
2005	A	B	C	
300mm	*****99*****			
400mm			98	
500mm	*****111*****			
600mm	*****118*****			
700mm	*****121*****			
800mm	121			
900mm		*****99*****		
2006	A			
400mm	117			
500mm	107			
600mm	113			
700mm	118			
800mm	114			
2007	A	B		
300mm		94		
400mm	*****101*****			
500mm	106			
600mm	*****104*****			
700mm	111			
800mm	110			
2008	A	B	C	
200mm		*****93*****		
300mm			88	
400mm	*****106*****			
500mm	*****106*****			
600mm	*****108*****			
700mm	*****109*****			
800mm		*****105*****		
900mm	123

Figure 9-1. Summary of bull trout relative weight from the 3-miles downstream of Libby Dam and the population below Kootenai Falls in April 2008.

Table 9-13. Summary of bull trout relative weights from below Libby Dam and below Kootenai Falls in the spring of 2008 and the results of ANOVA between 100mm length groups.

100mm Length Group	River Section	Sample Size	Mean Relative Weight	ANOVA p-value
500	Dam	21	106	0.191
	Troy	3	95	
600	Dam	36	108	0.002
	Troy	4	90	
700	Dam	26	109	0.018
	Troy	6	95	
800	Dam	11	109	0.201
	Troy	2	92	

Growth

Recaptured PIT tagged bull trout were used to calculate growth ($\text{mm}\cdot\text{day}^{-1}$ and $\text{g}\cdot\text{day}^{-1}$) since the date each fish was released. Only fish that were recaptured more than 14 days after the previous release date were used to minimize inflated growth estimates caused by measurement errors, specifically length measurements. Growth of bull trout approximately 400-500mm total length had growth ranging from $0.43\text{--}0.49\text{ mm}\cdot\text{day}^{-1}$, 600mm bull trout average about $0.2\text{ mm}\cdot\text{day}^{-1}$, and 800mm bull trout average near $0.1\text{ mm}\cdot\text{day}^{-1}$ (Figure 9-2). The amount of growth in fish length generally declined from 350 to 850mm as expected. Growth in $\text{g}\cdot\text{day}^{-1}$ was much less variable. The average was near 5 grams per day, with a few fish losing weight between recaptures, likely due to full versus empty stomachs (Figure 9-3). Two fish showed exceptional growth, 1 fish put on 3.6kg (8lb) in 1 year and another 0.9kg (lb) in a month and a half, amounting to over 20 grams per day of growth (Figure 9-3). No trends in growth (grams per day) were apparent. The average bull trout growth since 2004 has been steady, ranging from $0.05\text{ to }0.32\text{ mm}\cdot\text{day}^{-1}$ (Table 9-14). The negative growth of fish tagged in 2006 was due to slight discrepancies in length measurements. Fish were tagged during the population estimate in the spring and recaptured during spill monitoring in June. Different personnel measured fish possibly accounting for some of the negative growth. In 2007 and 2008, several smaller bull trout (i.e., $<300\text{mm}$) were PIT tagged downstream of Libby Dam, which will assist in quantifying growth of smaller bull trout in the Kootenai River. Currently maximum growth of bull trout occurs between 350 and 500mm total length at tagging, averaging 150-175mm per year (Figure 9-2). Rainbow trout growth estimated from recaptured PIT tagged fish has been much more variable, range from $0.00\text{ to }0.33\text{ mm}\cdot\text{day}^{-1}$. Sample sizes were one for each year (i.e., 2004 2006, and 2007). Only one westslope cutthroat trout has been recaptured for growth estimation, and the estimate was $0.06\text{ mm}\cdot\text{day}^{-1}$, similar to the rainbow trout and bull trout (Table 9-14). Average growth in grams per day has been steady for bull trout since 2004 (range $0.47\text{ to }8.35\text{ g}\cdot\text{day}^{-1}$; Table 9-15). Two fish ($6.72\text{ and }8.35\text{ g}\cdot\text{day}^{-1}$) caused high variability in the growth estimates of 2006 and 2007 recapture year estimates. Rainbow trout growth has averaged near 0.25 grams per day, with two significantly higher ($0.60\text{ g}\cdot\text{day}^{-1}$) and lower ($-0.72\text{ g}\cdot\text{day}^{-1}$) annual average growth estimates (Table 9-15).

Figure 9-2. Growth of recaptured bull trout ($\text{mm}\cdot\text{year}^{-1}$) in the Kootenai River below Libby Dam from 2004 to 2007. Only length measurements greater than 14 days were used to minimize measurement error effects on growth.

Figure 9-3. Growth of recaptured bull trout ($\text{g}\cdot\text{year}^{-1}$) in the Kootenai River below Libby Dam from 2004 to 2007.

Table 9-14. Summary of growth ($\text{mm}\cdot\text{d}^{-1} \pm \text{SD}$) measured by recaptured PIT tagged fish in the Kootenai River, Montana. Only length measurements greater than 14 days apart were used to calculate growth.

Species	Year Tagged	Year Recaptured				
		2004	2005	2006	2007	2008
Bull trout	2004	0.093 ± 0.173	0.221 ± 0.089	0.153 ± 0.093	0.075 ± 0.062	0.136 ± 0.026
	2005			0.046 ± 0.026	$0.183 \pm \text{NA}$	
	2006			-0.046 ± 0.117	0.326 ± 0.112	0.194 ± 0.142
	2007				0.242 ± 0.230	0.212 ± 0.150
Rainbow trout	2004			$0.001 \pm \text{NA}$	$0.086 \pm \text{NA}$	
	2005			0.062 ± 0.056	0.034 ± 0.006	
	2006			0.087 ± 0.072	0.054 ± 0.039	0.052 ± 0.021
	2007				-0.032 ± 0.150	0.049 ± 0.043
Westslope cutthroat	2004			$0.061 \pm \text{NA}$		
	2005					
	2006					
	2007					$0.082 \pm \text{NA}$

Table 9-15. Summary of growth ($\text{g}\cdot\text{d}^{-1} \pm \text{SD}$) measured by recaptured PIT tagged fish in the Kootenai River, Montana. Only weight measurements greater than 14 apart were used to calculate growth.

Species	Year Tagged	Year Recaptured				
		2004	2005	2006	2007	2008
Bull trout	2004	1.924 ± 4.329	5.701 ± 1.610	2.378 ± 1.799	1.110 ± 1.703	0.661 ± 2.186
	2005			-0.715 ± 0.139	$3.004 \pm \text{NA}$	
	2006			$-2.742 \pm \text{NA}$	3.681 ± 0.685	2.293 ± 2.733
	2007				8.349 ± 19.248	4.538 ± 3.005
Rainbow trout	2004			$0.163 \pm \text{NA}$	$0.604 \pm \text{NA}$	
	2005			0.297 ± 0.459	0.222 ± 0.026	
	2006			0.182 ± 0.177	0.298 ± 0.290	0.221 ± 0.097
	2007				$-0.724 \pm \text{NA}$	0.029 ± 0.087
Westslope cutthroat	2004			$-0.003 \pm \text{NA}$		
	2005					
	2006					
	2007					

CHAPTER 10 – Bull trout risk based population modeling

Methods

The bull trout risk based population modeling was contracted with Montana State University. The contract required production of an annual report / manuscripts that will be uploaded to the BPA site after completion.

Objective 1. Develop conservation theory and methods for effective application of risk-based monitoring to inland salmonid populations.

TASK 1. Develop analysis methods for population monitoring with a series of risk estimates in the VPM framework.

TASK 2. Develop analysis methods to account for sampling error and missing observations in exponential growth PVA.

Objective 2. Refine Flathead bull trout models for better predictive ability and management use.

TASK 1. Assist with sample design and data analysis for native fish data collection in Flathead and Kootenai rivers.

TASK 2. Refine Flathead bull trout models in light of new data

TASK 3. Use refined bull trout population models to make management recommendations and plan future population research.

Objective 3. Analysis and risk estimation for regional bull trout populations taking into consideration variation in environmental factors, dam operation, community structure, and life history.

TASK 1. Count-based VPM for regional populations

TASK 2. Model comparisons of regional bull trout populations

FUTURE RESEARCH NEEDS and DIRECTION

Although a lot of research and monitoring have been performed in the Kootenai River drainage in Montana since the late 1960's, several data voids remain and may be of interest for future research and monitoring efforts and include:

- Assess how entrainment of fishes has changed since the early 1990's as a result of dam operations and evaluate impacts to the fisheries upstream and downstream of Libby Dam
- Assess delta formation at major spawning tributaries in the Kootenai River drainage to see if they could become barriers to spawning fish at certain river levels. Delta formation can also be related to dam operations as the Kootenai River may lack the energy to remove materials due to reduced discharges
- Quantify the effects of modifying the thermal regime of the Kootenai River, specifically the thermal maximum temperatures in the summer months, and quantify how this would impact rainbow and bull trout growth bioenergetics
- Quantify the seasonal nature of *Didymosphenia geminata* blooms in the Kootenai River from Libby Dam to the Fisher River confluence and evaluate impacts of bloom severity in relation to abiotic conditions resulting from dam operations
- Sample white sturgeon downstream of Kootenai Falls to assess survival and growth of sturgeon stocked into the Montana portion of the Kootenai River downstream of Libby Dam. No baseline information exists on the sturgeon population downstream of Kootenai Falls and data will supplement data collected by Idaho Fish and Game and the Kootenai Tribe of Idaho in the Idaho portion of the Kootenai River
- Attempt to obtain a population estimate of bull trout downstream of Kootenai Falls. The estimate can be used for comparison to the population estimate from Libby Dam to the Fisher River confluence. We will also be able to compare growth and condition of the two populations above and below Kootenai Falls and assess survival of bull trout in the Kootenai River
- Assess the origin of large rainbow trout downstream of Libby Dam to see if they are entrained fish or originate from downstream of the dam
- Expand the existing IFIM models in the Kootenai River to the section from Libby Dam to the Fisher River as this section is most impacted by dam operations

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APPENDICES

Species abbreviations used in the text and tables of this report:

CRC = peamouth
CSU = largescale sucker
DV = bull trout
EBT = eastern brook trout
FSU = longnose sucker
HYB = hybridized rainbow trout and cutthroat trout
KOK = kokanee
LING = burbot
LMB = largemouth bass
MWF = mountain whitefish
NP = northern pike
NSQ = northern pikeminnow
PUMP = pumpkinseed
RBT = rainbow trout
RBTxWCT = rainbow trout x westslope cutthroat trout hybrid
RSS = redbside shiner
RSS x CRC = redbside shiner x peamouth hybrid
WCT = westslope cutthroat trout
YEP = yellow perch

Units or statistical abbreviations used in the text and tables of this report:

acre-ft = acre-feet
BW = body weight
CI = confidence interval
cfs = cubic feet per second
cm = centimeter
ft = foot or feet
ft² = square foot
ft³/s = cubic feet per second
in = inch
kcfs = thousand feet per second
km = kilometer
km² = square kilometer
m = meter
mg/l = milligrams per liter
mi = mile
mi² = square mile
m² = square meter

m^3/s = cubic meters per second

mm = millimeter

N = number or sample size

ppm = parts per million

rKm = river kilometer

rm = river mile

SD = standard deviation

SE = standard error

WETP = wetted perimeter

% = percent

Other abbreviation used in this report:

B.C. = British Columbia

spp. = species (refers to multiple species within the same genus)

U.S.A. = United States of America

W_r = relative weight

W_s = standard weight