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

Annual Report
July 1, 2005 – June 30, 2006

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Bonneville Power Administration Project No. 2006-008-00
Contract No. 28350

January 2007

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EXECUTIVE SUMMARY

A new project began in 2005 to monitor the biological and physical effects of the Northwest Power and Conservation Council (NPCC) Mainstem Amendment, which modifies dam operations at Hungry Horse and Libby Dams, Montana. Under the new operating guidelines, July through September reservoir drafts will be limited to 10 feet from full pool in the upper 80% of water supply years and 20 feet from full pool in the lowest 20% of water supply (drought) years. The Mainstem Amendment also imposes limits on how rapidly discharge from the Dams can be increased or decreased depending on time of year. The NPCC directed Libby and Hungry Horse Dams to implement and evaluate this interim summer operating strategy. This report highlights the monitoring methods and preliminary results that will be used to monitor the effects of the Mainstem Amendment on fisheries, habitat, and aquatic invertebrates above and below Libby Dam. Presently, the Mainstem Amendment has not been implemented, but aspects of the strategy have been incorporated in the United States Army Corps of Engineers (USACE) variable discharge (VARQ) flood control strategy.

A variety of methods will be used to monitor the biological and physical effects of the Mainstem Amendment on the habitat and fauna within portions of the Kootenai and Flathead watersheds. Evaluation methods will include modeling physical and biological conditions within the reservoir systems above and below Libby and Hungry Horse Dams, in conjunction with annual gill netting to assess reservoir conditions. Annual fish population surveys on sections of the Kootenai and Flathead Rivers, along with age estimates from scales, fin rays, and otoliths, will be used to estimate survival and growth of fishes in the mainstem rivers and selected tributaries within each basin. Radio telemetry will be used to validate existing Instream Flow Incremental Methodology (IFIM) / habitat use models developed for the Kootenai River below Libby Dam and will also be used to assess fish movements for comparison to previous radio telemetry monitoring efforts below Libby Dam. Fish movements and habitat use in relation to flow ramping rates will also be assessed. Passive integrated transponder (PIT) tags will be injected in fishes throughout the Mainstem Kootenai River and selected tributaries to provide information on growth, survival, and movement of fishes in relation to environmental variables. Model simulations will be used to calculate the effects of dam operations on the wetted perimeter and productivity in the Kootenai River below Libby Dam. Models (IFIM) will also be used to evaluate the impacts of dam operations on the amount of available habitat for several life stages and fish species in the Kootenai and Flathead Rivers.

Future project plans include more research focused on mainstem tributaries, specifically investigating fish growth and survival, timing of fish movements, and how environmental variables influence tributary fish populations and abundance. The recolonization of benthic invertebrates in the varial zone of the Kootenai River will be assessed to validate RIVBIO benthic production models and may be used to quantify the impacts of discharge fluctuations below Libby Dam, including quantifying the amount of productivity (e.g., numbers or biomass) lost or gained due to changing discharge levels. Additional research may include estimating the productivity of Lake Koocanusa, which was last assessed in the late 1980’s.

INTRODUCTION

The purpose of this report is to present methods and preliminary data that will be used to monitor the physical and biological effects of the Northwest Power and Conservation Council's Mainstem Amendment on fisheries above and below Libby and Hungry Horse Dams, Montana for the work period of July 1, 2005 to June 30, 2006. The nine objectives for this project are:

Objective 1 – Use LRMOD and HRMOD to model the physical conditions in Libby and Hungry Horse Reservoirs.

Objective 2 – Use LRMOD and HRMOD to model the biological conditions in Libby and Hungry Horse Reservoirs.

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

Objective 4 – Update reservoir models (LRMOD and HRMOD) to better predict or estimate the biological and physical conditions and unregulated flow component of the reservoirs.

Objective 5 – Use the Instream Flow Incremental Methodology (IFIM) and RIVBIO (wetted perimeter and benthic productivity) models to estimate the amount of habitat available for fishes and benthic production under different dam operating strategies.

Objective 6 – Estimate salmonid cohort survival and mortality in the Mainstem Kootenai and Flathead Rivers and relate survival to environmental conditions (e.g., temperature, variability) resulting from different dam operations.

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

Objective 8 – Assess how dam operations and tributary conditions affect survival, growth, life history, and hybridization of westslope cutthroat and rainbow trout in the upper Flathead River and selected tributaries in the Flathead River Basin. Objectives in the Kootenai River basin are to estimate survival, fish movement, and growth of fishes in Quartz Creek, a tributary to the Kootenai River below Libby Dam.

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

Several concepts have been formulated through time 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 exhibit natural conditions including 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 including precipitation, temperature, and elevation changes. However, many of the natural conditions and processes of rivers are altered by the construction of dams.

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 more small dams not inventoried (USACE 2006; http://crunch.tec.army.mil/nid/webpages/nid.cfm). Dams have been constructed for power production, flood control, municipal water sources, recreation, navigation, and a suite of additional reasons. Natural river conditions and processes before dam construction are often lost due to flow regulation and separation from the natural floodplain. Dam construction and 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).

Below dams, common changes include altered or reversed hydrographs, altered thermal conditions, lack of flooding below the dam, armoring of streambeds, changes in river channel morphology, lack of sediment transport and renewal, 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; 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 1999; Muhlfeld et al. 2000). Zubik and Fraley (1987) found that the 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. 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 above Altus Dam and changes in species composition relative to other streams not affected by the dam. Several studies have assessed fragmentation and isolation of populations, which can increase the likelihood of local extinction of species (Rieman and McIntyre 1993 1995, 1996; Dunham et al. 1997). Modified streamflows reduce fish community complexity (Bain et al. 1988) and streamflow variability can alter the functional organization of species and species assemblages (Poff and Allan 1995). Streamflow variability can also affect lower trophic levels, especially within the varial zone (Ward 1976). Blinn et al. (1995) found that permanently submerged channel areas supported 4 times the macroinvertebrate mass than the varial zone in the Colorado River, below Glenn Canyon Dam. The varial zone becomes unproductive because aquatic, terrestrial, and benthic vegetation that would normally provide nutrients, forage, and cover do not establish due to fluctuating river discharge. Cereghino and Lavandier (1998a) documented that hydropeaking reduced densities and biomass of mayflies (Ephemeroptera) and altered stream temperatures in the River Oriege, France. Diel fluctuations 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 during the 2 weeks prior to sampling in the Skagit

River, Washington, USA and abundance 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 abundances and diversity of neotropical fishes below Petit-Saut dam in South America. Fluctuating discharge has been shown to affect bull trout that use channel margins at night (Muhlfeld et al. 2003). 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; ISAB 1997; USFWS 1999; NOAA-Fisheries 2000; Conner et al. 2003). A balance between the hydropower systems' capability to provide power and the conservation of numerous fish species within the system must be achieved, while not extirpating species, negatively affecting species, or hindering recovery efforts within portions of the Columbia River Basin. The Mainstem Amendment may help 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). Reservoir drawdown may be increased to 20 feet (elevation 2439) from full pool during these months in drought years. The NPCC Mainstem Amendment is designed to stabilize water releases into the Kootenai and Flathead Rivers during the productive summer months and to protect aquatic resources in the headwaters of the Kootenai River drainage, while providing suitable conditions for anadromous species in the lower Columbia River. In addition to limiting reservoir drawdown, ramping rates of discharge will be limited at Libby and Hungry Horse Dams by daily and hourly maximum rates. The ramping rates vary depending on time of year, 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 Amendment is implemented, and monitoring and evaluation are completed. It may take several years to detect and quantify actual effects, particularly at higher trophic levels.

Several methods are available to quantify the potential effects of new dam operations at Libby and Hungry Horse Dams. Instream Flow Incremental Methodology (IFIM; Bovee 1982) research by Montana Fish, Wildlife, and Parks will allow quantification of physical habitat and habitat use relative to river discharge. Restoring the most natural flow regime during the summer months will protect ecosystem processes and may help restore native fish populations in the Kootenai River (Marotz et al. 2002). Reservoir biology of Lake Koocanusa was assessed in the 1980's and 1990's and led to the formation of several models of physical and biological conditions above and below Libby Dam (Chisholm et al. 1989; Marotz et al. 1996). The potential effects of four different dam operating strategies on sediment transport, fishes, river stage, and flow have been evaluated below Flaming Gorge Reservoir. 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 overwinter survival if coordinated with reductions in stocking efforts. These operational changes could also result in increased food production and spawning habitat availability (Hlohowskyj and Hayse 1995). In addition to reservoir and river models, evaluation of the effects of the Mainstem Amendment will incorporate other information obtained from annual gill netting, electrofishing, redd counts, population estimates, age and growth information, radio telemetry, and PIT tags.

STUDY AREA

Kootenai River watershed

The Kootenai River watershed is located in British Columbia (B.C.), Canada and Montana and Idaho, United States (Figure 1). The Kootenai River drainage covers an area of 45,584 km^2 (17,600 mi^2; Knudson 1994). The Kootenai River begins in Kootenay National Park, B.C. and 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 (98%; lodgepole pine and spruce forests), but has some agricultural areas in lower elevations along the river below Bonners Ferry, Idaho. Listed species under the Endangered Species Act (ESA) in the Kootenai River watershed include the bull trout *Salvelinus confluentus* and white sturgeon *Acipenser transmontanus.* The Kootenai River population of white sturgeon is listed as an endangered species and bull trout are listed as a threatened species under the Endangered Species Act (ESA; U. S. Fish and Wildlife Service 1999; U. S. Fish and Wildlife Service 2002). Additional species not listed include rainbow trout *Oncorhynchus mykiss*, burbot *Lota lota*, and westslope cutthroat trout *Oncorhynchus clarki lewisi* (Table 4).

Libby Dam and the Kootenai River

Construction of Libby Dam began in 1966 after authorization by the Columbia River International Treaty of 1964 and was completed in 1972 (Knudson 1994). The Kootenai River was officially impounded at river mile 221.7 on March 21, 1972 creating Lake Koocanusa (Woods and Falter 1982) approximately 25 km upstream of Libby Montana. Libby Dam was constructed to provide flood control, hydropower generation, recreation, and other uses for the surrounding area (Bonde and Bush 1982). Construction and operation of the dam significantly altered the hydrograph of the Kootenai River (Figures 2 and 3). Before dam construction, peak spring discharge of the Kootenai River occasionally reached 2,264 m^3/s (80,000 ft^3/s) and the average peak was 1,839.5 m^3/s (65,000 ft^3/s). After Libby Dam was completed, spring flows typically reach 600-700 m^3/s (20,000-25,000 ft^3/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 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 large peak discharge in late summer (Figures 3 and 4). Flow variation was also highly variable on an hourly, daily, and seasonal basis (Hauer et al. 1997) with no constraints on rates at which flow could be altered. If implemented, the Mainstem Amendment imposes constraints on the frequency and magnitude of discharge fluctuations in the Kootenai and South Fork Flathead Rivers (Tables 1 and 2). 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 seasonal thermal regimes of the Kootenai River have also been unnaturally altered Libby Dam. Although selective withdrawal capabilities have allowed management for more natural thermal conditions now compared to early operations, winter water temperatures remain warmer below Libby Dam, perhaps contributing to a decline in burbot abundance in the Kootenai River (Paragamian et al. 2001).

Lake Koocanusa

Lake Koocanusa 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 and area of 46,500 acres at full pool (Table 3). Lake Koocanusa provides popular sport fishing opportunities for rainbow trout, kokanee, and in recent years, for bull trout on an experimental basis, in addition to containing many other species (Table 4). Lake Koocanusa typically fills near the end of June. Recent spill events from Libby Dam have occurred in June and July 2002 and in June 2006. Post dam maximum flows from Libby Dam in 2002 reached 40,000 ft^3/s while peak flows were approximately 55,000 ft^3/s in June 2006, the highest on record since completion of Libby Dam and regulation of flows from the dam. These high flows were more typical of pre-dam flows and much greater than post dam discharges through Libby Dam (Figure 3). Lake Koocanusa was historically drafted more than 30 m (100 ft) but recent operations have resulted in smaller 40 to 50 foot drafts of the reservoir, creating more area for biological productivity and provide additional water surface area for uses such as recreation. 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.

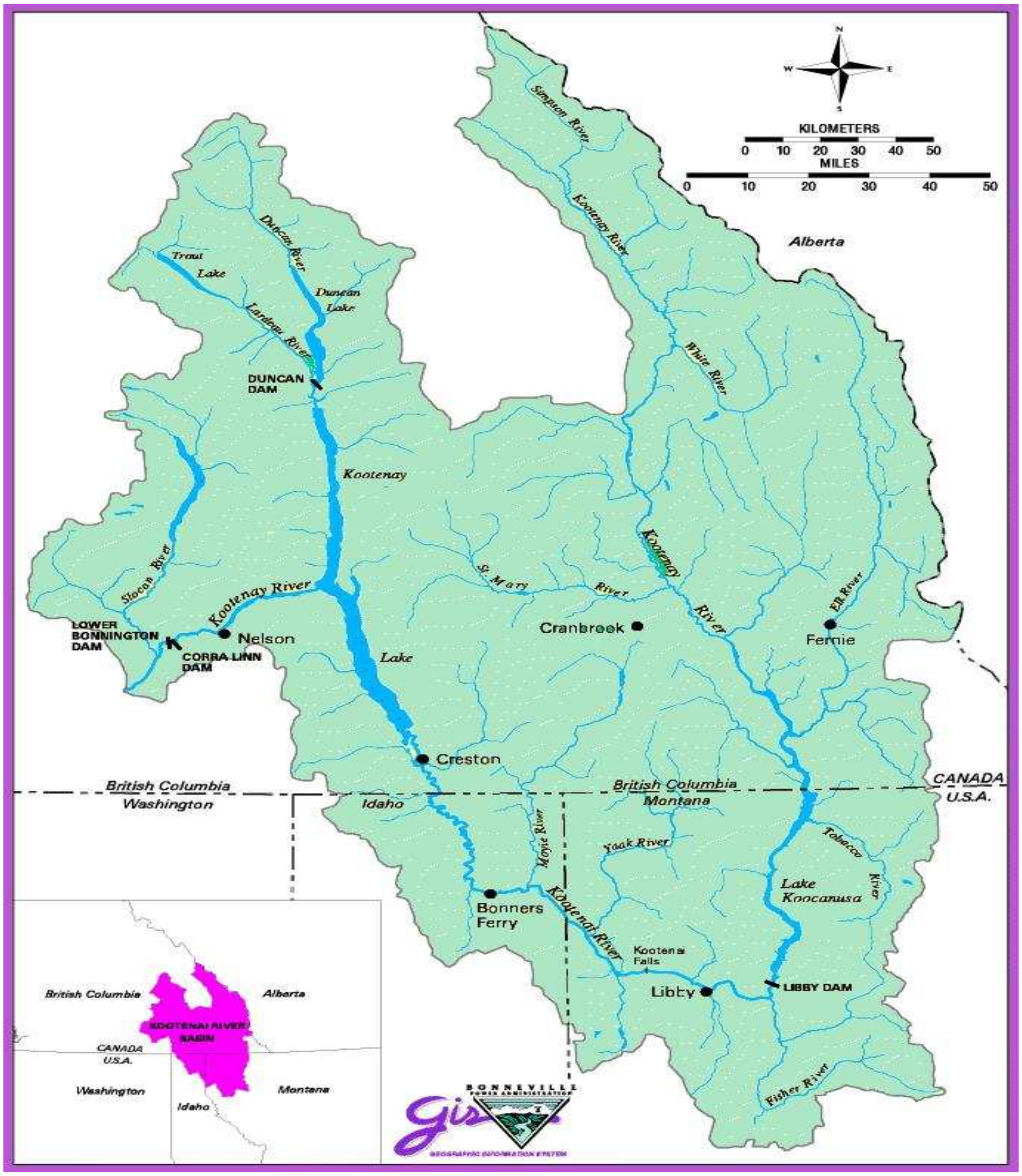


Figure 1. Location of the Kootenai River watershed in the United States and Canada along with several key features within the watershed (from Dunnigan et al. 2003).

Table 1. Daily and hourly ramp up and ramp down 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 interim summer operating strategy. The abbreviation cfs = cubic feet per second (ft^3/s).

Dam	Flow Range (cfs)	Ramp direction	Daily max (cfs day^{-1})	Hourly max (cfs $hour^{-1}$) 1 Oct–30 Apr	Hourly max (cfs $hour^{-1}$) 1 May–30 Sep
Libby	4,000 - 6,000	Up	1 unit day^{-1} (5,000 cfs day^{-1})	2,000	1,000
Libby	> 6,000-9,000	Up	1 unit day^{-1} (5,000 cfs day^{-1})	2,000	1,000
Libby	> 9,000-17,000	Up	1 unit day^{-1} (5,000 cfs day^{-1})	3,500	2,000
Libby	> 17,000	Up	No limit	7,000	3,500
Libby	4,000 - 6,000	Down	500 cfs day^{-1}	500	500
Libby	> 6,000-9,000	Down	1,000 cfs day^{-1}	500	500
Libby	> 9,000-17,000	Down	2,000 cfs day^{-1}	1,000	1,000
Libby	> 17,000	Down	1 unit day^{-1} (5,000 cfs d^{-1})	5,000	3,500

Table 2. Daily and hourly ramp up and ramp down rates for Hungry Horse Dam, Montana as measured by daily flows. These ramp rates are part of the Northwest Power and Conservation Council's Mainstem Amendment interim summer operating strategy. The abbreviation cfs equals cubic feet per second (ft^3/s).

Dam	Flow Range (cfs)	Ramp Direction	Daily Max (cfs day^{-1})	Hourly Max (cfs $hour^{-1}$)
Hungry Horse	3,500-6,000	Up	1,800	1,000
Hungry Horse	> 6,000-8,000	Up	1,800	1,000
Hungry Horse	> 8,000-10,000	Up	3,600	1,800
Hungry Horse	> 10,000	Up	No limit	1,800
Hungry Horse	3,500-6,000	Down	600	600
Hungry Horse	> 6,000-8,000	Down	1,000	600
Hungry Horse	> 8,000-12,000	Down	2,000	1,000
Hungry Horse	> 12,000	Down	5,000	1,800

Table 3. Statistics of Lake Koocanusa (Libby Reservoir) located in northwest Montana, approximately 25 km upstream of Libby, Montana (from Chisholm et al. 1989).

Statistic	**Value**
Surface elevation	
Max pool	749.5 m (2,459 ft)
Min operational pool	697.1 m (2,287 ft)
Min pool	671.2 m (2,222 ft)
Area	
Max pool	188 km^2 (46,500 acre)
Min operational pool	58.6 km^2 (14,487 acre)
Volume	
Max pool	7.24 km^3 (5,869,400 acre-ft)
Min operational pool	1.10 km^3 (890,000 acre-ft)
Max length	145 km (90 mi)
Max depth	107 m (350 ft)
Mean depth	38 m (126 ft)
Shoreline length	360 km (224 mi)
Shoreline development	7.4 km (4.6 mi)
Storage ratio	0.68 yr
Drainage area	23,271 km2 (8,985 mi^2)
Drainage area: surface area	124: 1

Table 4. 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	*Ameiurus melas*	Introduced	Rare
Bluegill	*Lepomis macrochirus*	Introduced	Rare
Brook trout	*Salvelinus fontinalis*	Introduced	Rare
Brown bullhead	*Ameiurus nebulosus*	Introduced	Rare
Brown trout	*Salmo trutta*	Introduced	Rare
Bull trout	*Salvelinus confluentus*	Native	Common
Burbot	*Lota lota*	Native	Common
Goldfish	*Carassius auratus*	Introduced	Rare
Kokanee salmon	*Oncorhynchus nerka*	Native	Common
Lake trout	*Salvelinus namaycush*	Introduced	Rare
Largemouth bass	*Micropterus salmoides*	Introduced	Rare
Largescale sucker	*Catostomus macrocheilus*	Native	Abundant
Longnose dace	*Rhinichthys cataractae*	Native	Rare
Longnose sucker	*Catostomus catostomus*	Native	Rare
Mottled sculpin	*Cottus bairdi*	Native	Rare
Mountain whitefish	*Prosopium williamsoni*	Native	Abundant
Northern pikeminnow	*Ptychocheilus oregonensis*	Native	Abundant
Northern pike	*Esox lucius*	Introduced	Rare
Peamouth	*Mylocheilus caurinus*	Native	Abundant
Pumpkinseed sunfish	*Lepomis gibbosus*	Introduced	Rare
Pygmy whitefish	*Prosopium coulteri*	Native	Rare
Rainbow trout	*Oncorhynchus mykiss*	Introduced	Abundant
Redband trout	*Oncorhynchus mykiss subspecies*	Native	Rare
Redside shiner	*Richardsonius balteatus*	Native	Common
Slimy sculpin	*Cottus cognatus*	Native	Common
Smallmouth bass	*Micropterus dolomieu*	Introduced	Rare
Torrent sculpin	*Cottus rhotheus*	Native	Rare
Western mosquitofish	*Gambusia affinis*	Introduced	Rare
Westslope cutthroat trout	*Oncorhynchus clarki lewisi*	Native	Common
White sturgeon	*Acipenser transmontanus*	Native	Rare
Yellow perch	*Perca flavescens*	Introduced	Rare

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

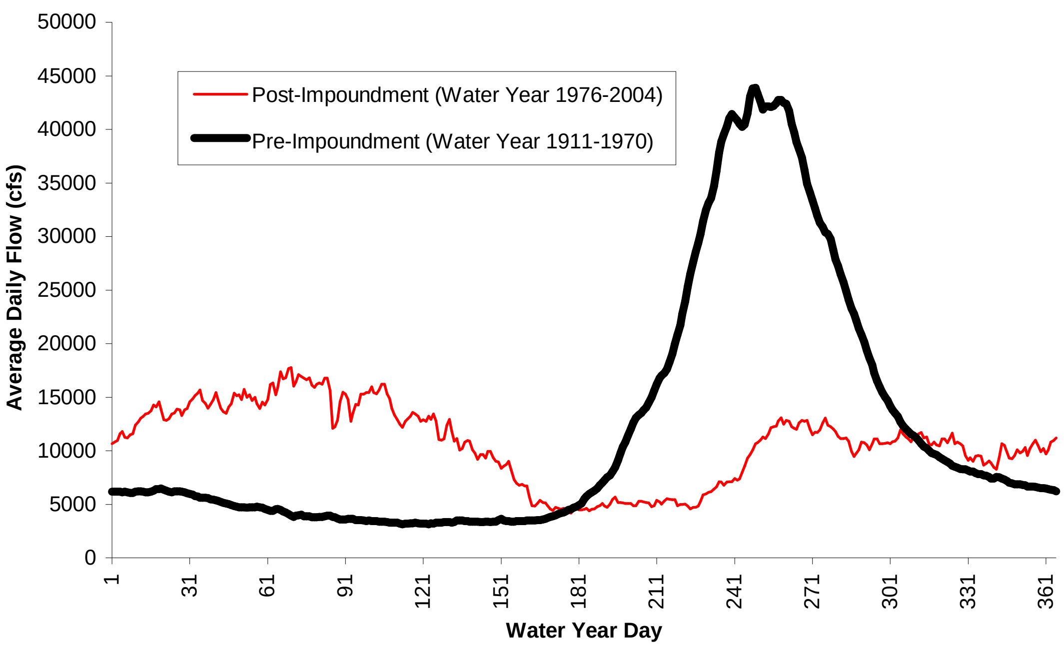


Figure 3. Average pre (USGS station 12303000) and post dam (USGS station 12301933) hydrographs of the Kootenai River below Libby Dam for the period of 1910-2004. Water years start on 1 October and end on 30 September. Leap year data for 29 February were excluded.

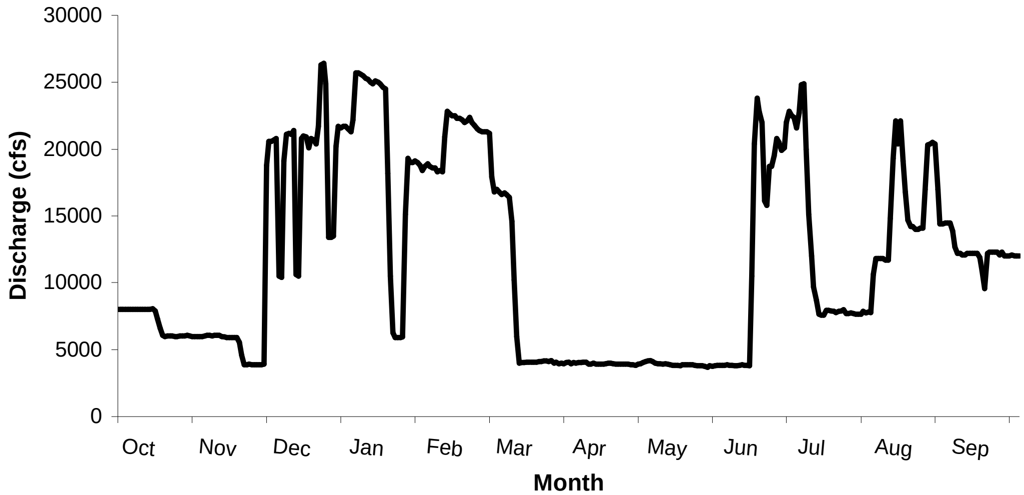


Figure 4. Water year 1999 discharge below Libby Dam. Notice the unnatural double summer peak resulting from flow augmentation for anadromous fishes called for by NOAA Fisheries Biological Opinion 2000 (NOAA-Fisheries 2000) and the unnatural winter peaks resulting from hydropower generation.

METHODS

River Modeling

Model simulations (RIVBIO; Marotz et al. 1996) of Kootenai River and South Fork Flathead River productivity and habitat conditions will be applied using average daily inflow, outflow, and surface elevation data obtained from United States Geological Survey, United States Army Corps of Engineers, or Bureau of Reclamation from Libby and Hungry Horse Dams for periods since dam construction. Benthic productivity in the Kootenai River will be calculated using average daily flows and analyzed using increments of 15, 30, 47, 60, 75, and 90-day recovery periods for benthic fauna. Forty-seven days (unregulated flow recovery time) will be considered the minimum standard recovery time for model simulations (Gersich and Brusven 1981).

Instream flow incremental methodology (Bovee 1982) models were used to develop habitat utilization curves for various fishes in the Mainstem Kootenai River (Miller and Geise 2004) and the Flathead Rivers (Miller et al. 2003). These models will be used to assess habitat availability for various life stages of fishes under different dam operating strategies to help evaluate whether or not recent dam operations provide more available suitable habitat than previous operational strategies. Discharges from Libby and Hungry Horse Dams will be used as inputs into the habitat use function curves (i.e., discharge versus area available) for juvenile and adult fishes and for diel habitat availability for bull trout. Habitat use curves were developed using known fish locations (i.e., water depth and water velocity) in surveyed reaches of the river under varying discharge levels. Habitat use curves and discharge data will be used to develop and analyze time series of habitat availability. Hourly, daily, monthly, seasonal, and annual flow variation will be quantified and compared between operating strategies where data are available.

Reservoir Modeling

Model simulations of Lake Koocanusa and Hungry Horse Reservoir productivity, habitat conditions, and fish growth (HRMOD and LRMOD; Marotz et al. 1996) will be run using, reservoir inflow, outflow, and surface elevation files for Lake Koocanusa and Hungry Horse Reservoir. Annual data files (*.dat) will be entered into the model interface and results will be compiled in Microsoft Excel for analysis. Additional data including water temperatures and climatic information (e.g., precipitation, air temperatures) will also be 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 will be evaluated and ranked according to modeled habitat conditions and biological conditions in each of the reservoirs.

Water availability (i.e., sum of the average daily discharge) from April 1 – August 31 and for the entire water year (i.e., October 1 – September 30) will be used to rank water availabilities for each water year. Water years will be stratified (e.g., 1-5; 1 = high water availability, 5 = low water availability) and model simulations will be run for similarly ranked years across dam operating strategies.

Invertebrate Recolonization of the Varial Zone

Forty-seven days is considered the minimum recolonization time for macroinvertebrates in unregulated systems, although 66 days were required in regulated streams (Gersich and Brusven 1981). Shaw and Minshall (1980) found that numbers of organisms on introduced substrates peaked before day 64. The 66-day recolonization time required may be closer to the true value in the Kootenai and Flathead River systems but the actual recolonization time is unknown. Blinn et al. (1995) found that two, 12-hour exposure periods may require more than 4 months to recover to permanently submerged levels of macroinvertebrates below Glenn Canyon Dam. Varial zone recolonization below Libby Dam will be assessed during May and June using a 1-m^2 kick sampler with 250 μm mesh to assess species composition, numbers, and colonization rates of macroinvertebrates in the Kootenai River.

The recolonization sample area is located at the Libby Dam Recreation Vehicle Park approximately 1.6 km (1 mi) downstream of the Osprey Landing Fishing Access (river mile 209.6; Figure 5). A channel profile or discharge versus wetted area map will be obtained prior to sampling as spring flows increase. The developed profile or map will allow samples to be obtained from the correct distance or area for the required number of wetted days depending on discharge. Areas in the riffle that have been wetted for a predetermined number of days (e.g., 5, 10, or 30 day intervals) during the summer months will be sampled to assess species recolonization time, species composition, and numbers of aquatic insects in newly wetted areas compared to areas in the permanently wetted channel. On each sampling day, a 0.25 m^2 grid will be placed in a random location within the predefined wetted area. One person will hold a kick net (1.0 m^2) downstream of the sample grid to collect dislodged invertebrates from substrates disturbed within the 0.25 m^2 sample area. Three invertebrate samples will be collected on each sampling interval and stored in 95% ethanol in 1 liter polypropylene bottles. Depth (m), velocity (m/s), and GPS coordinates will be recorded at each location to avoid duplicating sample locations within the sample area. Invertebrates (N = 300-500) from samples will be sorted using Montana DEQ guidelines and sorted to taxonomic Order before being sent to a lab for identification, enumeration, and calculation of additional metrics.

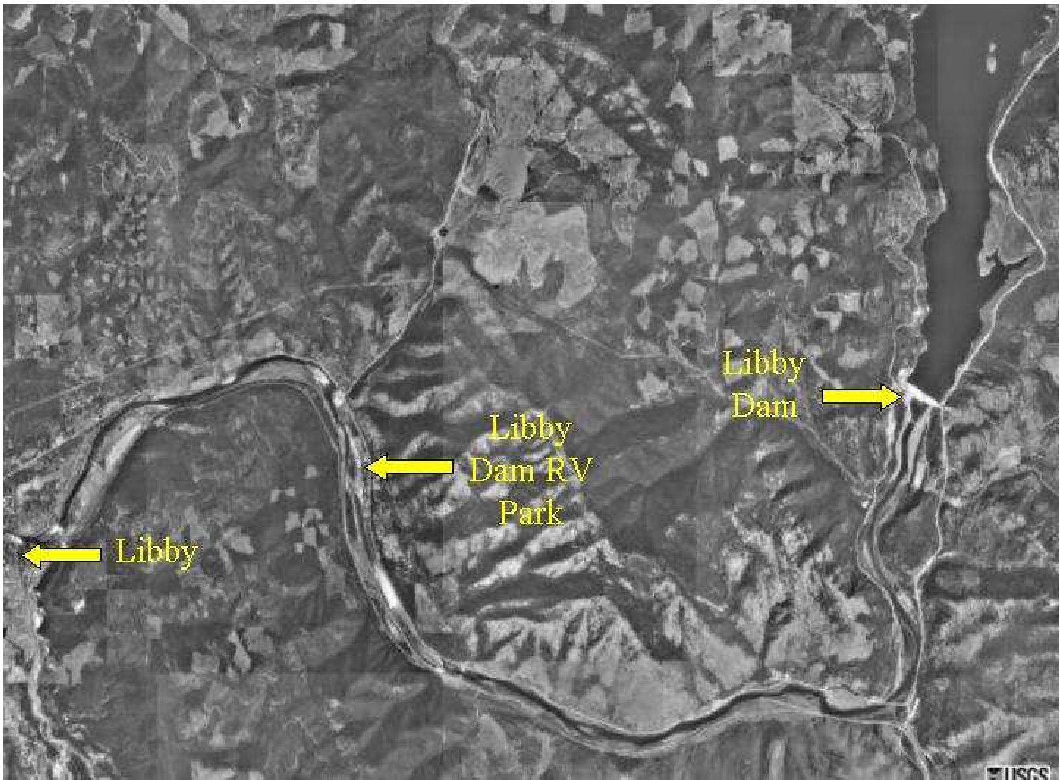


Figure 5. Location of the aquatic invertebrate recolonization study between Libby, Montana and Libby Dam. Sampling is scheduled to occur at the Libby Dam RV Park at river mile 209.6 in the spring of 2007.

Kootenai River Electrofishing

Mainstem electrofishing will be performed at night, using two boats with boom-mounted electrodes to sample the left and right banks of the river. Each boat crew will include one driver and two netters. Boats will be equipped with 4,000 or 5,000-watt generators and either a Coffelt Mark 22 or Mark 15 VVP rectifying unit. Straight DC will be used with outputs maintained at 2-3 amps and 200-300 volts. All fish sampled will be netted and placed in holding tanks in each boat until fish can be transferred to larger holding cages in the river at the fish work up station. A third boat will measure each fish, and inspect fishes for PIT tags, mark, and injuries. Captured fish will be anesthetized using an aqueous buffered solution of tricaine methanesulfonate (MS-222). As fish begin to loose equilibrium, they will be measured for total length (mm) and weight (g). During population estimates, all fishes are marked with a fin clip that is easily recognizable during recapture sampling. Recapture sampling will occur about one week after the last fish were marked depending on water conditions and weather. Population estimates will be calculated using modified Petersen and partial log-likelihood estimators using Fisheries Analysis Plus software (Fisheries Analysis + 2004).

Fish population monitoring in the Kootenai River will be accomplished using population estimates from three sections of the Kootenai River (Figure 6). River sections will include: 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).

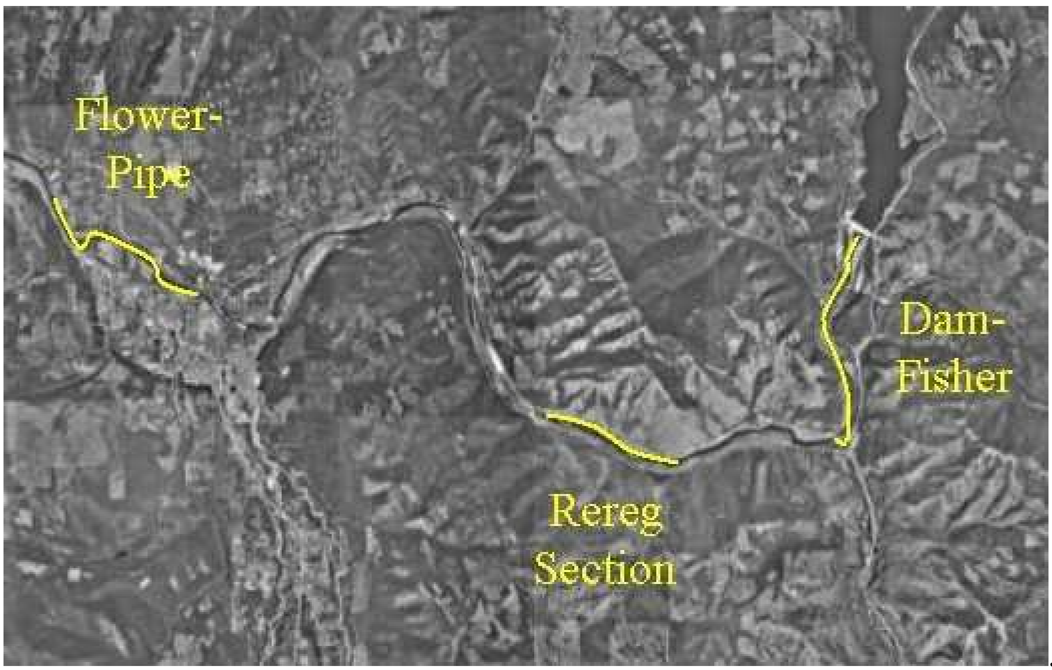


Figure 6. Location of population estimate reaches in the Kootenai River below Libby Dam, Montana. Photo courtesy of the United States Geological Survey.

Age and Growth

Fish used for age and growth analyses will be collected during nighttime electrofishing. Scales will be collected from at least the first five fish handled in length groups of 1 centimeter. Scales will be collected between the dorsal and anal fins above the lateral line. Species, length, weight, sample date, and location will be recorded on each scale envelope prior to scales being placed inside an envelope to dry. Samples will be pressed onto acetate slides using a Carver model C press at 150 ^{o}F at 15,000 PSI for 1 minute. Annuli will be distinguished following methods described in DeVries and Frie (1996). Sagittal otoliths (salmonids and burbot) and lapilli otoliths (catostomids) will be collected if possible (e.g., mortality). Otoliths will be viewed whole or if necessary, transverse sections will be obtained using a Metaserve 2000 grinder/polisher or an Isomet slow speed saw at a thickness varying from 0.25-0.5 mm. Annuli will be distinguished as a translucent band followed by an opaque band. Age 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 may be collected 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, 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. Digital images of annuli on scales, fin rays, and otoliths will be digitally recorded and measured. Annual increment lengths (i.e., Weisberg method) will be related to environmental variables including flow variation, dam operation strategy, and other environmental conditions (DeVries and Frie 1996; Weisberg and Frie 1987). Mean length-at-age will be back-calculated. Annual growth increments, mean length at age, and mean length at capture will be compared between years, between dam operation strategies, and compared to environmental variables. Once age frequencies are completed or can be estimated, survival and mortality estimates will be calculated.

Survival and Mortality Estimates

Annual survival and mortality rates will be calculated in various sections of the Kootenai River for bull trout, rainbow trout, and westslope cutthroat trout when sample size and age data is available. Additional fishes may need to be sampled to estimate age frequencies for some years of interest. Survival and mortality rates will be calculated using age data from scale and otolith samples and length frequencies from each section of river (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 is 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), population parameters (e.g., number per mile or per thousand feet), and dam operating strategy.

Fish Condition Indices

Condition of fish will be calculated using Fulton's condition factors (K and C) for species without accepted or proposed standard weight equations or relative weight (Wr; Anderson and Neumann 1996) for species with accepted or proposed standard weight equations using the formulas:

K = ((Observed weight / (length^3))*100000) for metric units (millimeters, grams)
Wr = ((Observed weight / standard weight) *100)

Length and weight measurements will be expressed in metric units. Relative weight length categories will be calculated following recommendations of Gabelhouse (1984). The midpoint of each length category range (i.e., stock, quality, preferred, memorable, and trophy) will be determined and that number will be rounded down to the nearest 50-mm interval to obtain a minimum length using the following percentages: substock <20%, stock 20-26%, quality 36-41%, preferred 45-55%, memorable 59-64%, and trophy 74-80% (Gabelhouse 1984). Mean relative weights for different species and length categories will be assessed and may provide an index of fish condition under different operating strategies. Examples of calculations used to calculate minimum lengths for species without proposed minimum length categories are presented in Table 5, proposed minimum lengths in Table 6, and standard weight equations in Table 7.

Table 5. Example of calculated minimum lengths used for relative weight length categories for a fish species without previously proposed minimum lengths.

	Substock	**Stock**	**Quality**	**Preferred**	**Memorable**	**Trophy**
Percent range	<20	20-26	36-41	45-55	59-64	74-80
World Record Length	1000	1000	1000	1000	1000	1000
Minimum Length		200	360	450	590	740
Maximum Length		260	410	550	640	800
Midpoint Length		230	385	500	615	770
Minimum Length Used	0	200	350	500	600	750

Table 6. Minimum lengths (mm) for length categories used to calculate a relative weight (W_r) for various fish species within the Kootenai River and Lake Koocanusa, Montana. The minimum lengths for mountain whitefish were not completed at the time this annual reported was completed.

Fish Species	Minimum Length (mm)	Source	Substock	Stock	Quality	Preferred	Memorable	Trophy
Bull trout	120	Hyatt and Hubert 2000	<20	20	35	50	60	75
Rainbow trout	120	Simpkins and Hubert 1996	<25	25	40	50	65	80
Mountain whitefish	140	Rogers et al. 1996	NA	NA	NA	NA	NA	NA
Cutthroat trout	130	Kruse and Hubert 1997	<20	20	35	45	60	75
Kokanee	120	Hyatt and Hubert 2000	<10	10	20	30	35	45
Burbot	200	Fisher et al. 1996	<20	20	38	53	67	82

Table 7. List of fish species and their associated standard weight equation intercept and slope and minimum length. The standard weight equation format is Log 10 (Ws) = a + b*(Log 10 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
Rainbow trout	Lentic	-4.898	2.990	120	Simpkins and Hubert 1996
Cutthroat trout	Lotic	-5.192	3.086	130	Kruse and Hubert 1997
Cutthroat trout	Lentic	-5.189	3.099	130	Kruse and Hubert 1997
Brook trout		-5.186	3.103	120	Hyatt and Hubert 2001
Mountain whitefish		-5.086	3.036	140	Rogers et al. 1996
Yellow perch		-5.386	3.230	100	Willis et al. 1991
Northen pike		-5.437	3.096	100	Willis 1989
Burbot		-4.868	2.898	200	Fisher et al. 1996
Kokanee		-5.062	3.033	120	Hyatt and Hubert 2000

Lake Koocanusa Gill Netting

Gill nets will be used to monitor the Lake Koocanusa fishery using annual spring and fall gill net series. 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) will be set overnight and pulled the following day according to standardized sampling methods (Dunnigan et. al 2003). All rainbow trout, bull trout, westslope cutthroat trout, and burbot will be measured for total length (mm) and weight (g). Scales and otoliths will be collected from all bull trout, rainbow trout, and westslope cutthroat trout and fin rays may be collected as a third structure for age estimation purposes. Scales will also be collected from kokanee if fish condition allows condition. Growth, age estimation, and condition analyses will performed using the same techniques as in the mainstem Kootenai and South Fork Flathead Rivers.

Radio Telemetry

Rainbow and bull trout will be captured for radio telemetry using nighttime electrofishing techniques mentioned previously. Fishes will be anesthetized using an aqueous non-buffered solution of MS-222 prior to examination for marks (fin clips), tags (e.g., radio or PIT), and injuries (e.g., spinal damage, predation injuries, hook scars), and before being measured for total length (mm) and weight (g). Only fish that appear healthy will be implanted with a radio tag.

Tags will be purchased from Lotek Wireless Incorporated of New Market, Ontario. A Lotek Model SRX-400 telemetry receiver will be used for mobile monitoring from boats, vehicles, or fixed-wing aircraft using a single or double tuned loop antenna, as appropriate. Fish movement and visual observations will indicate live fish. Fishes will be tracked hourly, daily, weekly or biweekly depending on season and discharge associated with dam operations. Fish handling, surgical procedures, radio tag implantation, and acquisition of fish locations will follow methods described in Dunnigan et al. 2003, Muhlfeld et al. 2003, Muhlfeld et al. 2005, and Summerfelt and Smith 1990. Radio telemetry work is intended to verify existing IFIM models developed for the Kootenai River and to help evaluate the effects of discharge fluctuation on fish movement and habitat use.

PIT tagging, tributary population estimates, and Remote PIT tag station(s) in Quartz Creek

Electrofishing in tributary streams will be conducted in daytime during the summer months when tributaries are at low flow conditions. Backpack electofishers or electrofishing equipment mounted to a canoe will be used for fish collection. Electrofishing equipment (i.e., generator and VVP) will be identical to that used in population estimates collected in the mainstem Kootenai and Flathead Rivers. Throwable electrodes will be used in larger tributaries, while mobile handheld electrodes are used in smaller streams. Elapsed time electrofishing will be recorded to calculate fish catch per unit effort of fishes (i.e., fish per hour) that can be used for comparisons between years in reaches that are sampled annually. All fish will be processed for length, weight, collection of scales if applicable, inspected for injuries and marks, and tagged using methods identical to those used in large rivers mentioned above. Fish (i.e., >150 mm) will be PIT tagged (2 x 12 mm FDX 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 7; courtesy Muhlfeld et al. 2004). PIT tags will be injected into the dorsal sinus or body cavity following conventional procedures (Figure 8; PIT Tag Steering Committee 1999). All adult bull trout captured while electrofishing will receive a PIT tag if they not previously tagged. All other fishes will receive PIT tags if fish and tag sizes are compatible and conditions are suitable for tag injection (e.g., water temperatures) depending on research needs. Fish that have been previously PIT tagged and identified as such by an adipose fin clip, will be scanned for tag identification numbers using a Destron Fearing 2001F-ISO portable transceiver. Tag identification numbers are stored in the unit but will also be recorded on corresponding data sheets and scale envelope if applicable. Depletion rate methods will be used to estimate fish abundance. A capture efficiency of 70 to 75% between consecutive passes will be required to end additional sampling. Block nets will be used at the upper and lower bounds of each reach to prevent emigration and immigration of fishes during sampling. Population estimates will be performed using Fisheries Analysis Plus software (Fisheries Analysis + 2004).

Figure 7. Photographs courtesy of Muhlfeld at al. 2004. The left panel is a picture of 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.

Figure 8. Location of PIT tag injection sites for fishes in the Kootenai and Flathead River basins for use with remote PIT tag interrogation systems and for use in growth and survival estimation. Photographs courtesy of Vince Tranquilli of the Oregon Department of Fish and Wildlife.

Statistical Analysis

Model simulations of biological and physical conditions will be summarized at the daily, monthly, and annual levels. Analysis of variance (ANOVA) will be used to test for statistical differences between groups and the appropriate post hoc test will be used to test for significant differences between specific groups or water years.

Annual population estimates in the Kootenai River will be analyzed using the Fisheries Analysis Plus software (Montana Fish, Wildlife, and Parks, Fisheries Information Services, 1400 South 19th Avenue, Bozeman, MT 59718). Depletion (smaller tributaries) and mark-recapture (larger rivers) methods will be used to estimate the numbers of fishes within specific reaches. Two forms of mark-recapture estimates may be used depending on the resolution needed from the estimates. Partial log-likelihood estimates occasionally lump several length groups together reducing the amount of resolution needed for additional analysis (e.g., mortality and survival estimates). If this occurs, the modified Petersen method may be used to retain better resolution, however, a valid grouping interval (e.g., age) method must be determined. Valid grouping intervals may be based on length groups or age groups as determined by mean length-at-age or back-calculated length at age to achieve the most biologically meaningful method to provide the greatest resolution.

Gill net data will be used to calculate species composition (% of catch by species), mean length (mm), mean weight (g), relative weight, and catch per net trends trough time in Lake Koocanusa. Species composition changes may be tested using Chi-square analysis to test for statistical differences in fish community structure between various operating strategies.

Mean length at capture will also be determined once age estimates are obtained. Previously PIT tagged fishes will have growth assessed as changes in fish length or fish weight since the last time they were caught. Fish growth will be compared to other variables including water temperature, discharge fluctuations, and population densities associated with the area where the fish were caught. Previously PIT tagged fish will have age estimates validated using scales collected at the initial capture event and at subsequent recapture events. Mean length at age and the actual annual growth increments will be compared between dam operation strategies and related to environmental variables using simple linear correlations and regression analyses. Multiple regression analysis of biotic and abiotic conditions may also be used to identify possible combinations of conditions that can predict growth increments of fishes in the Kootenai River.

Radio telemetry analysis will be performed using a GIS based program such as ArcView GIS 3.2 depending on software availability. Fish movements (meters per day between known locations) will be compared between operating strategies and ramping rate (i.e., increasing, decreasing, or stable). Movement data may need to be stratified into subgroups (e.g., species, sex, length group, tagging date or season) to test for differences between smaller groups of fishes implanted with radio tags. ANOVA will be used to test for significant differences between these groups with a p-value equal to or less than 0.05 indicating statistical significance.

All statistical analysis will be performed in SPSS version 4.0 or Microsoft Excel. A p-value less than or equal to 0.05 indicates statistical significance between operating strategies, groups, or years of data used for testing hypotheses suggesting that dam operation strategy affects the biological or physical metrics above and below Hungry Horse and Libby Dams, Montana.

RESULTS

Objective 1 – Use HRMOD and LRMOD to model physical habitat conditions

Modeling of Lake Koocanusa was completed using reservoir inflow, outflow, and surface elevation files created for different water years. Models simulations (LRMOD) indicated that stratification and thermal energy in the reservoir varied among water years (Figures 9-22). In most years, the reservoir was isothermal from approximately December 1 to April 1 each year. Typical maximum water temperatures were between 18 and 22 degrees Celsius in late July and early August before surface water temperatures begins to cool. Water temperature data on the face of Libby Dam were available for water years 2000-2005. Modeled and actual isotherms did not agree very well during the fall months and for the coldest water temperatures. Actual fall isotherms of the four and 6-degree isotherms typically were 20-40 meters deeper in the reservoir than were indicated by the model simulations (Figures 17-22). Actual summer 4 and 6-degree isotherms were slightly underestimated, with colder water extending deeper in the water column than estimated by model simulations. Destratification of the water column in the fall occurred later than the reservoir model predicted. Model simulations indicated the reservoir was isothermal November or December, but actual data showed destratification in January or February at the face of Libby Dam. Summer stratification also started later than model simulations, with stratification starting near the middle of April to early May (Figures 9-22). The number of degree days in recent years has been lower than previous years, perhaps due to recent increases in reservoir elevation, that slow cooling and warming of the reservoir (Figure 23).

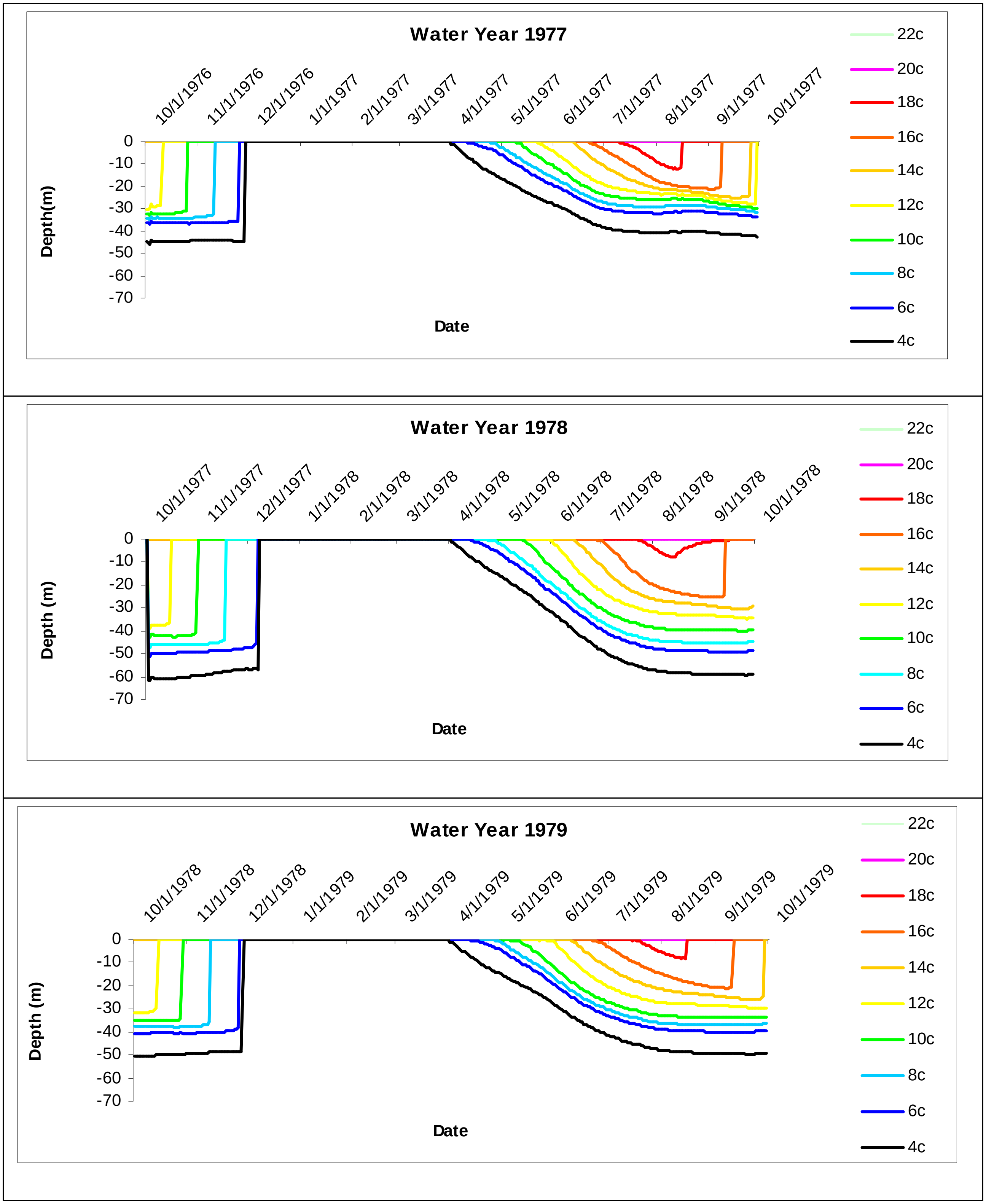


Figure 9. Modeled isotherms in Lake Koocanusa, Montana for water years 1977-1979.

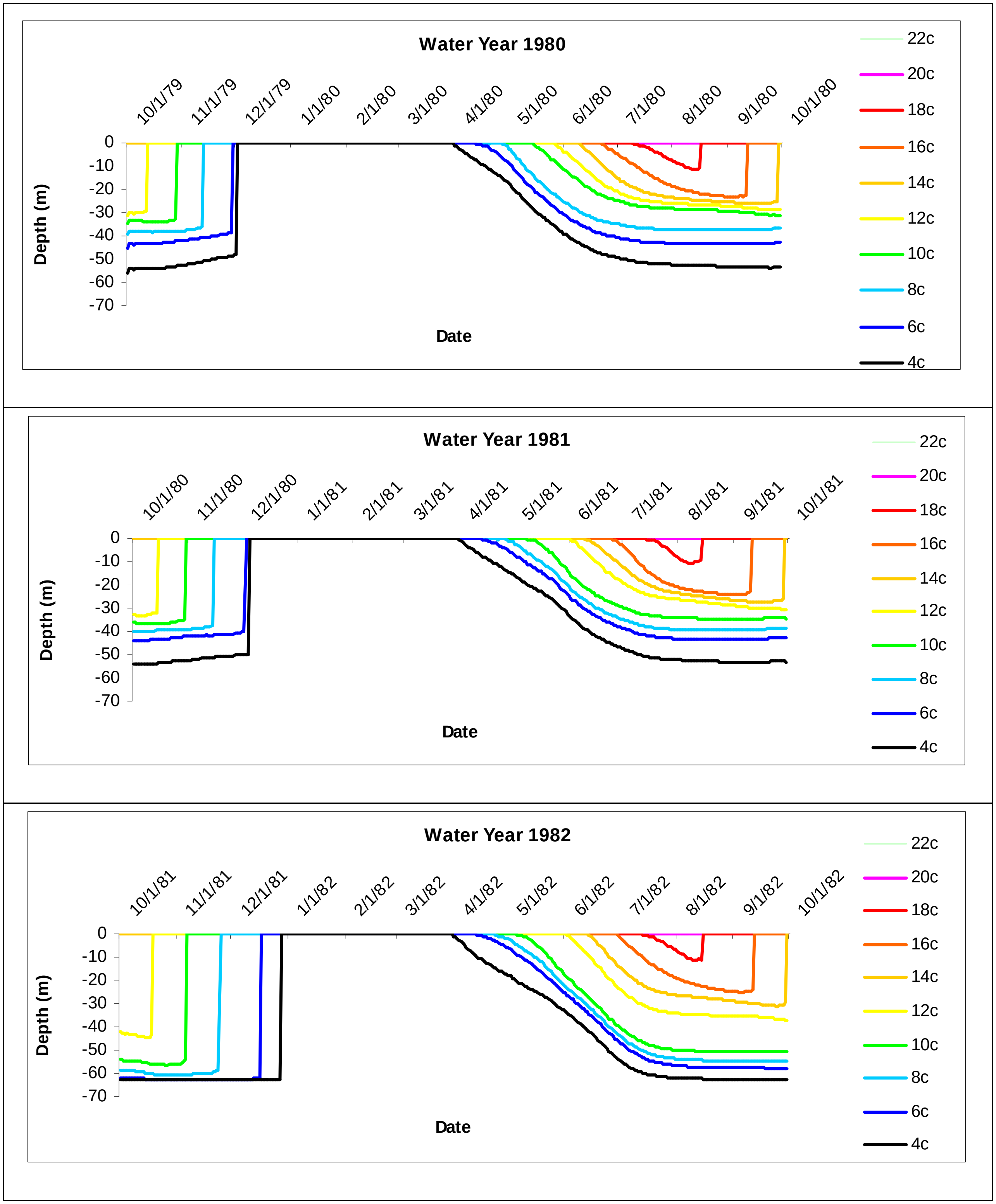


Figure 10. Modeled isotherms in Lake Koocanusa, Montana for water years 1980-1982.

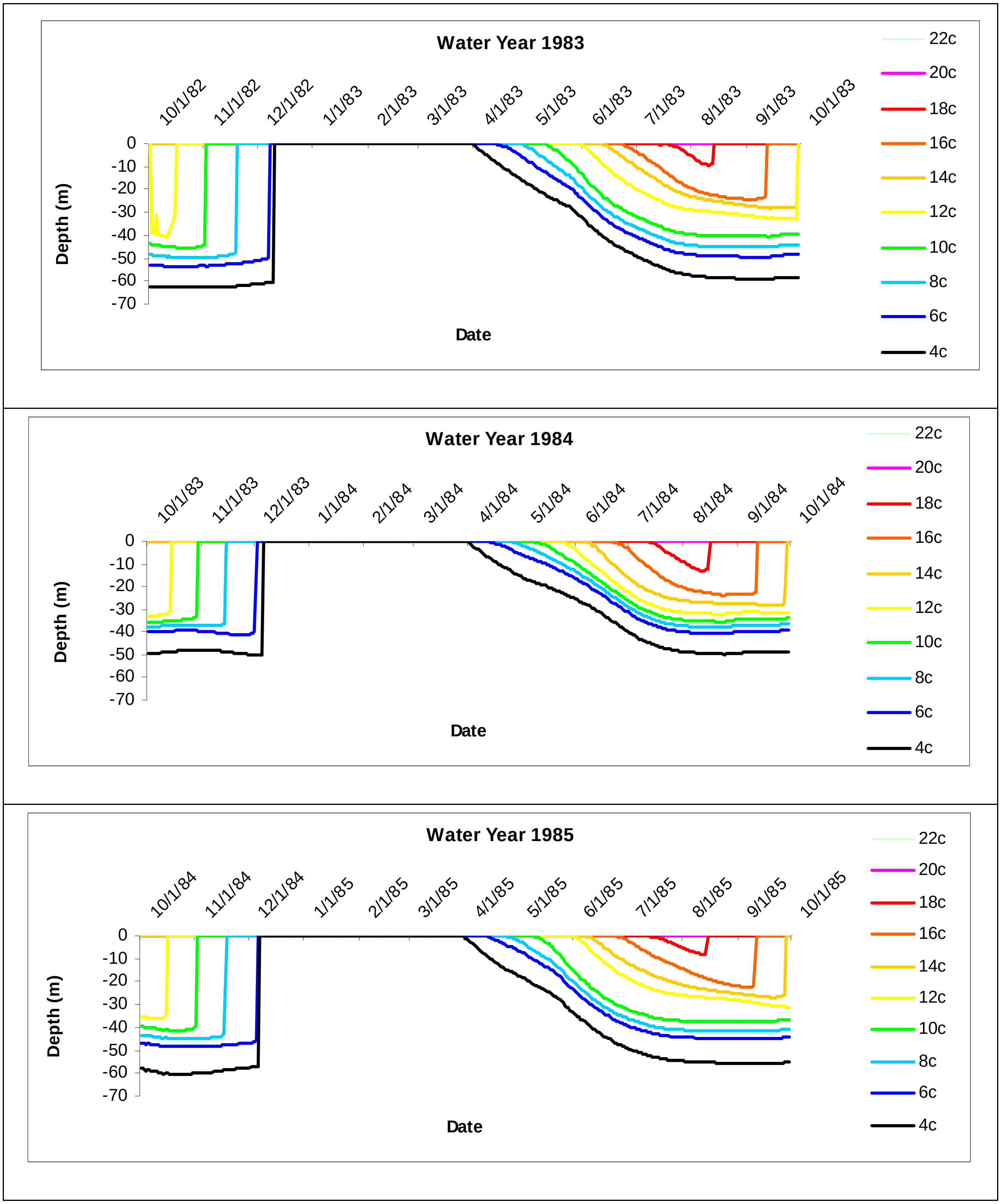


Figure 11. Modeled isotherms in Lake Koocanusa, Montana for water years 1983-1985.

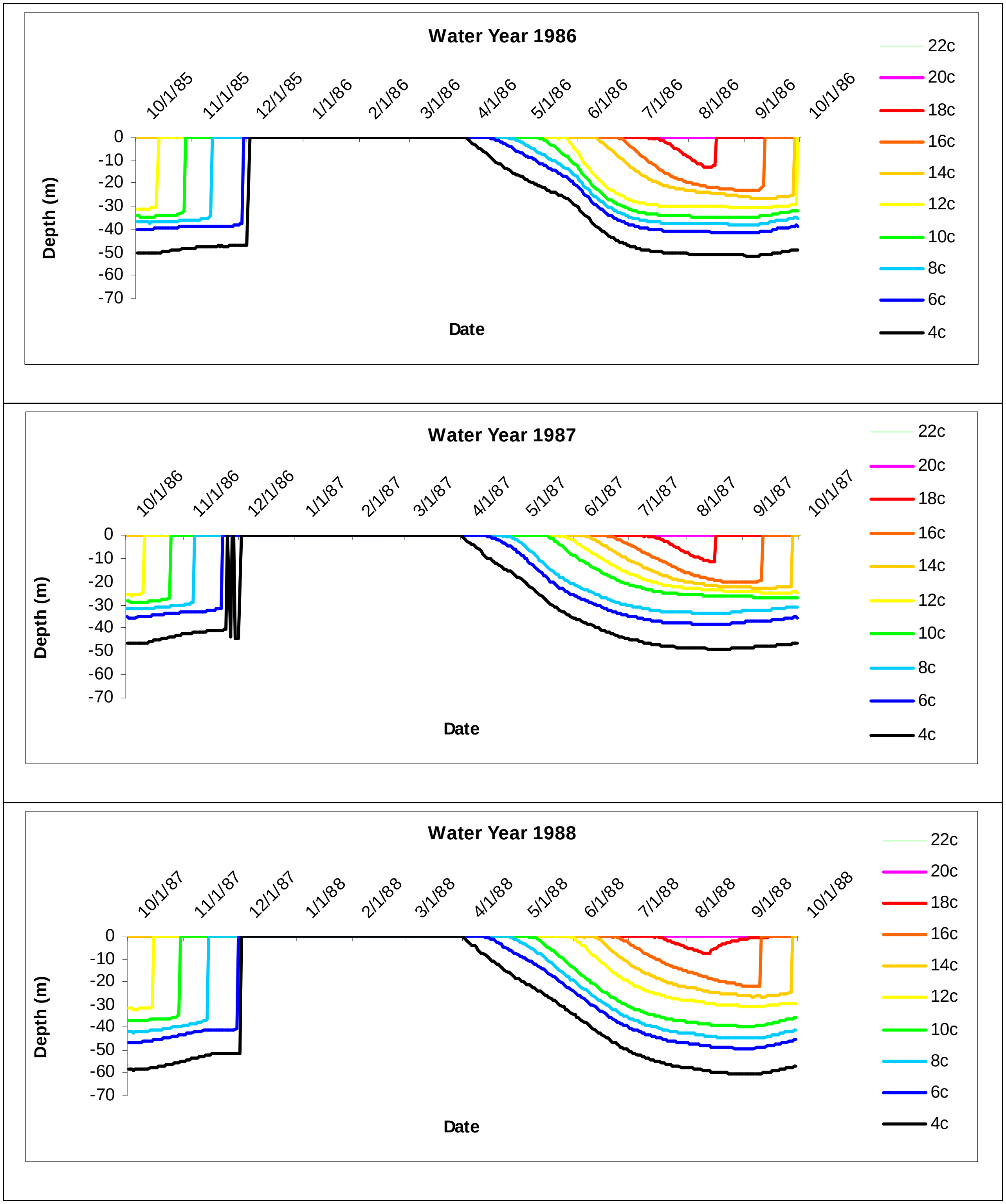


Figure 12. Modeled isotherms in Lake Koocanusa, Montana for water years 1986-1988.

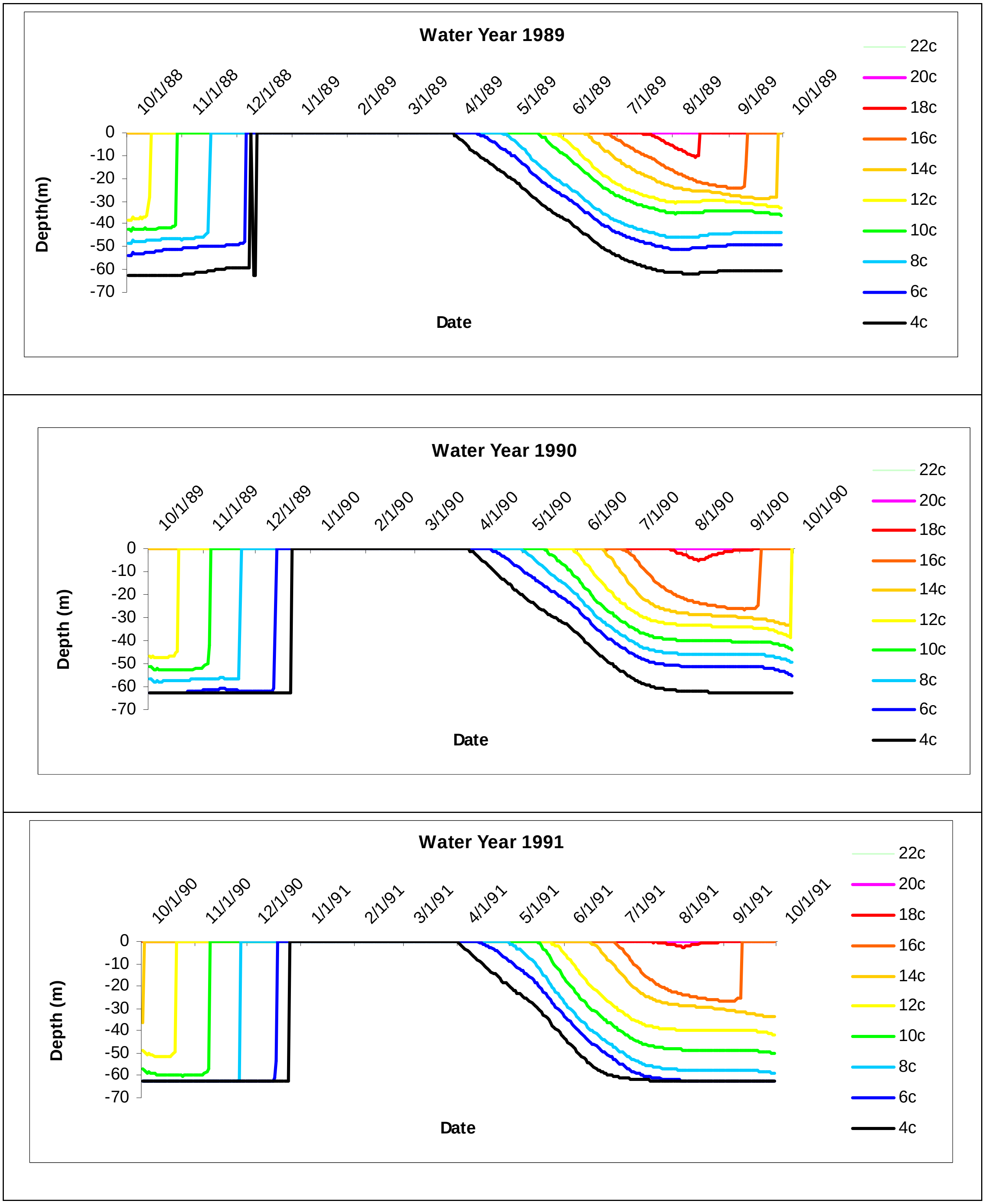


Figure 13. Modeled isotherms in Lake Koocanusa, Montana for water years 1989-1991.

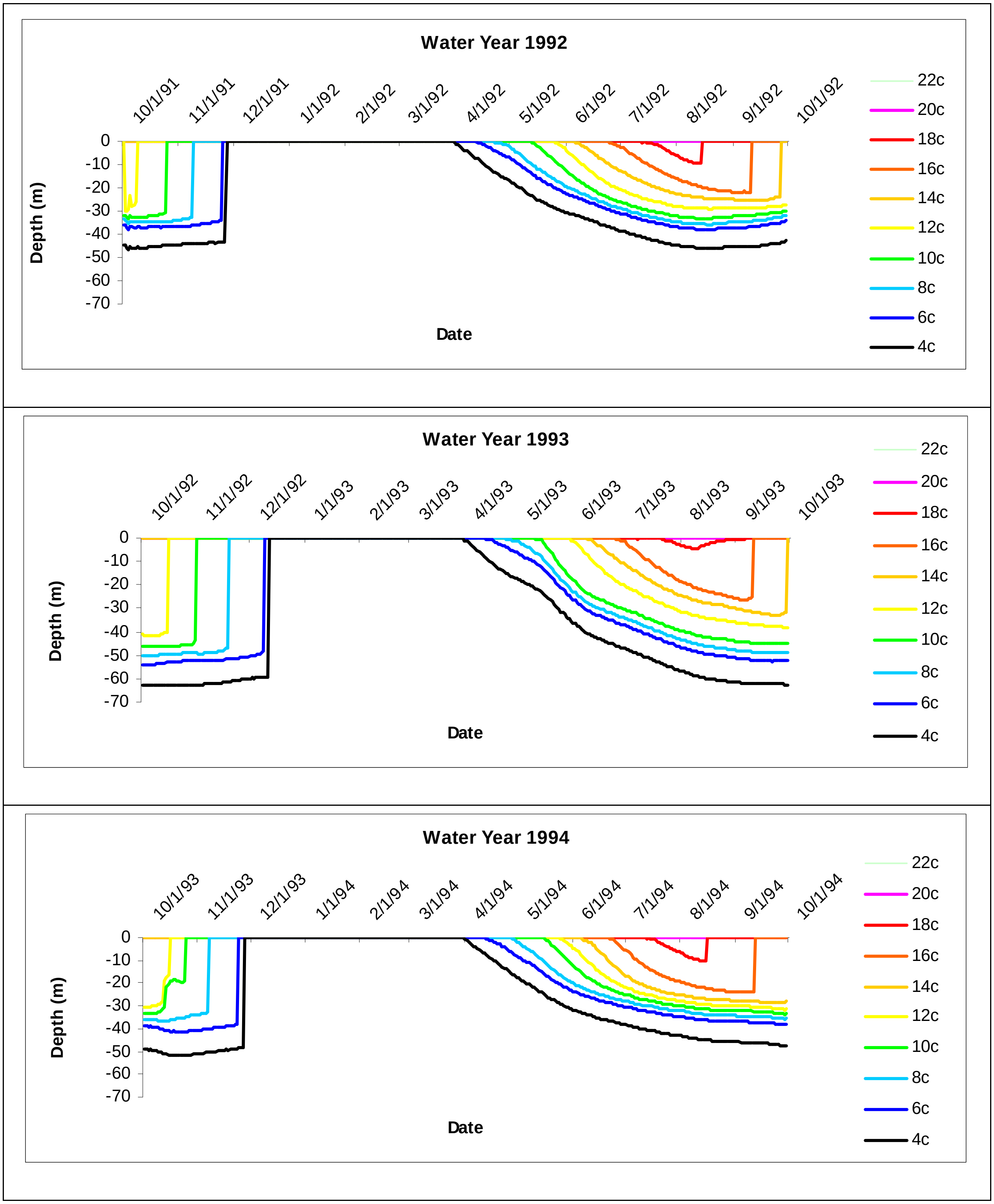


Figure 14. Modeled isotherms in Lake Koocanusa, Montana for water years 1992-1994.

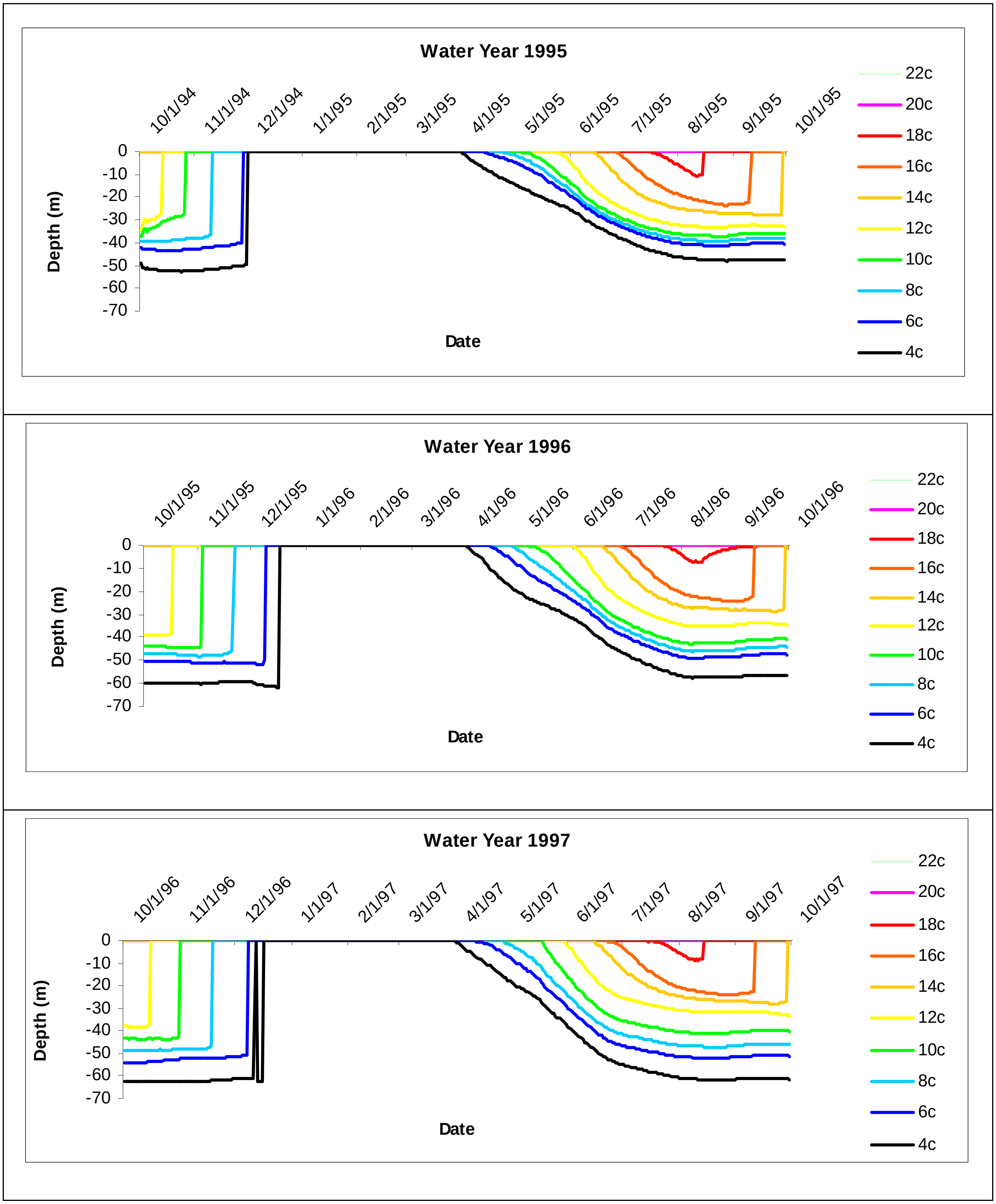


Figure 15. Modeled isotherms in Lake Koocanusa, Montana for water years 1995-1997.

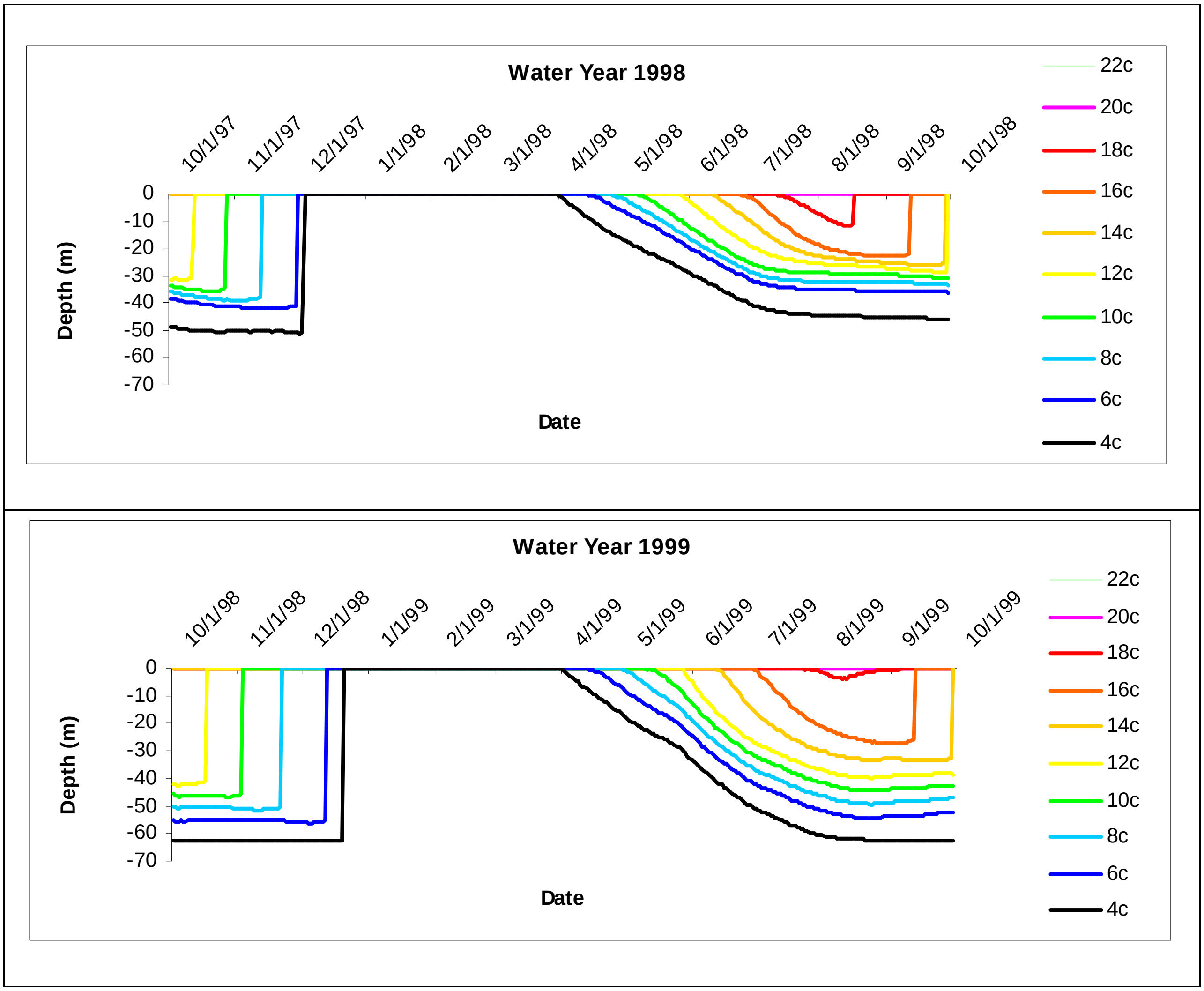
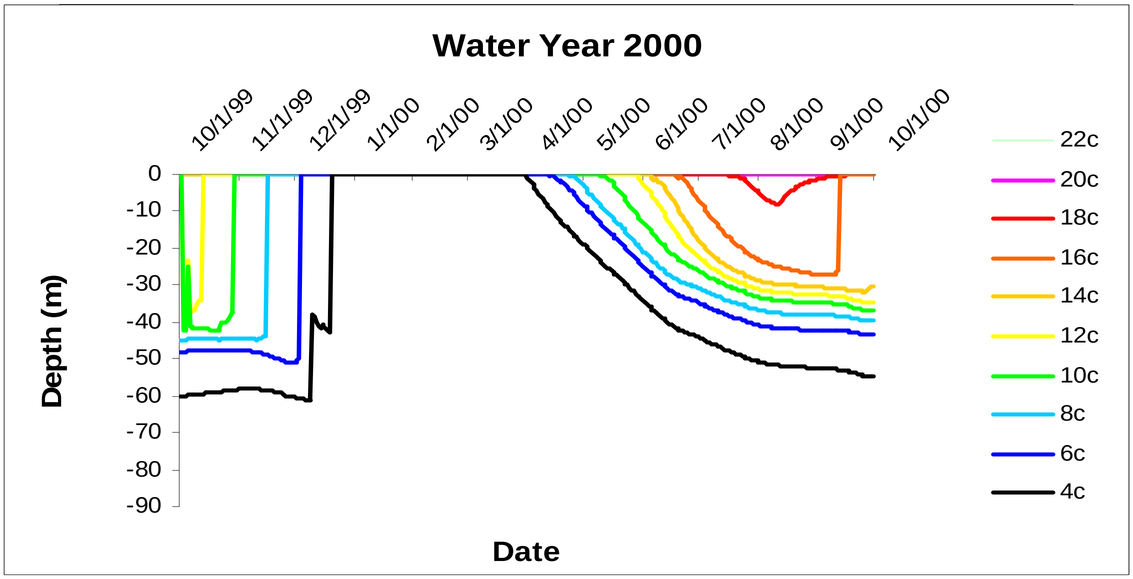
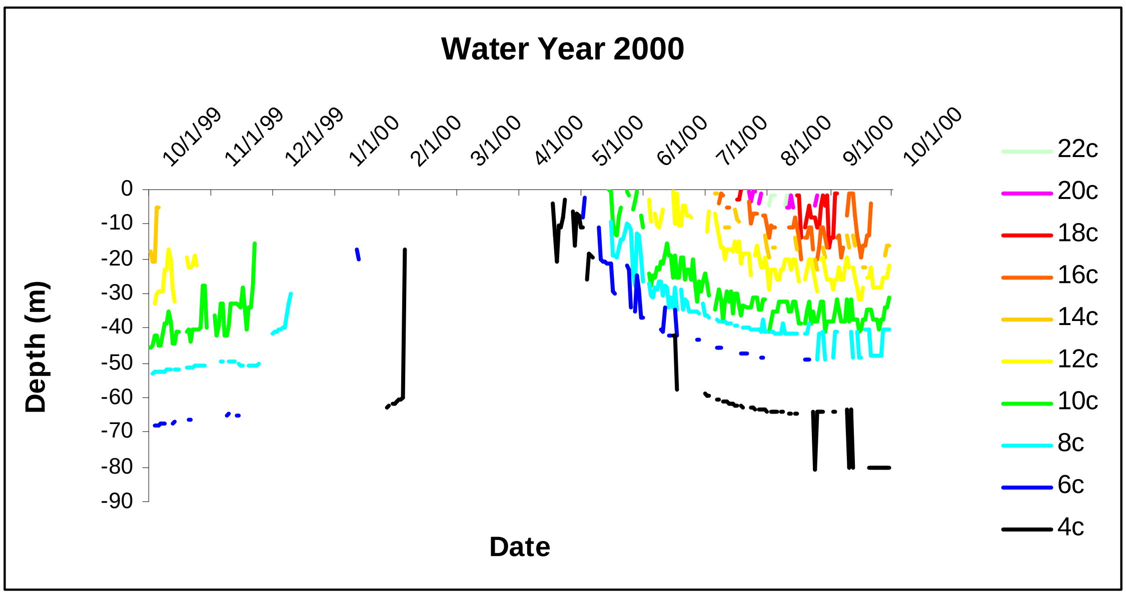


Figure 16. Modeled isotherms in Lake Koocanusa, Montana for water years 1998-1999.

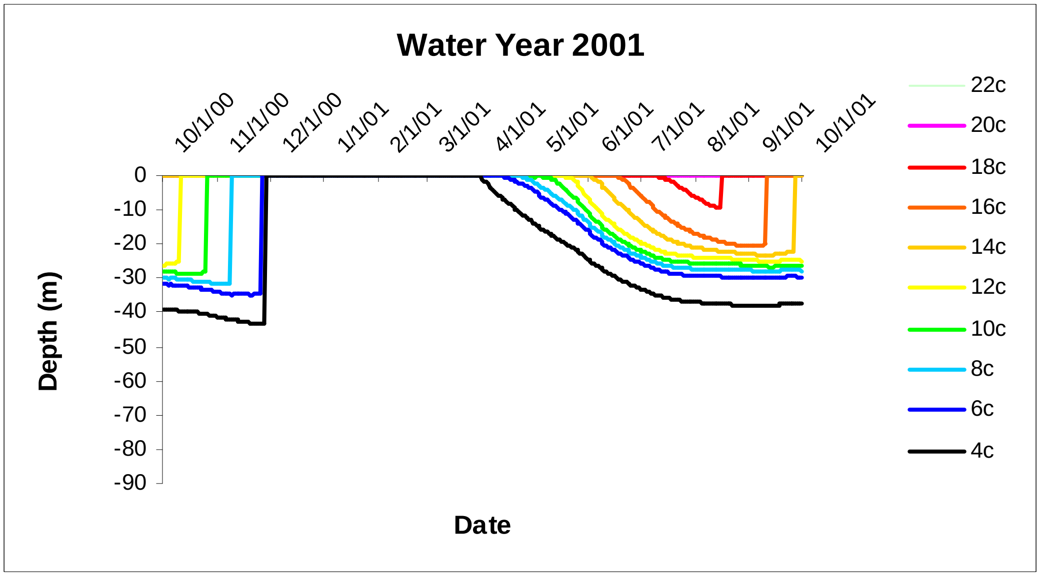


Modeled

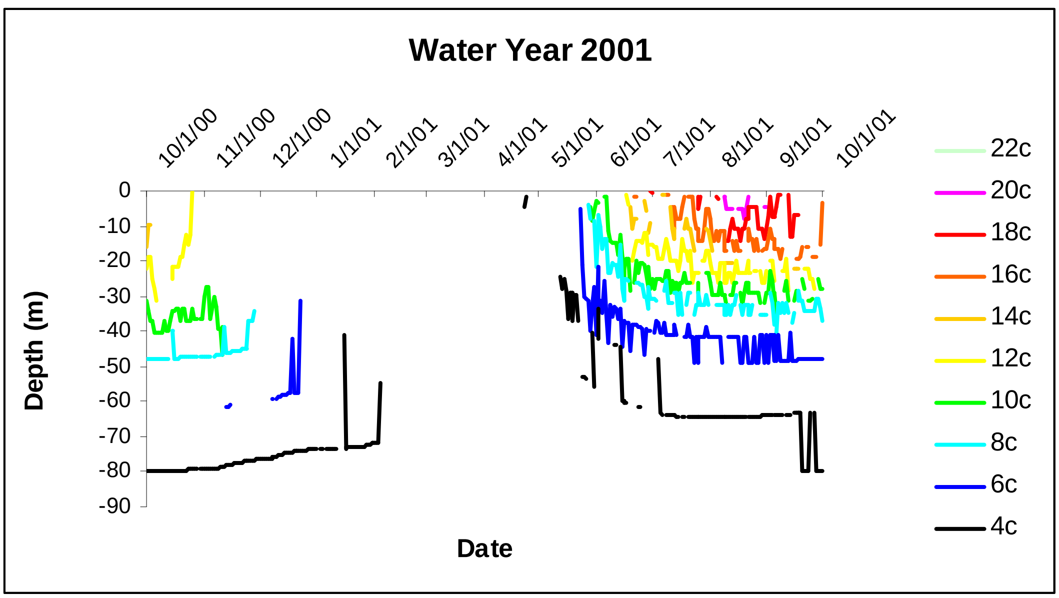


Actual

Figure 17. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2000.



Modeled



Actual

Figure 18. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2001.

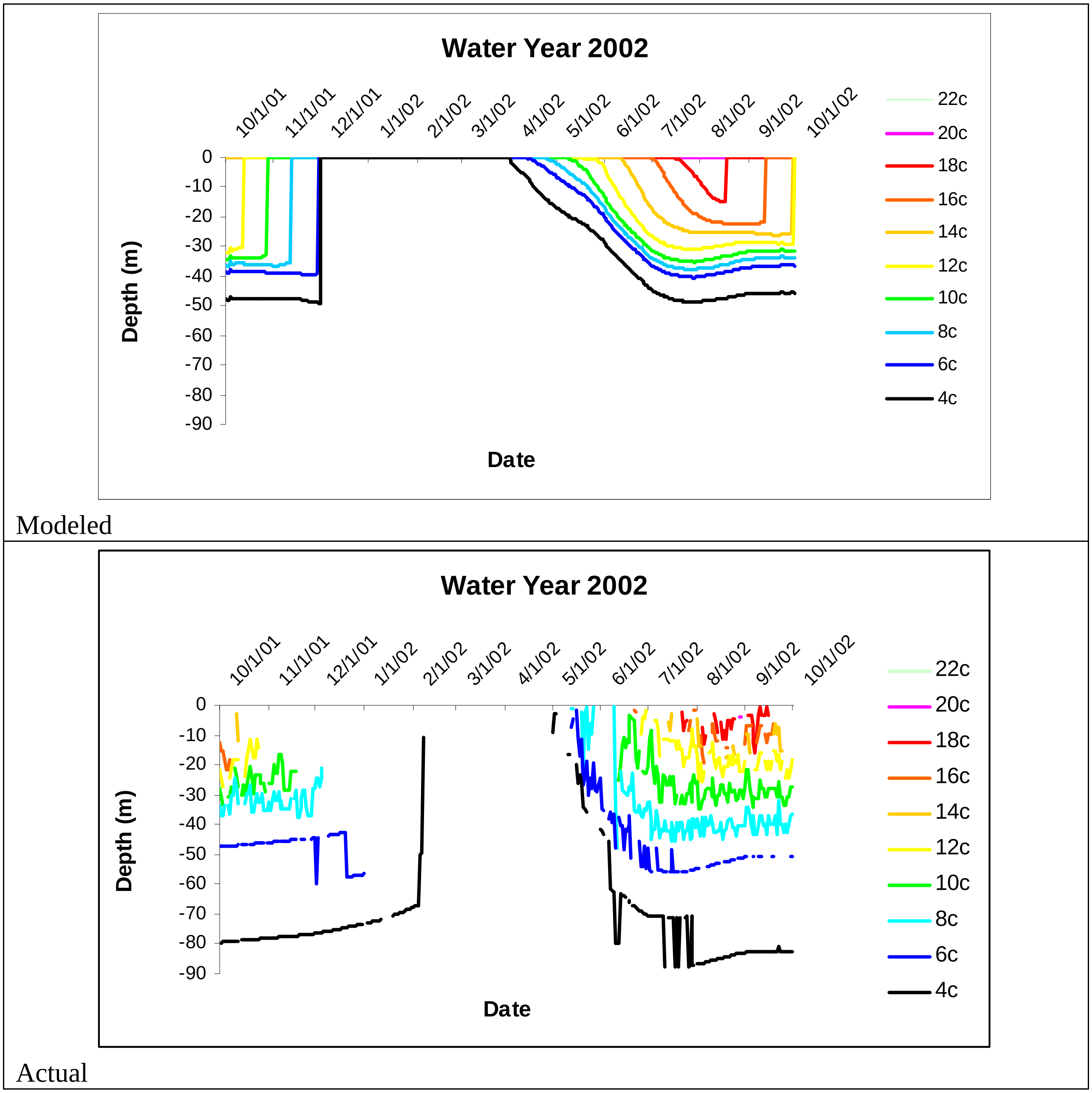


Figure 19. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2002.

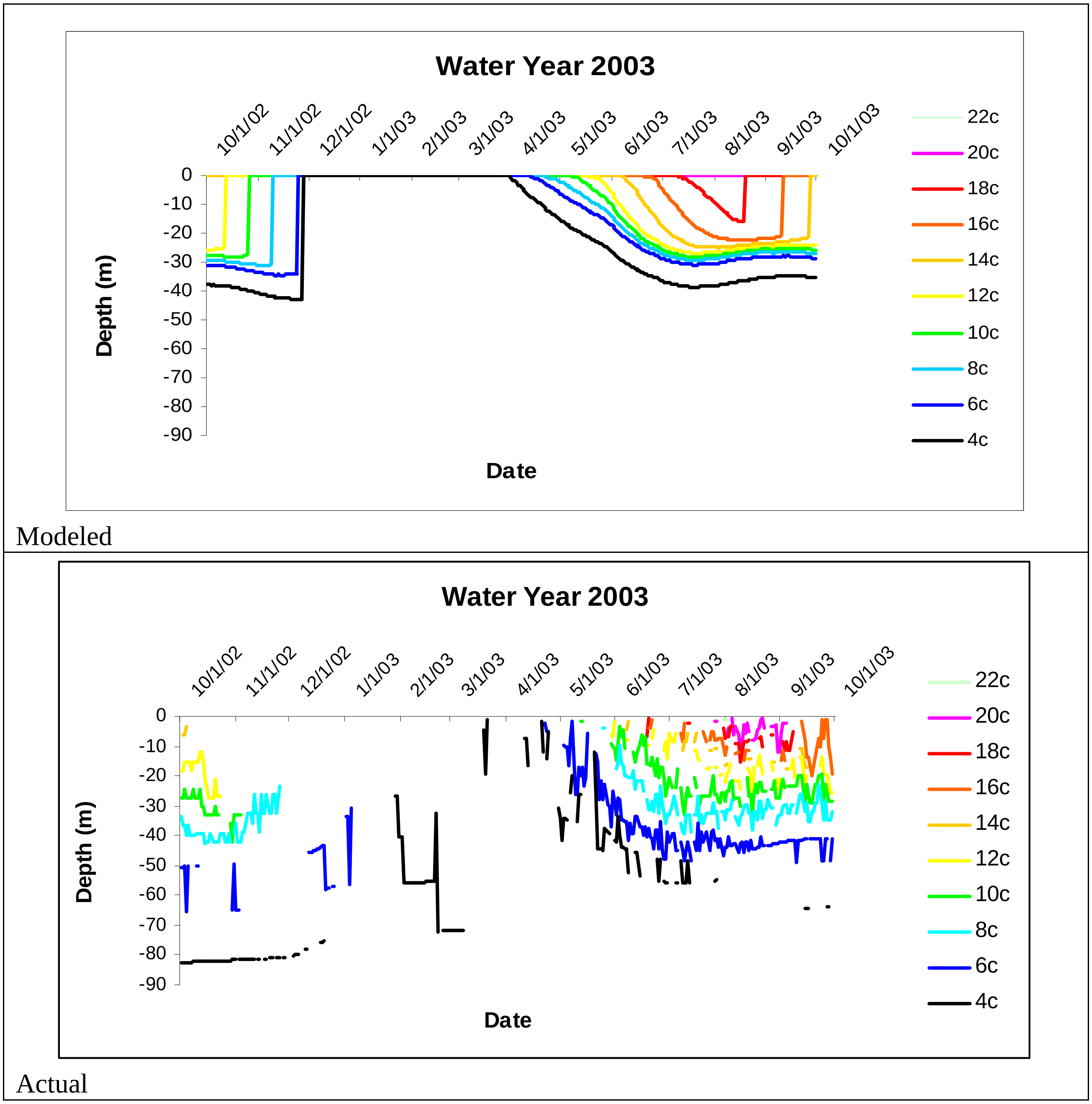
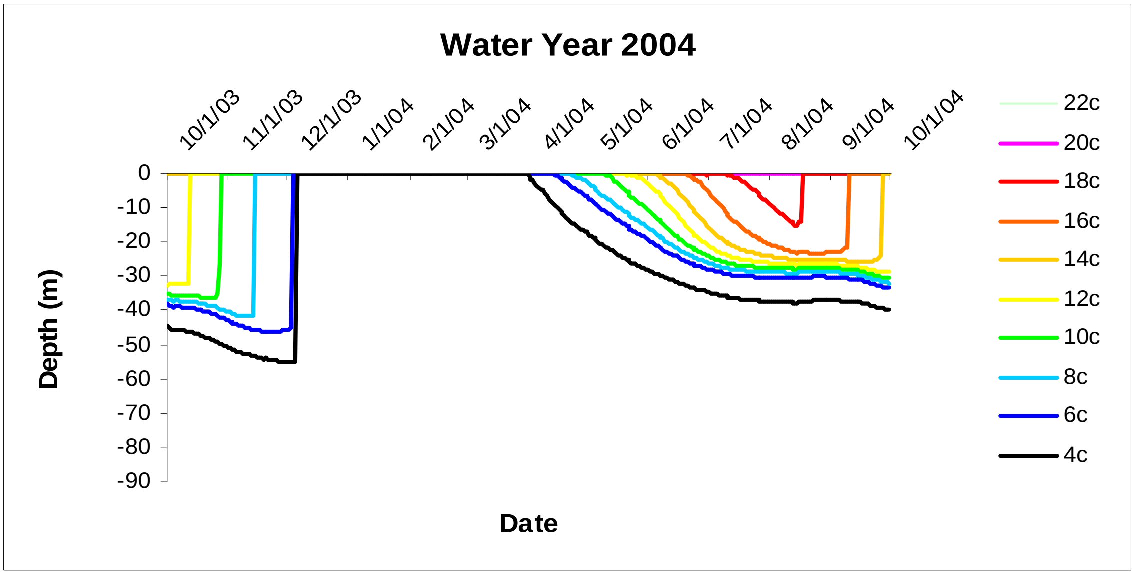
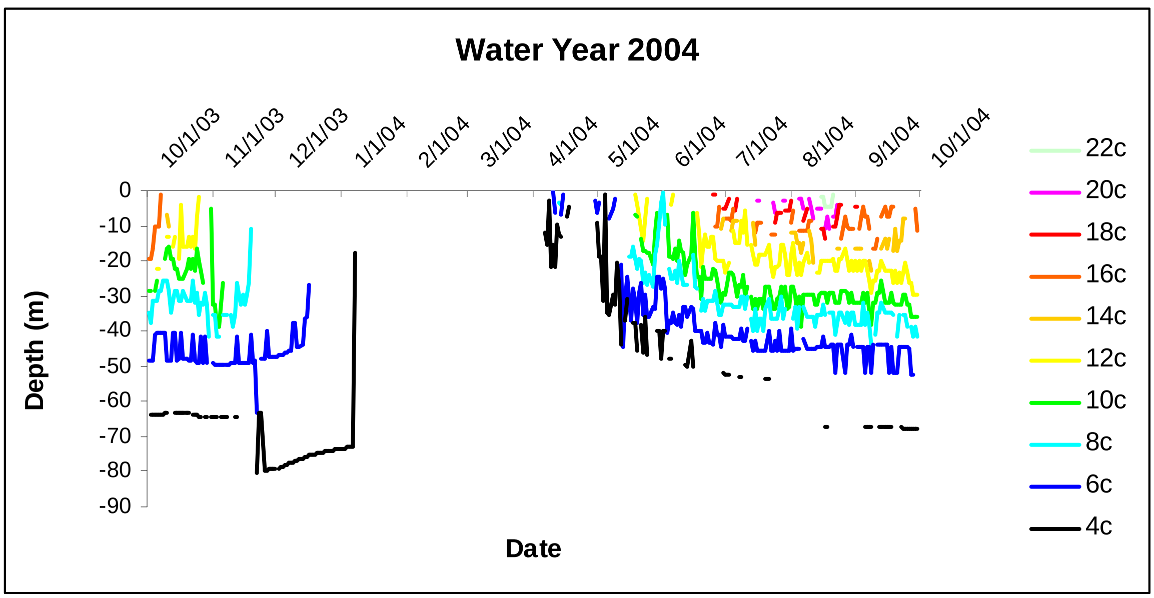


Figure 20. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2003.

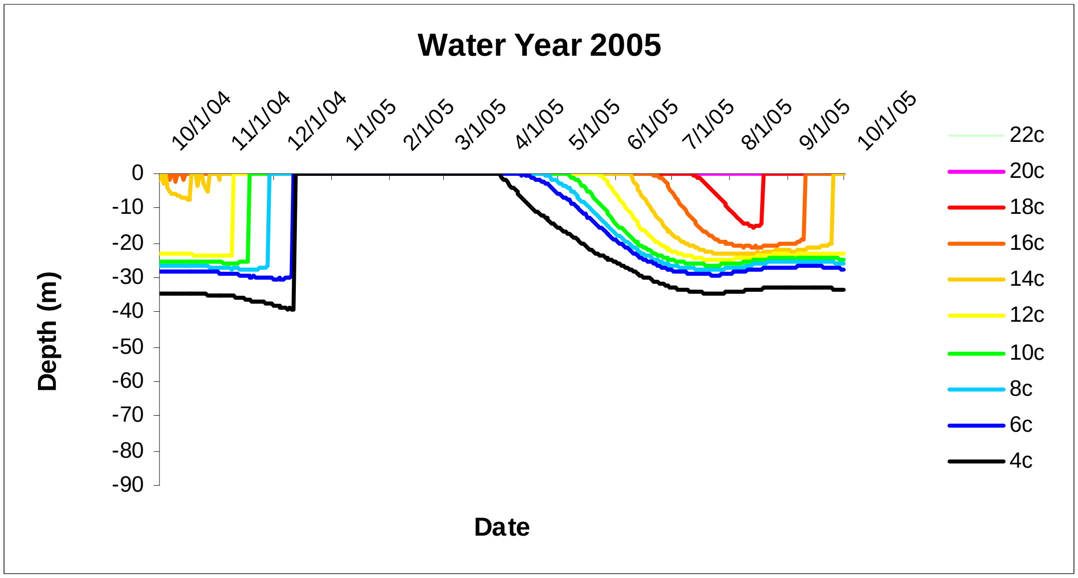


Modeled

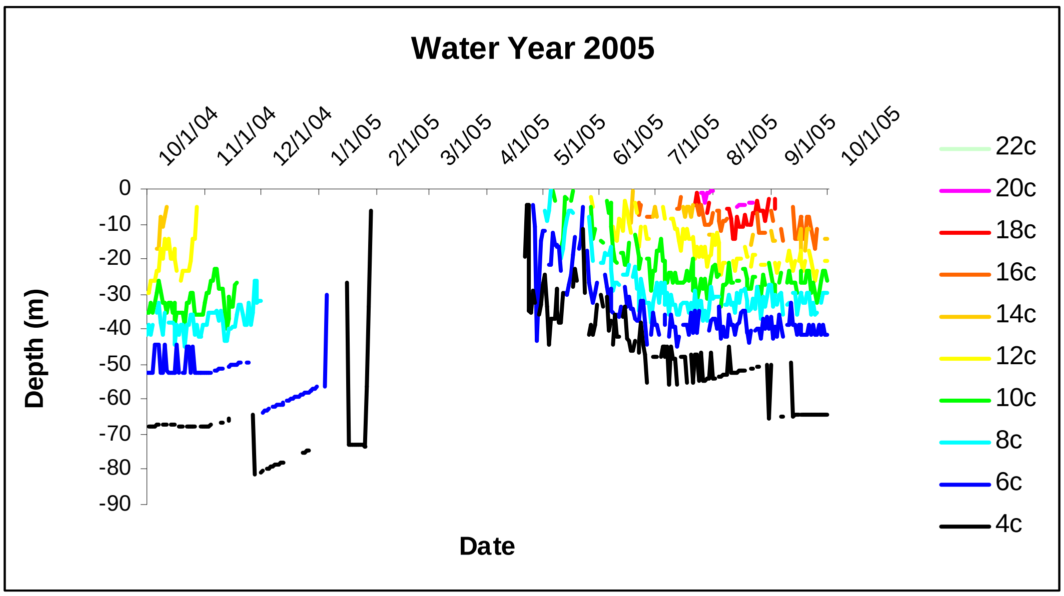


Actual

Figure 21. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2004.



Modeled



Actual

Figure 22. Comparison of modeled isotherms (upper panel) versus actual isotherms (lower panel) for Lake Koocanusa, Montana for water year 2005.

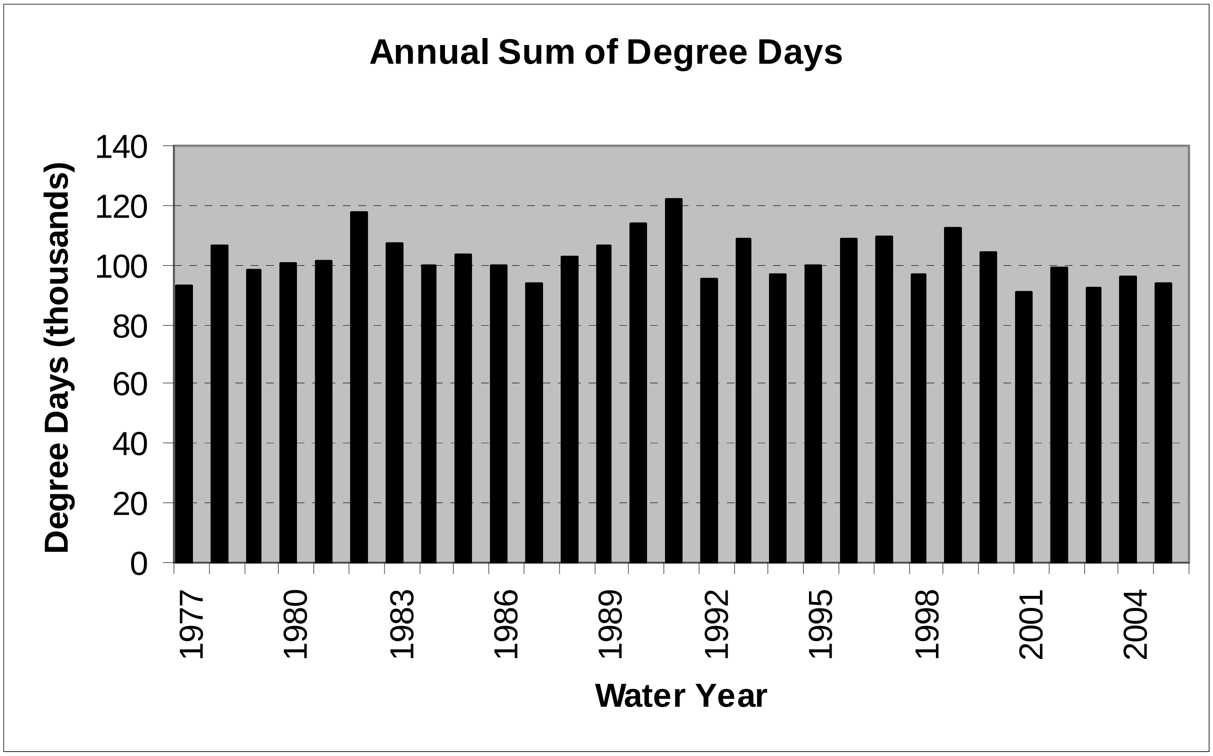


Figure 23. Annual sum of degree-days in Lake Koocanusa, Montana for water years 1977-2005.

Objective 2 – Use LRMOD to model biological conditions in Lake Koocanusa and LRMOD in Hungry Horse Reservoir

Model simulations (LRMOD) indicated that water years 2003-2005 had the potential to result in high annual primary productivity, but did not exceed the highest values recorded since the filling of Lake Koocanusa (Figure 24). Water years 1980, 1987, 1998, 1986, and 1981 were the five top water years respectively for potential primary productivity. Water years 2003-2005 were in the top 5-10 since water year 1977. Primary production washout through Libby Dam during the summer months was highest in water years 2002, 1996, 1981, 2005 and 1997 and the highest annual washout years were 2005, 2003, 1998, 2004, and 1980 according to model simulations (Figure 25). Recent years (i.e., 2002-2005) had the potential for higher primary production washout due to high summer flows below Libby Dam resulting from flow augmentation for anadromous salmon in lower portions of the Columbia River Basin. Simulations of aquatic insect production these same years showed the potential for as much as a 10% decrease in maximal production of Hymenoptera, Homoptera, and Hemipterans compared to water years 1977-1999 (Figure 26). Coleopteran production from water years 2000-2005 indicated that there was the potential for a steady increase, approaching 90 percent of maximal production (Figure 26). Zooplankton production in Lake Koocanusa for water years 1977-2002 fluctuated between 1200 and 1400 metric tons, but model simulations for water years 2003-2005 all showed higher potential zooplankton production, with values approaching 1500 metric tons per year, possibly resulting from higher reservoir elevations (Figure 27). The average number of Daphnia per liter collected in monthly samples from 1983 to 2004 has been highly variable both within and among months (range 0.01-16.16) (Table 8; Figure 28). In an average year, the density of Daphnia peaks in July and is lowest in March and April. Densities are highly variable between months and years and among samples. The highest average monthly density (16.16 per liter) occurred in November 1990 and was influenced by one sample that containing 74 per liter. This sample is likely an outlier and may influence the significance of monthly and annual comparisons of zooplankton densities in Lake Koocanusa.

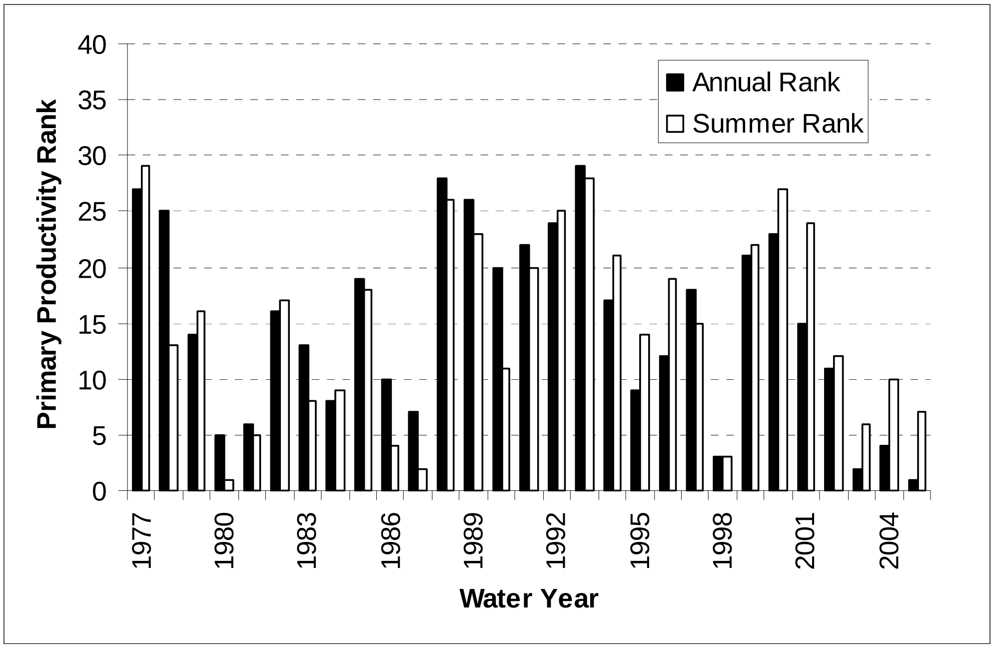


Figure 24. Annual water year ranking of LRMOD modeled primary productivity in Lake Koocanusa, Montana above Libby Dam.

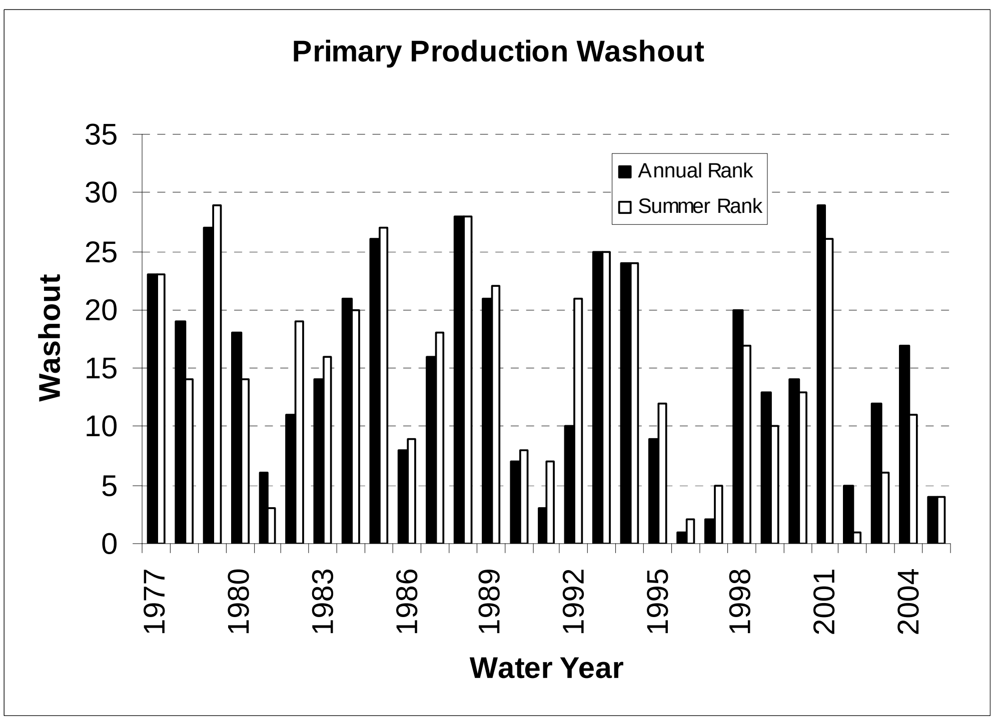


Figure 25. Annual water year ranking of LRMOD modeled primary productivity washout in Lake Koocanusa, Montana above Libby Dam for water years 1977-2005.

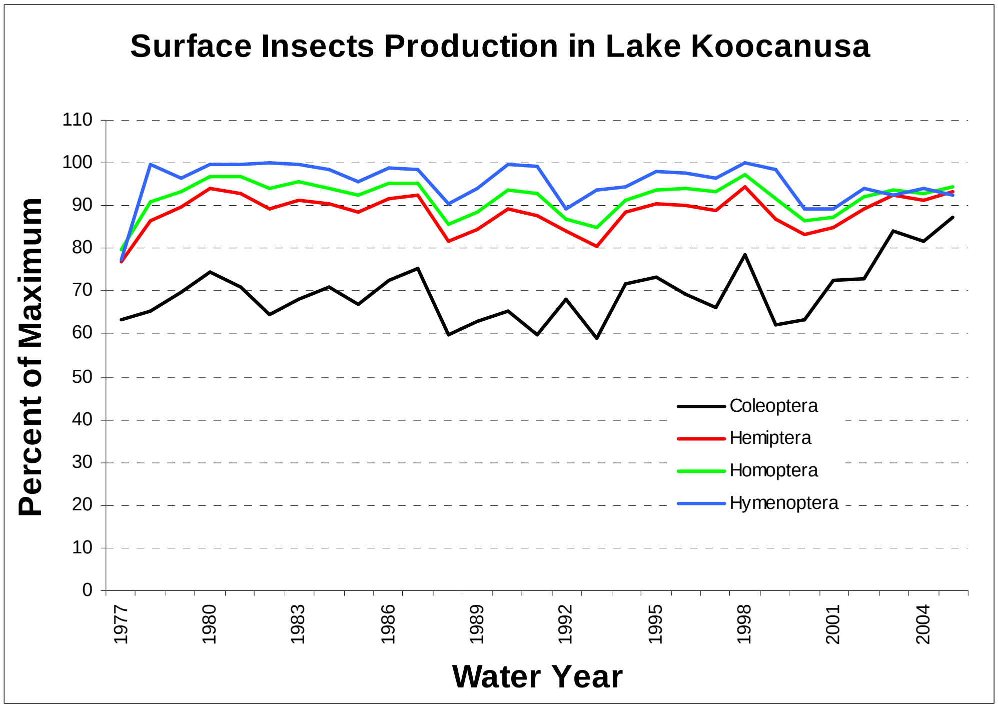


Figure 26. Percent of maximum production of invertebrate Orders in Lake Koocanusa, Montana using LRMOD model simulation for water years 1977-2005.

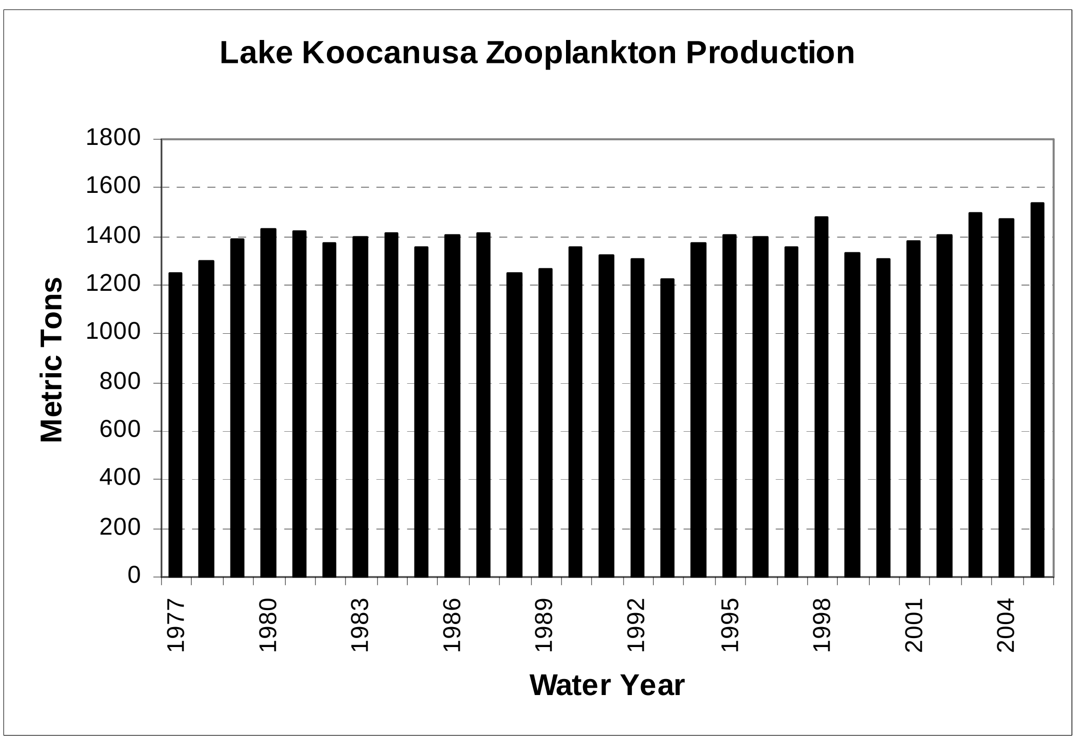


Figure 27. Production of zooplankton (metric tons) in Lake Koocanusa, Montana using LRMOD model simulations for water years 1977-2005.

Table 8. Average number of Daphnia per liter collected in monthly samples from Lake Koocanusa, Montana from 1983-2004.

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1983								0.87	1.82	1.97	3.92	0.50
1984	1.00	3.19	0.63	1.19	3.23	2.20	2.91	2.60	0.96	3.67	1.58	0.56
1985	0.89	0.91		0.54	0.73	4.70	3.27	1.74	2.14	2.29	1.94	0.74
1986	1.94			0.96	4.69	3.80	2.22	1.44	2.52	1.00		
1987	0.50		0.45	1.08	1.29	5.46	2.65		1.50		1.01	
1988			0.50	0.22	1.13	0.92	1.69	1.31	0.65	1.33	1.58	1.41
1989	0.39			0.06	0.14	0.25	0.22	2.10	0.71	6.46	1.56	1.50
1990	0.75	0.19	0.04	0.03	0.01	0.13	0.71	2.22	0.46	1.63	16.16	2.89
1991	1.40			0.07	0.05	0.92	6.36	1.66	1.09		0.95	2.98
1992				1.20	1.74	2.22	1.38	1.97	1.06			
1993				0.02			0.94	5.23		2.14	0.45	
1994				0.24	0.60	1.66	2.35	1.84	5.65	2.47	0.45	
1995	0.88		0.37	0.13	0.25	1.50	1.43	0.86	3.75	2.92	3.64	1.14
1996	0.52			0.01	0.12	0.30	5.00	4.73	0.87	3.47		0.56
1997				0.06	0.19	5.42	6.19	4.65	1.36	2.75	0.88	
1998				0.40	2.83	3.77	4.65	0.94	1.90	1.79	1.09	
1999				0.08	0.48	2.02	3.84	3.74	2.70		1.18	
2000				0.08	0.47	1.53	1.70	1.41	1.29	1.03	0.75	
2001				0.12	0.24	1.61	3.49	2.35	2.75	0.95	1.09	
2002				0.16	0.29	2.97	5.90	2.06	0.58		1.66	
2003				0.36	0.95	9.79	5.51	1.95	4.40	3.63	0.79	
2004				0.15	0.63	2.62	5.11	1.29	2.20	3.03	1.75	

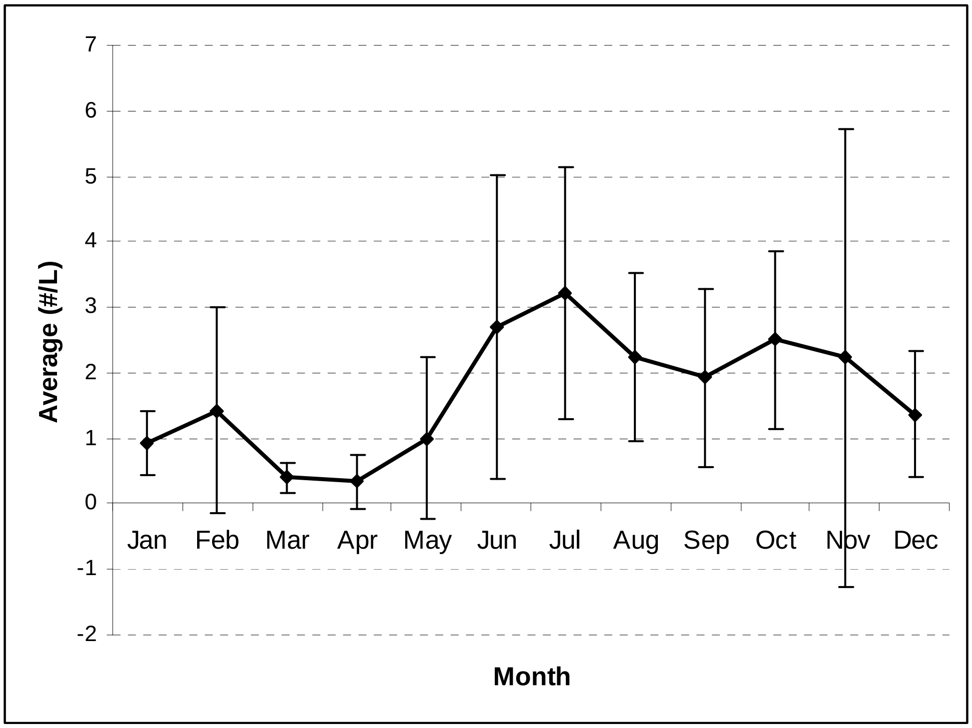


Figure 28. Overall average number of Daphnia per liter (+/- SD) by month collected in Lake Koocanusa from 1983-2004.

Objective 3 – Reservoir age, growth, and condition in Lake Koocanusa

Seventy thousand gillnet records have been compiled from 1983-2005 in Lake Koocanusa. Data include both regularly occurring spring and fall net series, and samples collected less frequently at other times of the year. Additional records from sampling conducted before 1983 have not yet been added to this database.

Since 1984, the catch per unit effort of bull trout in the spring gill net series has increased from nearly 1 fish per net to about 6 per net in 2005 (Figure 29). Bull trout were listed under the endangered species act in 1998, and this stopped harvest and targeted angling for bull trout in Lake Koocanusa. The mean length of bull trout has increased since the early 1980's, when the average length was about 400 mm. In the 2005 spring series, the average length of bull trout was 550 mm (Figure 30). Since the mid 1990's, there has been a steady increase in the mean length of bull trout. Bull trout currently represent about 4% of al fishes caught compared to about 1% in the 1980's (Figure 31). Listing of bull trout and changes to their harvest regulations in the 1990's may be reflected by spring gill net sampling.

Relative weight of bull trout in Lake Koocanusa has varied through time and by length category. Very few substock to stock length bull trout (< 200 mm; < 8 in) are caught in the gill nets because most smaller bull trout remain in tributary streams. Relative weight of stock to quality length bull trout (i.e., 200-349 mm) has ranged from 90 to100 and the highest average relative weight ($W_r = 115$) occurred in 2005 (Figure 32). Condition of quality to preferred length (i.e., 350-499 mm) bull trout has remained steady since 1984, contrasted with preferred to memorable length bull trout (500-599 mm), which have had highly variable relative weights since 1984. Bull trout measuring 650 to 799 mm have also had variable mean relative values and have shown a substantial decrease in mean relative weight from 1995 (W_r =120) until 2005 (W_r = 95; Figure 32). The mean relative weight of all bull trout caught has slightly increased from 2002 until 2005, but values are within the variability seen from 1984-2005 (Figure 33). Despite decreases in mean relative weights for some size categories, most size classes bull trout in Lake Koocanusa have mean relative weights close to or exceeding 100, indicating that fish are in good condition.

Kokanee catch per unit effort in the fall gill net series has been variable since 1983, ranging from less than 5 to 25 fish per net (Figure 34). There have been small peaks in catch per unit effort at about 3 year intervals since 1985. Mean length of kokanee has declined since 1986 when the average length was nearly 400 mm to a record low in 2005 of about 225 mm (Figure 35). Peaks in mean length of kokanee occur regularly every 6 years (Figure 35), although the amplitude of these peaks has been decreasing over time. This may be a result of several factors such as a newly formed reservoir slightly before the introduction of kokanee, which led to fast growth and heavy utilization of unexploited reservoir habitats. There are also higher densities of fish and additional fish species in the reservoir now than when kokanee first appeared in Lake Koocanusa, possibly leading to intraspecific and interspecific competition resources. The percent of all fishes caught in gill nets represented by kokanee has fluctuated from nearly 1% to 30% on an annual basis since 1983 (Table 9; Figure 36).

Relative weight of substock to stock length kokanee (<100 mm) and stock to quality length kokanee (100-199 mm) has been variable since 1983, but these smaller kokanee are not readily caught during the fall gill net series (Figure 37). Quality to preferred length (200-299 mm) and preferred to memorable length (300-349 mm) kokanee mean relative weight values have been nearly constant since 1983 (Figure 37). Memorable to trophy length (350-449 mm) kokanee showed a more cyclical pattern in mean relative weight during the 1980's into the late 1990's. Kokanee longer than 450 mm are no longer captured in the fall gill net series, evidenced by the decreasing mean length of kokanee since 1986 (Figures 35 and 37). Trophy length kokanee (>450 mm) have not been captured since 1987 and thus have no mean relative weight since that time. The overall mean relative weight of kokanee in the fall gill net series has fluctuated from about 85 to 100 since 1983 (Figure 38).

Species composition of fishes caught during the spring and fall gill net series is dominated by kokanee, peamouth, and northern pikeminnow, which collectively represent nearly 90% of all fishes caught in gill netting efforts (Table 9). The percentage represented by northern pikeminnow and bull trout caught in gill nets has increased since the mid 1990's, now representing nearly 20% and 5% of the total catch respectively. The percentage of rainbow trout and westslope cutthroat trout in the gill nets has decreased since the early 1980's, although they were never more than 5% of the catch from 1983-2005.

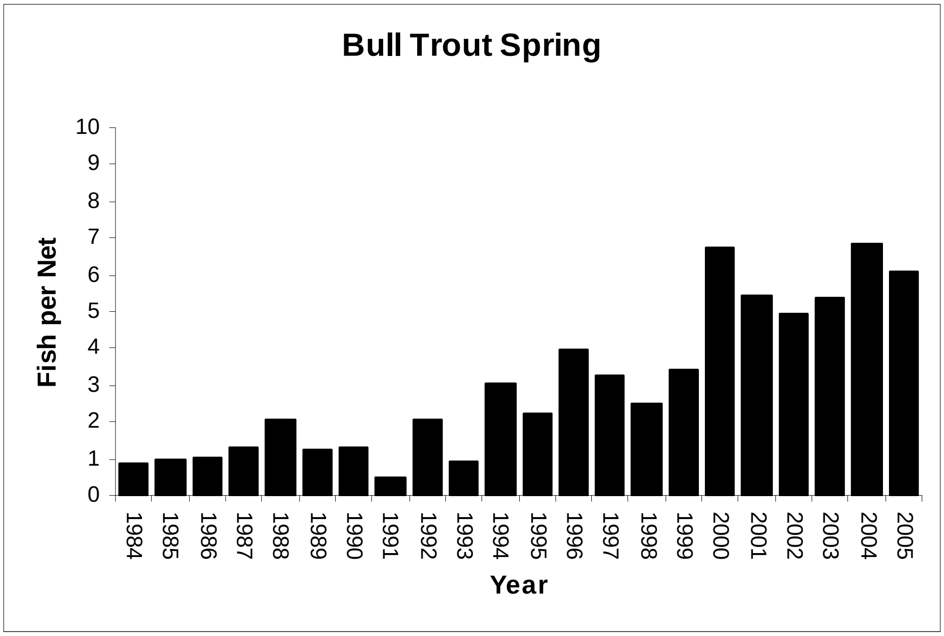


Figure 29. Catch per unit effort of bull trout during the spring gill net series in Lake Koocanusa, Montana.

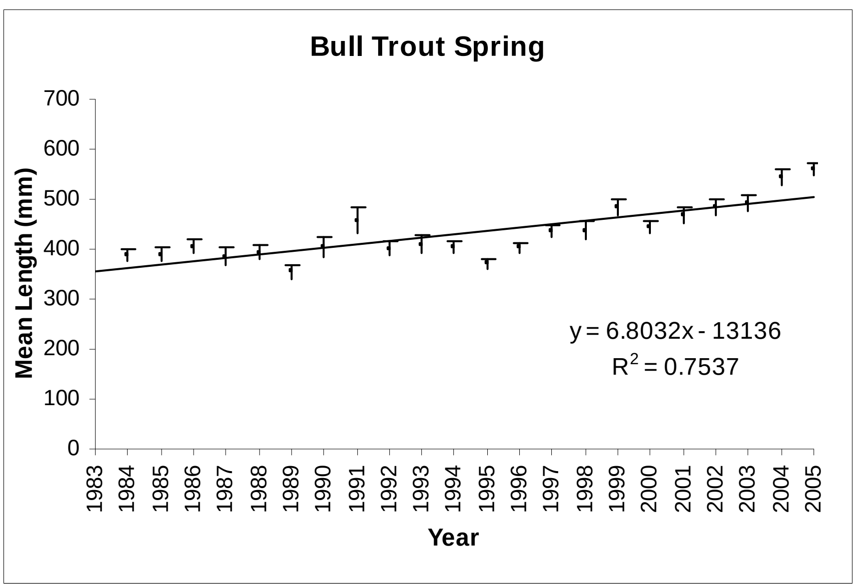


Figure 30. Mean length of bull trout (+/- SE) caught during the spring gill net series in Lake Koocanusa, Montana.

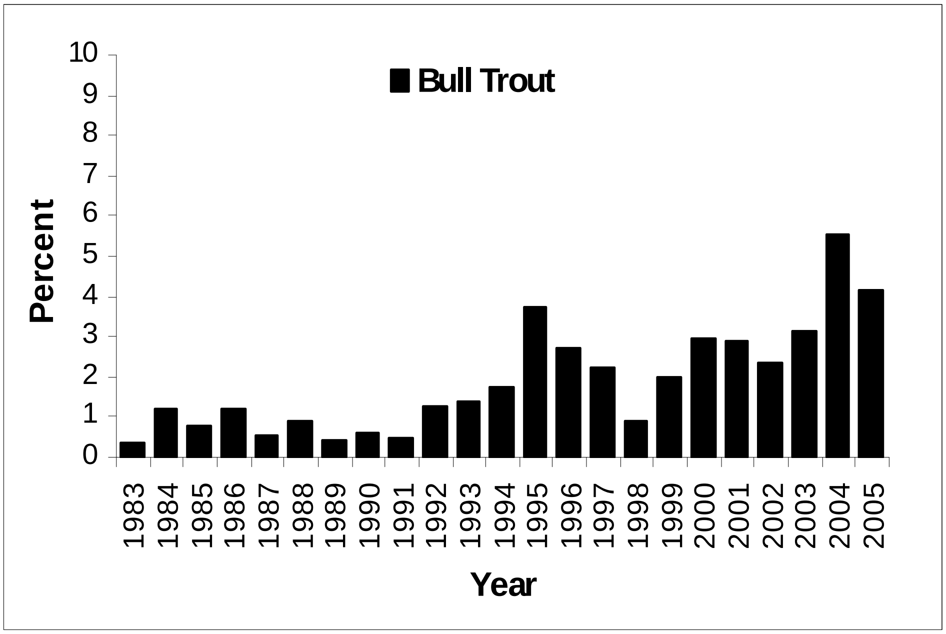


Figure 31. Bull trout as percent of total catch during spring and fall gill net series in Lake Koocanusa, Montana.

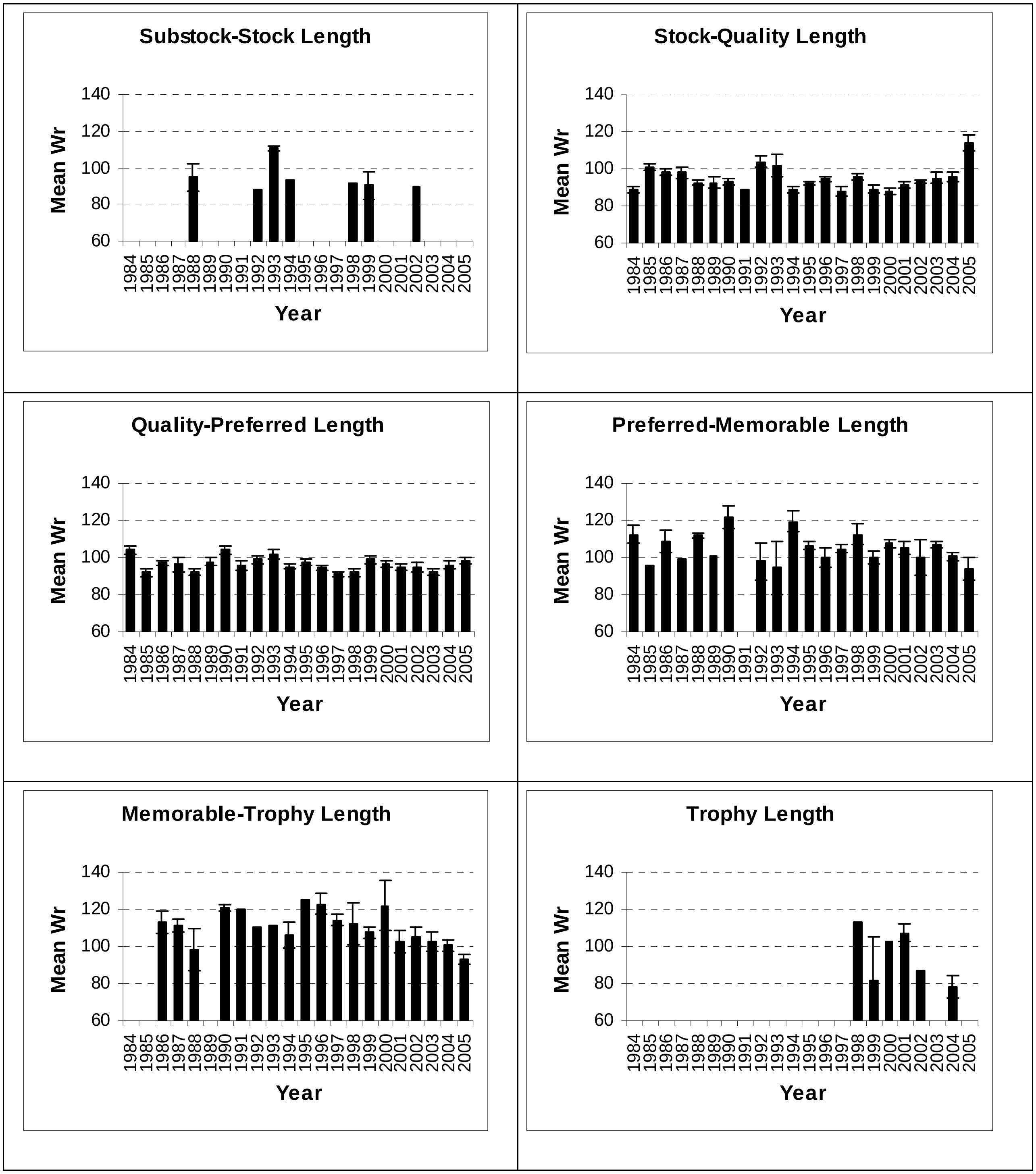


Figure 32. Mean relative weight (+/- SE) of bull trout during the spring gill net series in Lake Koocanusa, Montana by length category.

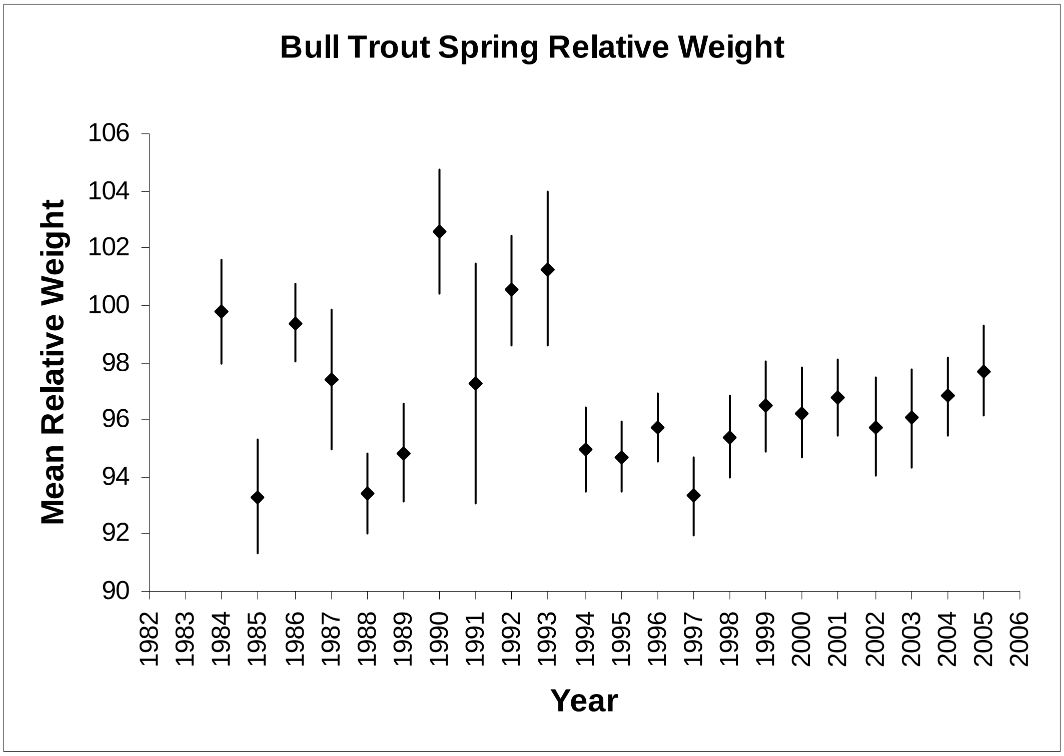


Figure 33. Mean relative weight (+/- SE) of all bull trout from the spring gill net series in Lake Koocanusa, Montana.

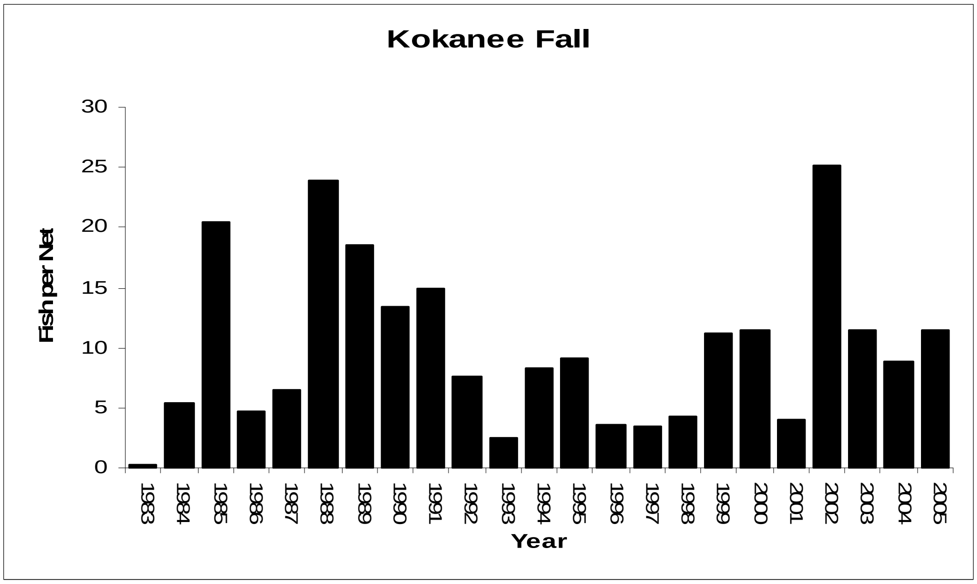


Figure 34. Catch per unit effort of kokanee during fall gill net series in Lake Koocanusa, Montana.

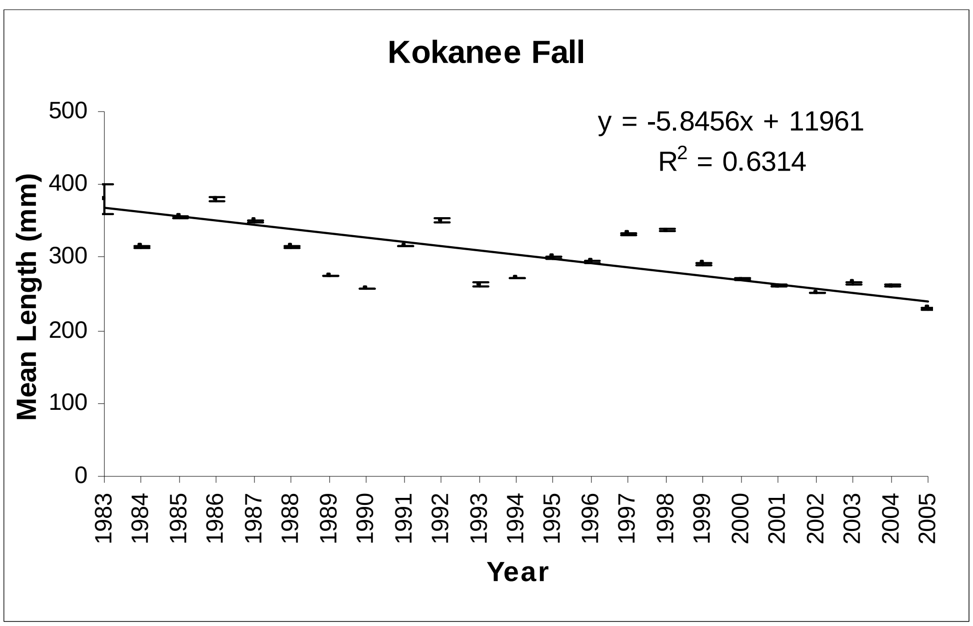


Figure 35. Mean length of kokanee during the fall gill net series in Lake Koocanusa, Montana.

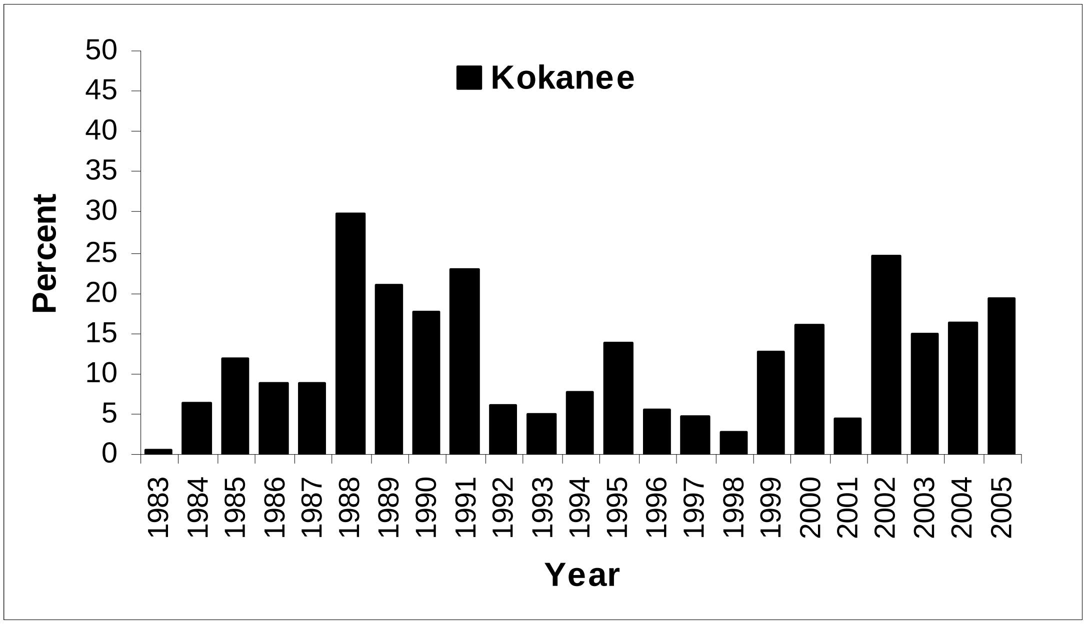


Figure 36. Kokanee as percent of total catch during spring and fall gill net series in Lake Koocanusa, Montana

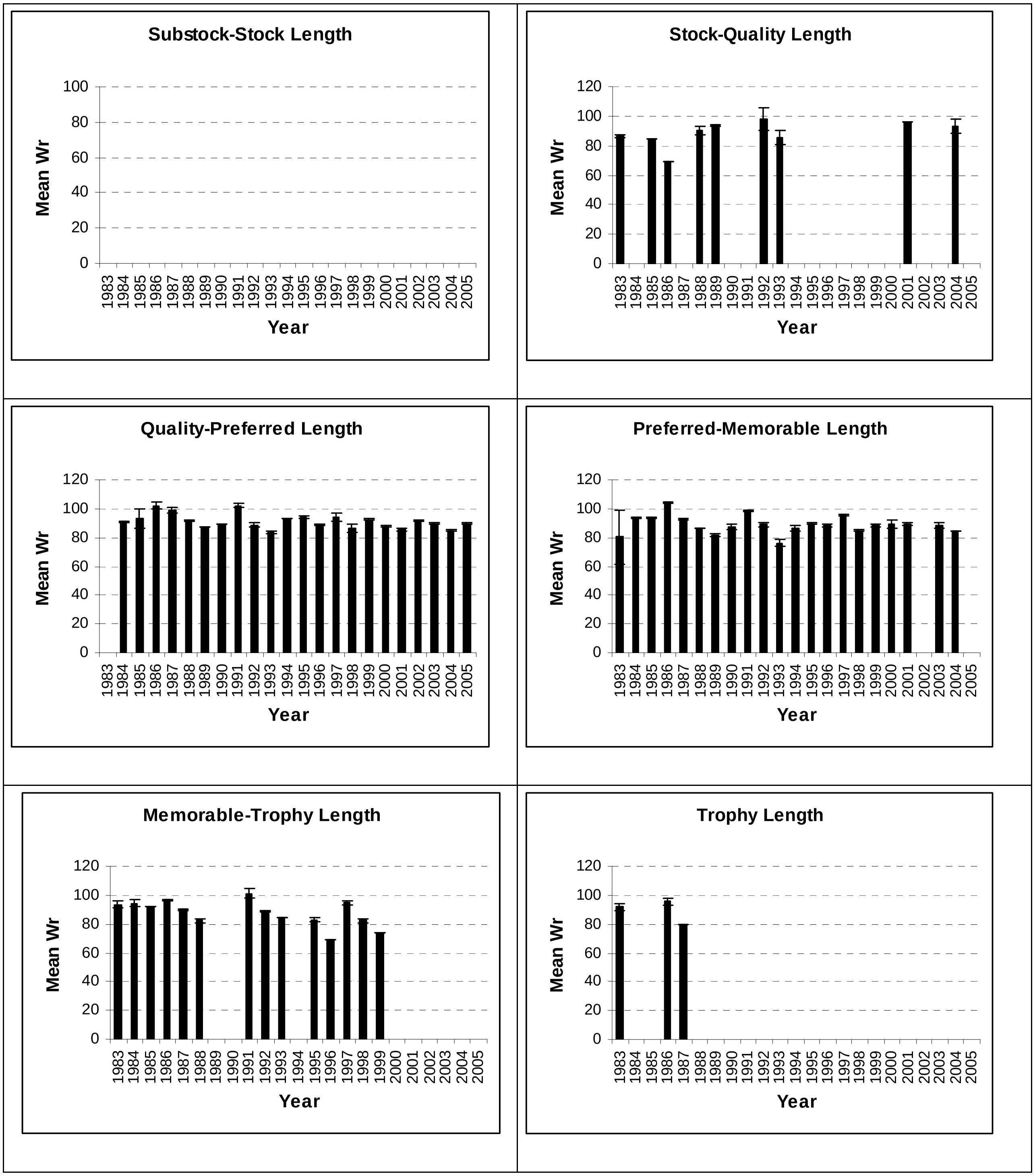


Figure 37. Mean relative weight (+/- SE) of kokanee during fall gill net series in Lake Koocanusa, Montana by length category.

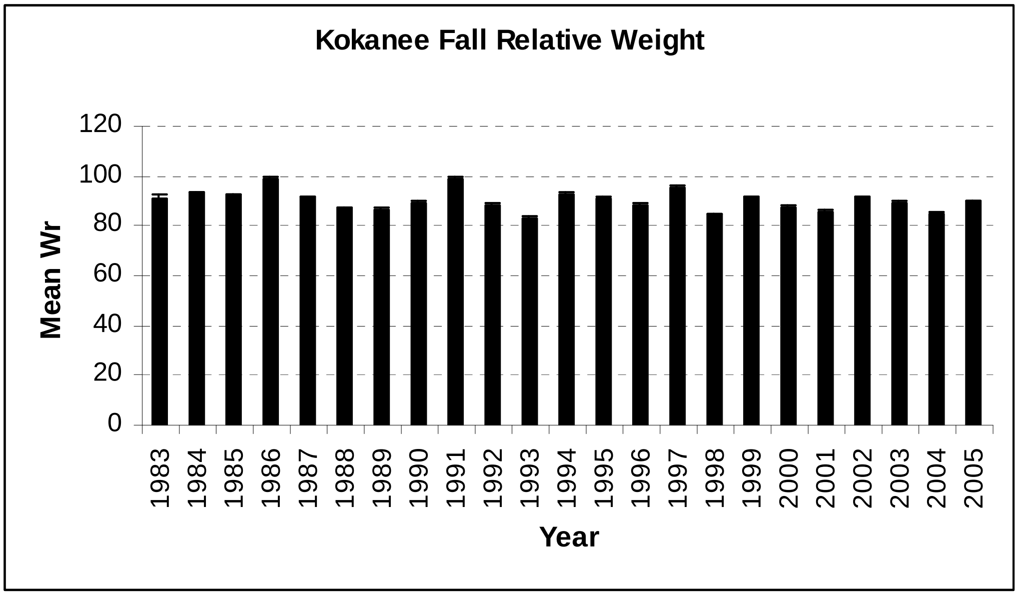


Figure 38. Mean relative weight (+/- SE) of all kokanee during fall gill net series in Lake Koocanusa, Montana.

Table 9. Species composition of fish caught during spring and fall gill net series in Lake Koocanusa above Libby Dam from 1983-2005. Species abbreviations correspond to the following species: CRC = Columbia river chub or peamouth; CSU = large-scale sucker; BT = bull trout; EBT = eastern brook trout; FSU = longnose sucker; HYB = rainbow trout x cutthroat trout hybrid; KOK = kokanee; LING = burbot; LMB = largemouth bass; MWF = mountain whitefish; NOP = northern pike; NSQ = northern pikeminnow; PUMP = pumpkinseed; RBT = rainbow trout; RSS = redside shiner; WCT = westslope cutthroat trout; and YEP = yellow perch.

	Species Abbreviation																
Year	CRC	CSU	BT	EBT	FSU	HYB	KOK	LING	LMB	MWF	NOP	NSQ	PUMP	RBT	RSS	WCT	YEP
1983	55	13	0	0	0	4	1	0	0	3	0	12	0	6	2	4	0
1984	56	10	1	0	1	3	6	0	0	3	0	7	0	6	1	4	0
1985	64	7	1	0	1	2	12	0	0	1	0	5	0	4	1	1	1
1986	65	6	1	0	1	3	9	0	0	4	0	5	0	4	0	1	1
1987	68	6	1	0	1	1	9	1	0	2	0	7	0	2	0	0	3
1988	52	6	1	0	1	0	30	0	0	1	0	4	0	2	0	0	2
1989	66	3	0	0	0	0	21	0	0	0	0	5	0	0	0	0	3
1990	68	3	1	0	1	0	18	0	0	1	0	6	0	1	0	0	2
1991	61	3	0	0	1	0	23	0	0	1	0	6	0	1	0	1	3
1992	77	7	1	0	2	0	6	0	0	1	0	4	0	0	0	0	1
1993	74	6	1	0	3	0	5	0	0	1	0	7	0	1	0	1	1
1994	70	5	2	0	4	0	8	0	0	1	0	9	0	0	0	0	1
1995	54	10	4	0	3	0	14	0	0	1	0	10	0	1	0	0	2
1996	58	15	3	0	3	0	5	0	0	1	0	9	0	1	0	0	3
1997	59	10	2	0	3	0	5	0	0	2	0	13	0	1	1	0	3
1998	74	8	1	0	3	0	3	0	0	1	0	8	0	0	0	0	1
1999	59	5	2	0	3	0	13	0	0	1	0	14	0	1	0	0	1
2000	59	6	3	0	2	0	16	0	0	1	0	12	0	1	0	0	1
2001	68	9	3	0	1	0	5	0	0	1	0	12	0	0	0	0	1
2002	50	6	2	0	1	0	25	0	0	1	0	14	0	0	1	0	0
2003	52	8	3	0	1	0	15	0	0	1	0	16	0	1	1	0	1
2004	49	6	6	0	0	0	16	0	0	2	0	19	0	1	0	0	1
2005	45	9	4	0	1	0	19	0	0	1	0	18	0	1	0	1	1

Objective 4 – Update reservoir models LRMOD and HRMOD

No work has been performed on this Objective to date. Dr. Craig Althen will be performing model updates and additional work with discharges modeling from Libby Dam.

Objective 5 – IFIM modeling of river habitat and RIVBIO modeling

Approximately 245,000 hourly flow records have been compiled from 1976 until September 2005 and another 34,000 daily flow records have been compiled since 1910 courtesy of the United States Geological Survey (USGS) and the United States Army Corps of Engineers (USACE) at and below Libby Dam. Dam operating strategies resulting from various Biological Opinions and other operational strategies have affected how Libby Dam is operating. In general, power peaking has been all but eliminated from current operations although occasional spikes are seen during the winter months. This change has greatly reduced the absolute average hourly discharge variation in the Kootenai River below Libby Dam, except during the spring peak discharges and on the descending limb of the hydrograph. Average hourly discharge variation was 14 m^3/s (500 ft^3/s) for the entire water years in the late 1970's and again in the early 1990's (Figure 39). Since 2000, dam operations have reduced the average hourly change in discharge to approximately 1.4 m^3/s (50 ft^3/s) per hour both on an annual basis and during the productive summer months. Less discharge fluctuation should result in greater productivity of the river (i.e., algae and invertebrates) due to more stable conditions within the varial zone. Peak discharges have also been greatly reduced. Before Libby Dam, peak discharge of the Kootenai River averaged about 1,857 m^3/s (65,000 ft^3/s) per year. Since completion the dam, average peak is now between 714-800 m^3/s (25,000 to 28,000 ft^3/s), although occasional spills have resulted in larger discharges more typical of pre-dam conditions. A water spill in June of 2006 produced 1,571 m^3/s (55,000 ft^3/s) total discharge from Libby Dam, the largest peak since regulated flows began in late 1974 (Figure 40). Spilled water accounted for 56% (885 m^3/s; 31,000 ft^3/s) of the total water released from Libby Dam during that event.

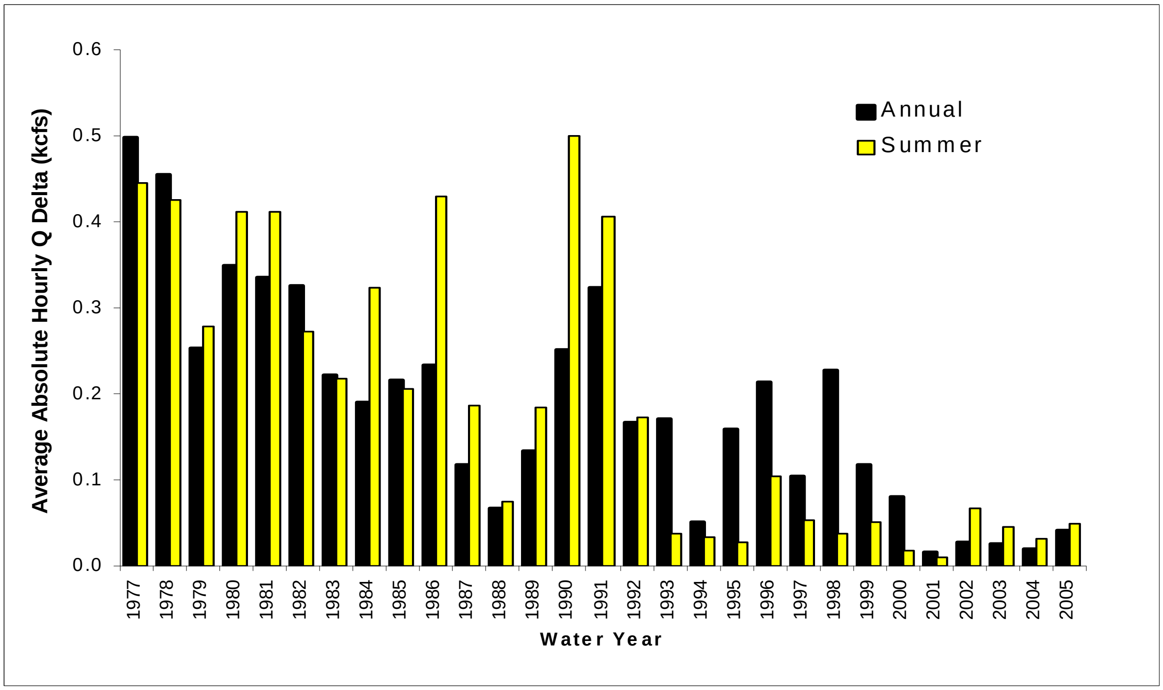


Figure 39. Absolute average daily discharge variation (kcfs) in the Kootenai River below Libby Dam, Montana.

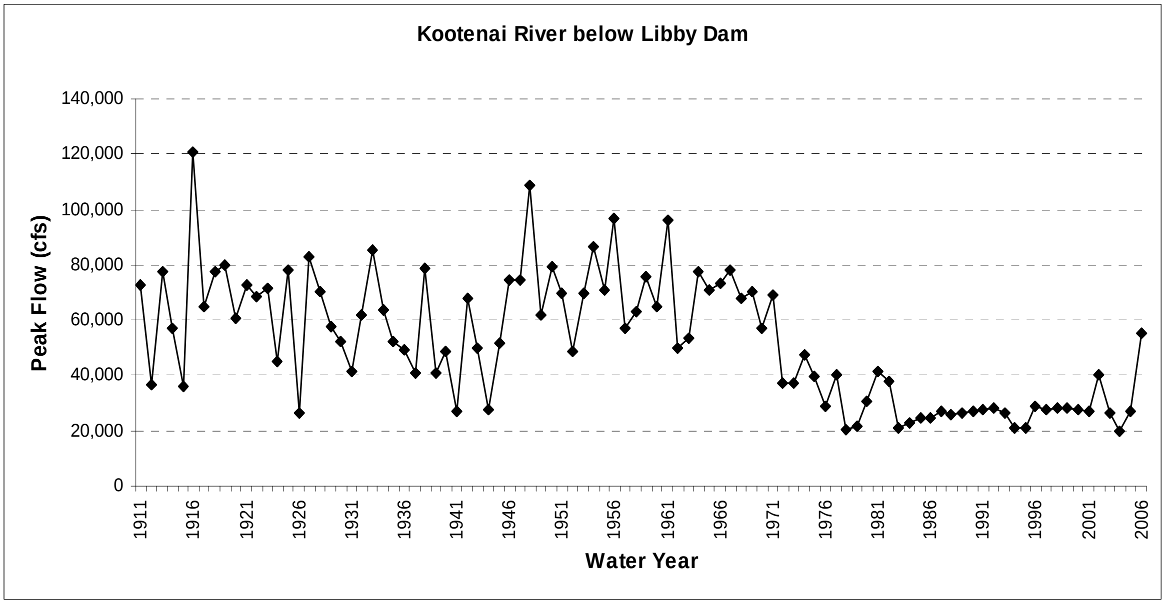


Figure 40. Peak discharge of the Kootenai River near Libby Dam for water years 1911-2006. Data from the United States Geological Survey and the United States Army Corps of Engineers data.

Wetted perimeter versus discharge of water released from Libby Dam is a logarithmic relationship with an inflection point of about 128 m^3/s (4,500 ft^3/s; Figure 41). Average daily wetted perimeter from water years 2000 to 2005 has been increased in the summer months compared to prior post dam years. These increases in wetted perimeter are due to high flows during the spring freshets, increased summer discharge due to the spill events, and higher than historical summer flows intended to benefit anadromous salmon in the lower Columbia Basin. Historically (i.e. 1970's and 1980's), the average daily wetted perimeter of the Kootenai River was greatest during the winter months (i.e., due to power peaking) and during the spring freshet (Table 10). Summer rankings for average daily wetted perimeter in 2002, 2003, and 2005 were 2, 4, and 1, respectively, due to unusually high summer flows. Summer flows below Libby Dam in 2005 averaged about 571 m^3/s (20,000 ft^3/s), much higher 142 m^3/s (5,000 ft^3/s) to 285 m^3/s (10,000 ft^3/s) before the dam was built (Figure 3).

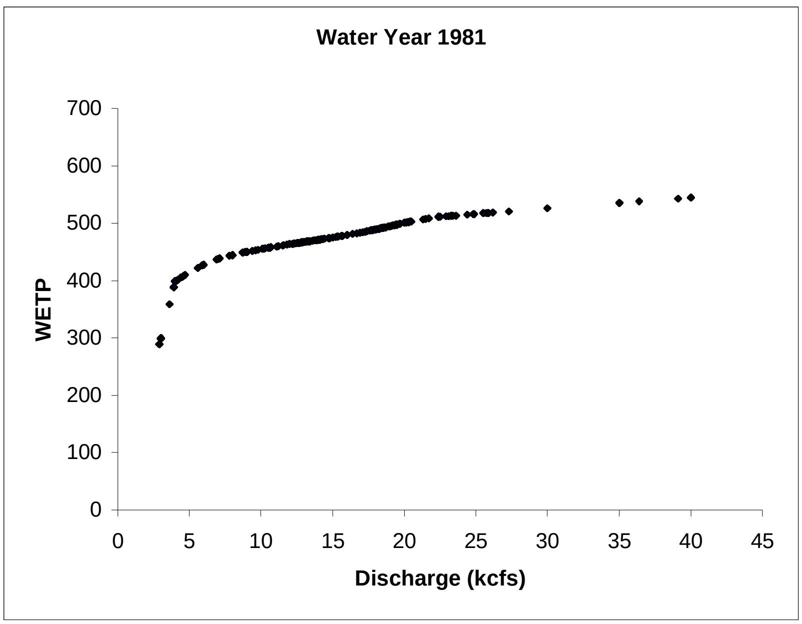


Figure 41. Relationship of wetted perimeter versus discharge (kcfs) for the Kootenai River below Libby Dam for water year 1981. The relationship was generated using RIVBIO model simulations.

Table 10. Summary of average daily wetted perimeter in the Kootenai River by month and for the entire water year and the annual and summer rankings of each water year.

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Daily AVG WETP	June-Sept Daily AVG WTP	Annual Rank WETP	June-Sept Rank WETP
1977	480	471	471	439	411	428	404	326	325	445	435	425	422	408	21	24
1978	451	483	428	448	444	355	299	339	433	464	449	454	421	450	22	15
1979	468	501	502	483	402	395	339	295	383	324	399	432	410	384	25	28
1980	460	506	462	437	388	339	324	324	452	431	408	402	411	424	23	22
1981	468	476	479	490	482	401	298	316	469	517	468	444	442	474	13	7
1982	458	460	490	490	466	441	435	462	417	445	454	441	455	439	6	16
1983	462	496	481	499	481	423	406	417	399	447	455	455	451	439	9	17
1984	462	452	498	485	418	396	384	355	375	451	462	448	433	434	19	19
1985	452	474	513	503	384	353	326	325	330	365	399	444	406	385	26	27
1986	493	493	459	485	393	403	384	305	456	481	447	480	440	466	14	9
1987	513	494	415	441	432	344	299	299	351	439	445	464	411	425	24	21
1988	516	445	422	508	480	347	325	325	325	328	346	489	404	372	28	29
1989	467	484	491	400	396	330	325	325	334	359	491	425	402	402	29	25
1990	486	476	485	411	510	463	428	399	468	488	458	445	459	464	4	12
1991	496	436	509	515	499	452	443	440	468	491	470	469	474	475	2	6
1992	495	516	472	403	399	363	396	430	426	399	438	477	434	435	18	18
1993	452	494	460	392	386	400	353	361	426	354	368	424	406	393	27	26
1994	471	492	505	428	399	399	399	437	485	416	399	410	437	427	15	20
1995	443	464	438	479	407	399	401	467	499	440	469	422	444	458	12	13
1996	415	491	499	515	464	437	478	468	517	476	483	450	474	482	1	3
1997	465	469	487	498	485	417	446	464	507	469	464	456	469	474	3	8
1998	466	467	467	435	444	403	399	443	497	464	490	450	452	475	8	5
1999	437	420	495	494	505	426	399	399	457	460	478	464	453	465	7	11
2000	462	476	511	513	486	416	399	399	479	445	445	440	456	452	5	14
2001	428	448	443	416	457	405	399	399	399	428	428	427	423	420	20	23
2002	428	430	450	467	462	413	399	424	503	517	486	429	451	484	10	2
2003	422	413	488	399	399	399	399	399	497	481	483	440	435	475	16	4
2004	407	438	478	428	399	399	399	403	473	465	465	460	435	466	17	10
2005	424	470	500	406	399	399	399	440	501	505	485	449	448	485	11	1

Model simulations using RIVBIO were completed using 15, 30, 47, 60, 75, and 90-day benthic recolonization times for water years 1977-2005. Daily productivity of the Kootenai River generally highest during the months of July and August. Winter productivity values are approximately half of the summer maximum. Faster recolonization rates generally resulted in higher productivity regardless of season because short duration increases in discharge allow for newly wetted areas to become more productive faster than longer recolonization periods, while long periods of stable discharge have the same productivity regardless of recolonization or recovery period (Figure 42 and Figures 42-71). Annual productivity with recovery rates of 15, 30, 60, 75, and 90-days in the Kootenai River varied from –13.8% to +22.0% of the 47-day recovery period that we considered the baseline minimum recovery time needed for newly wetted substrates. Monthly productivity varied from –37.4 % to +80.9 % in water year 1985. A recovery time of approximately 60 days which approximates the recolonization time of newly wetted substrates (Shaw and Minshall 1980; Gersich and Brusven 1981) resulted in annual productivity differences of -5.3% to -0.3% of the 47-day recolonization period in the Kootenai River (Tables 11-15).

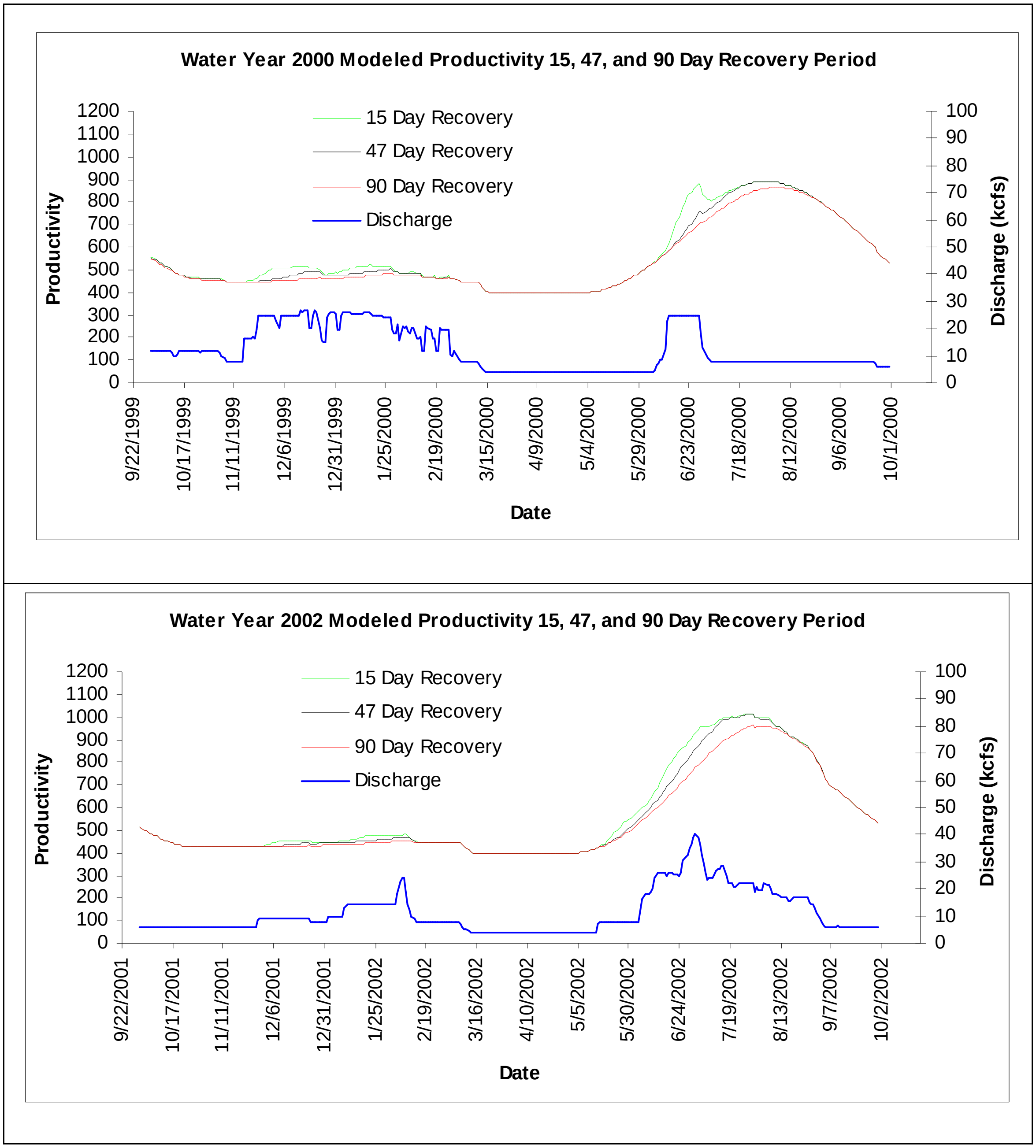


Figure 42. Example of how daily productivity varies by benthic recovery time in the Kootenai River for water year 2002. Flat discharge levels do not result in different benthic production (2000 panel) and shorter recolonization times result in greater productivity when short duration discharge changes occur (2002 panel).

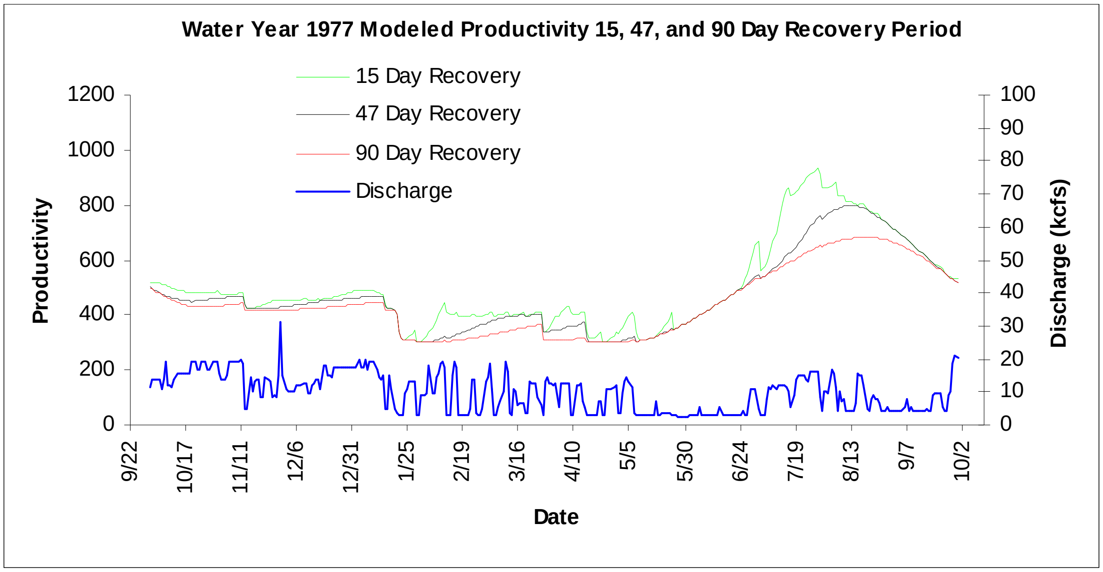


Figure 43. Comparison of water year 1977 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

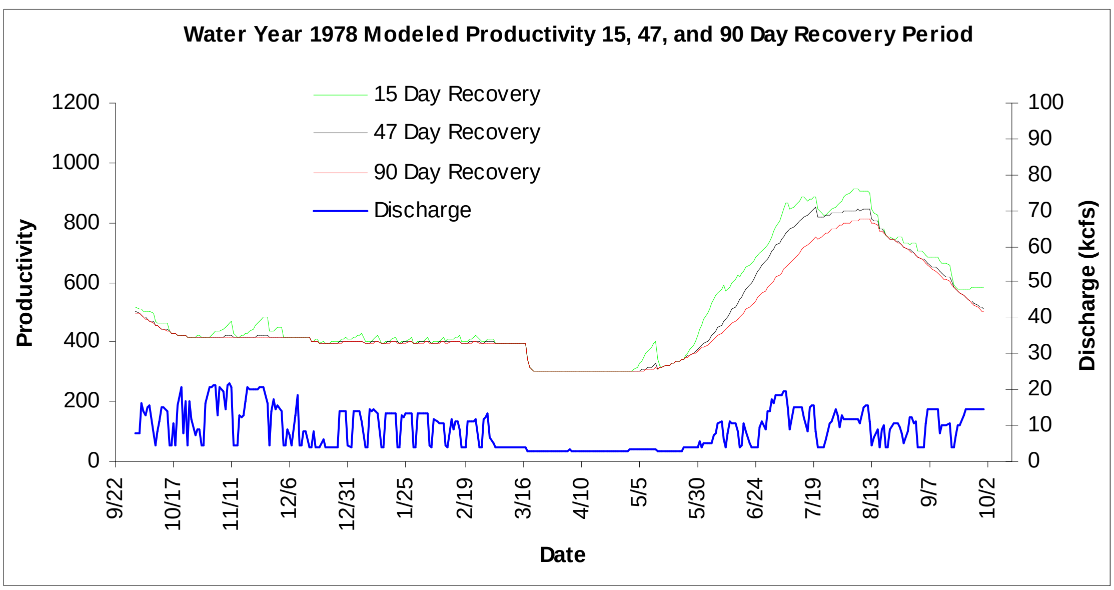


Figure 44. Comparison of water year 1978 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

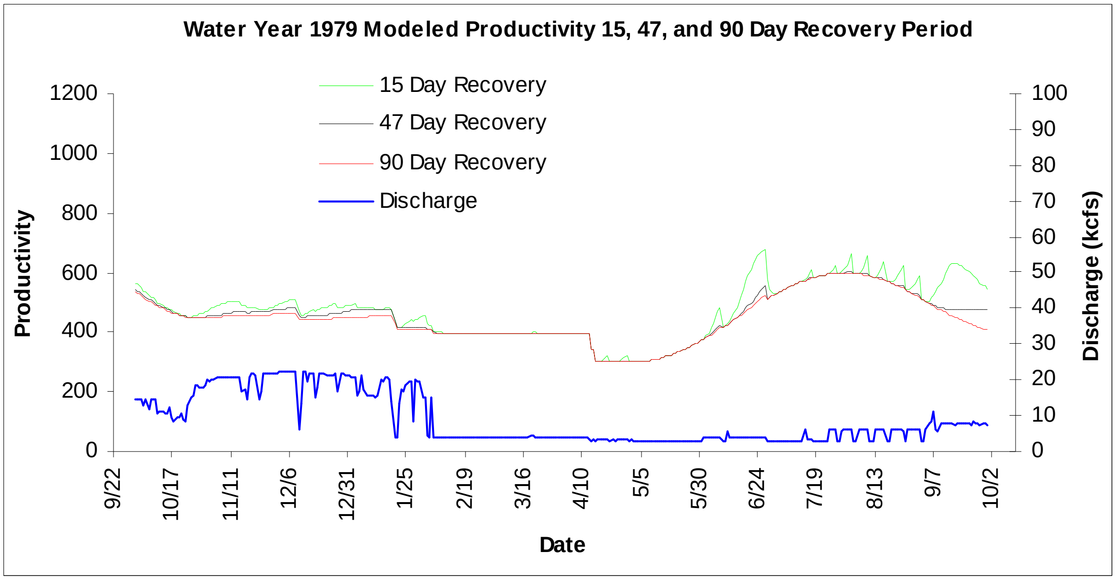


Figure 45. Comparison of water year 1979 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

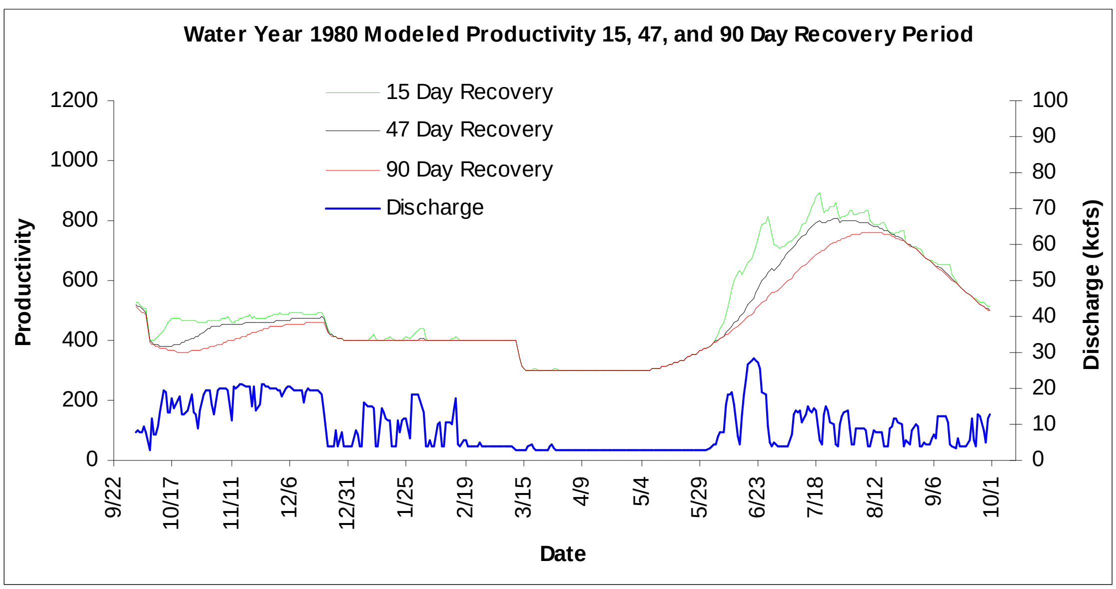


Figure 46. Comparison of water year 1980 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

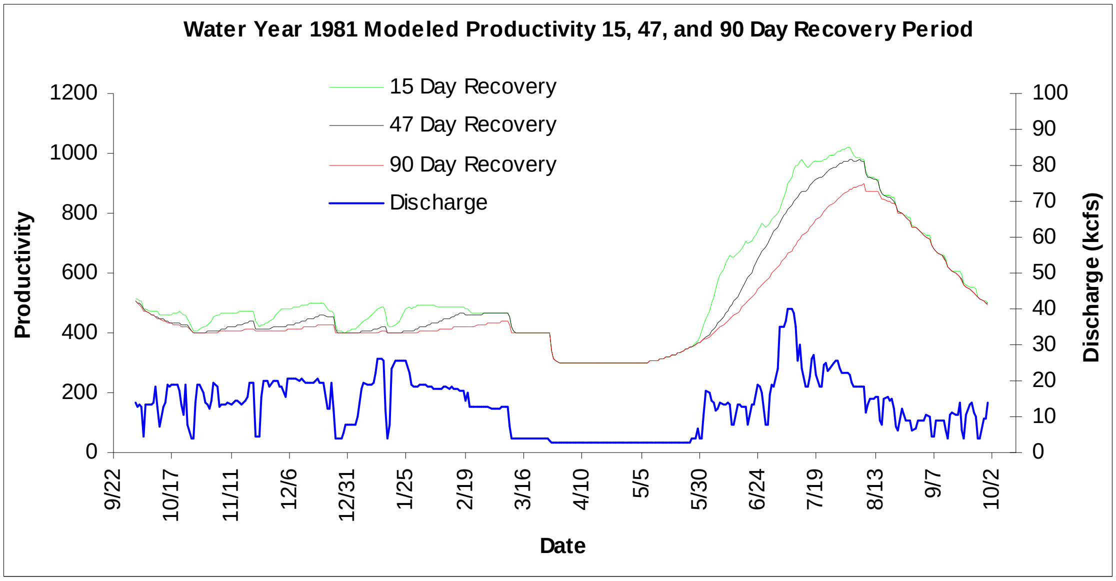


Figure 47. Comparison of water year 1981 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

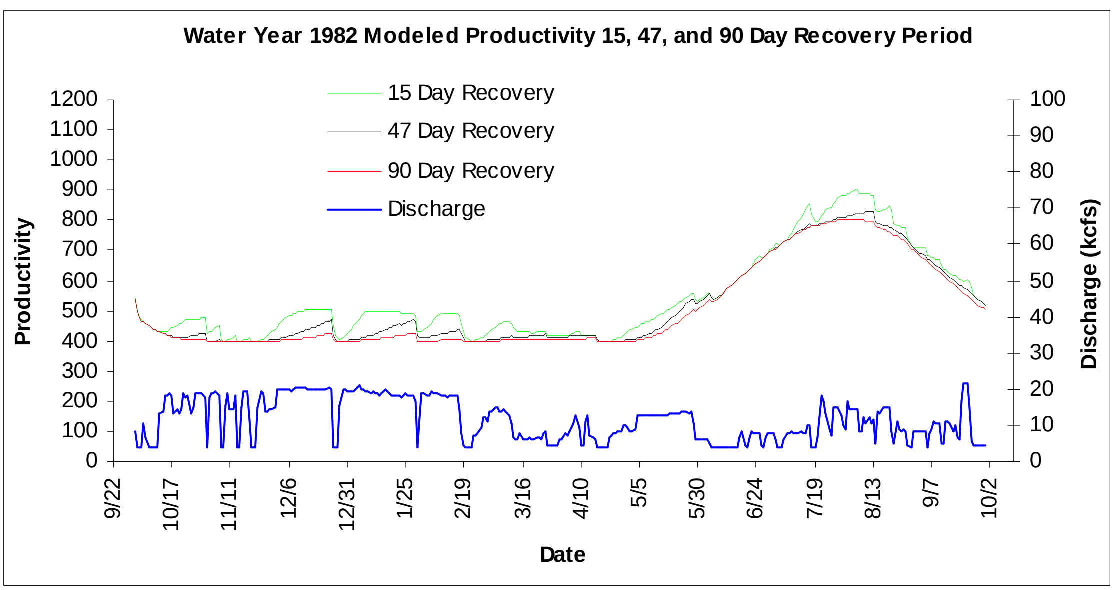


Figure 48. Comparison of water year 1982 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

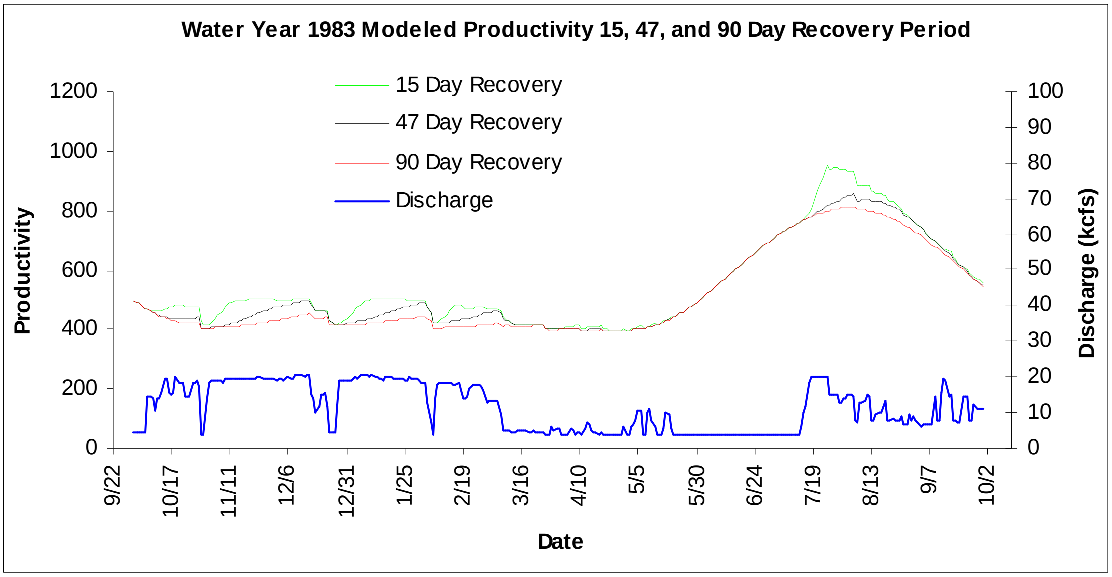


Figure 49. Comparison of water year 1983 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

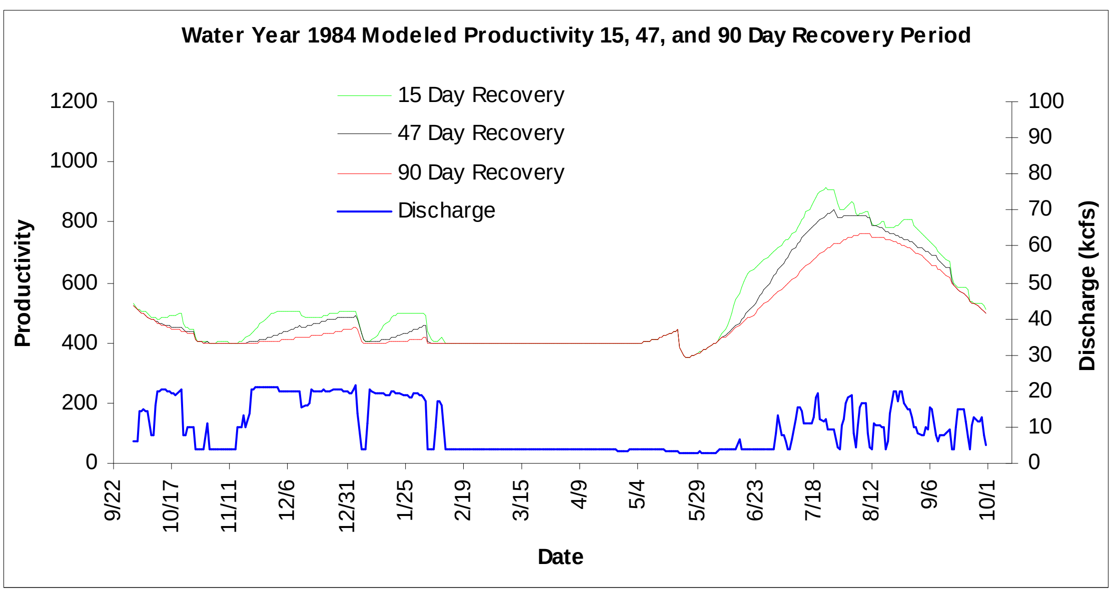


Figure 50. Comparison of water year 1984 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

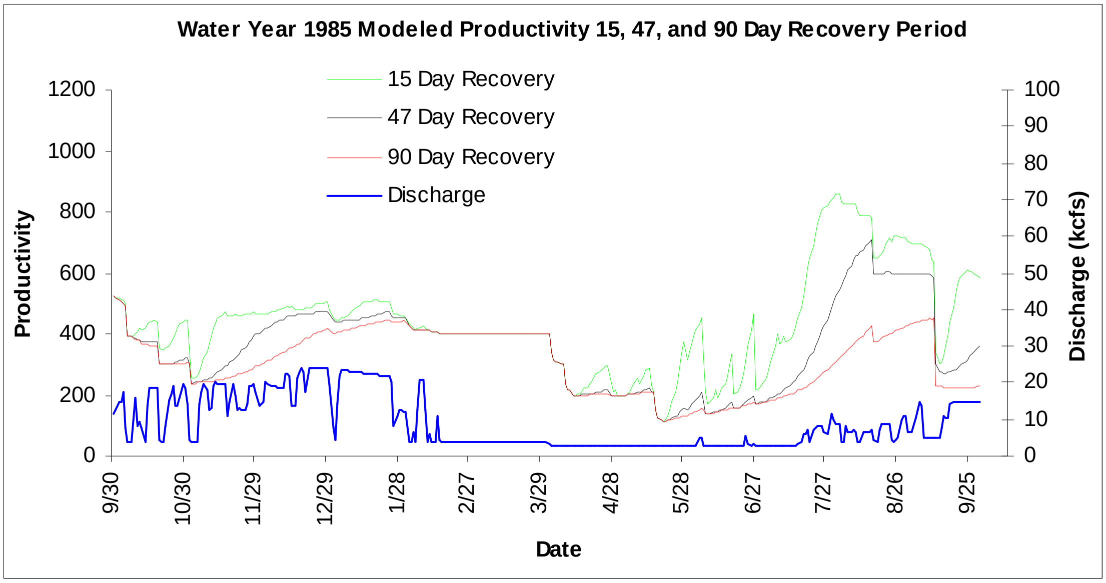


Figure 51. Comparison of water year 1985 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

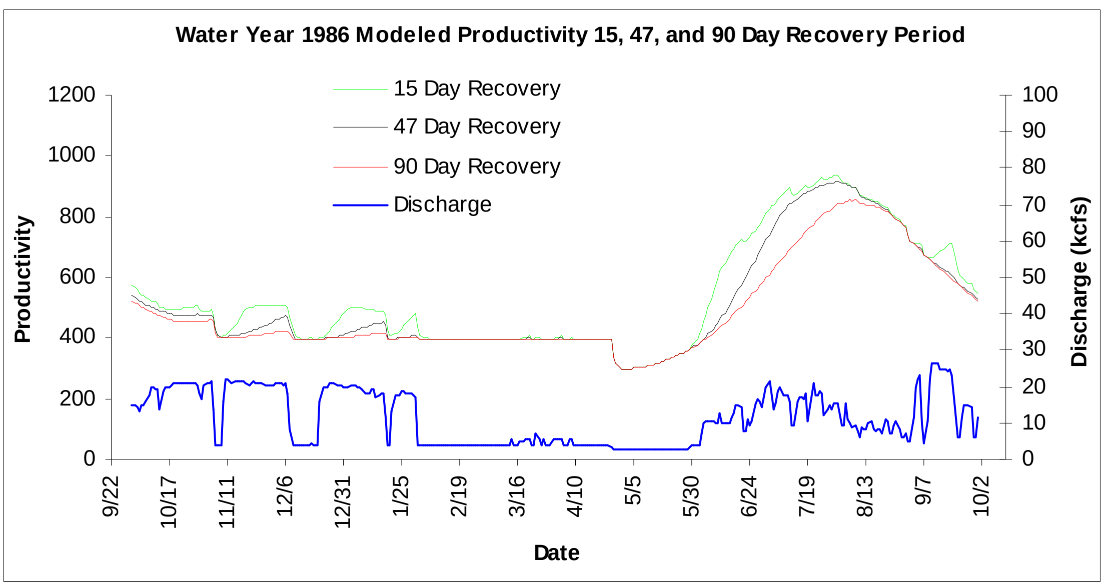


Figure 52. Comparison of water year 1986 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

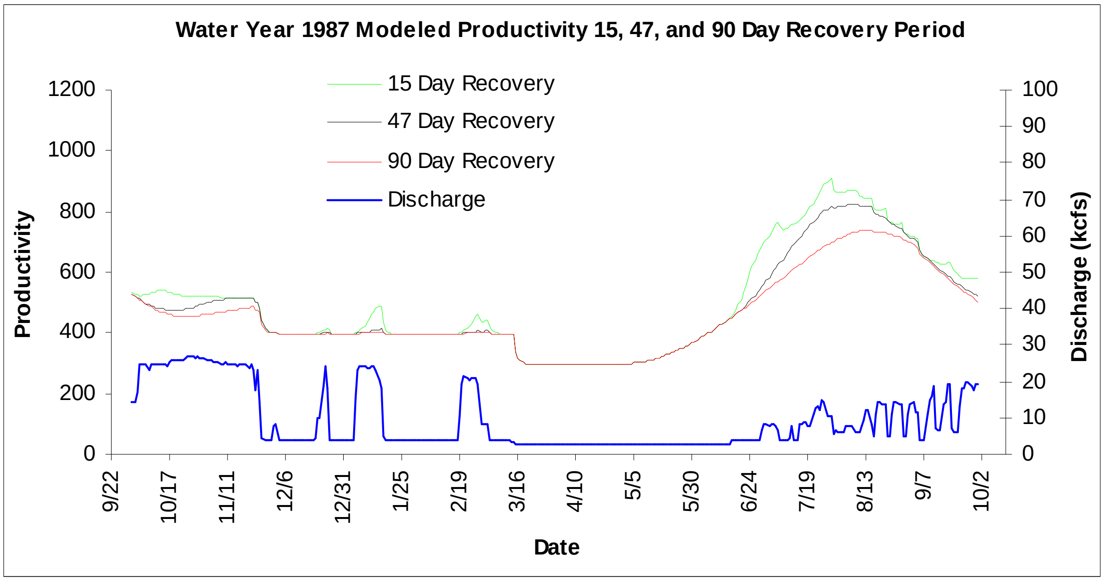


Figure 53. Comparison of water year 1987 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam

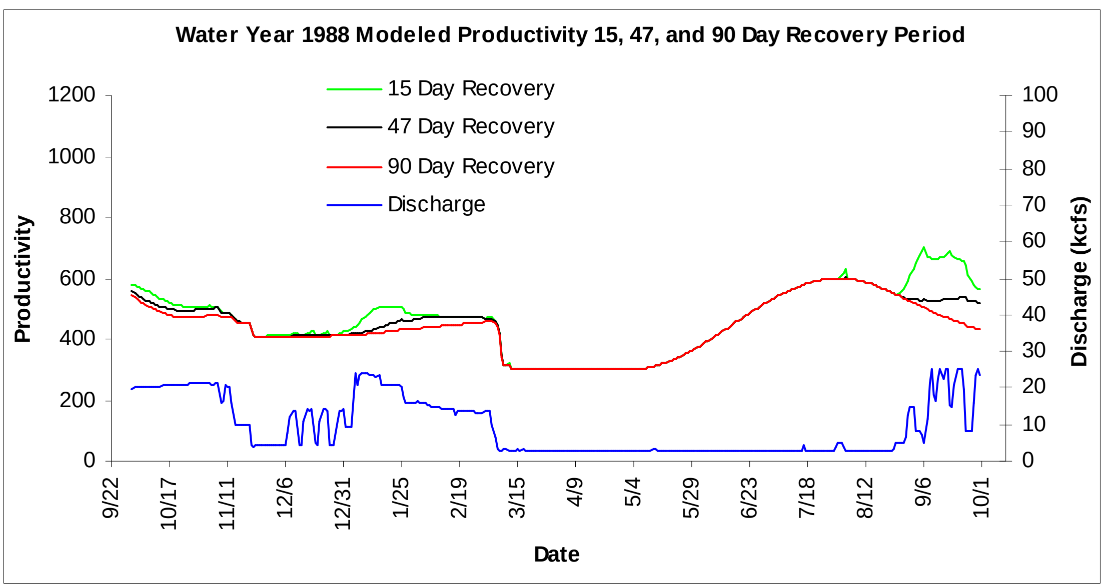


Figure 54. Comparison of water year 1988 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

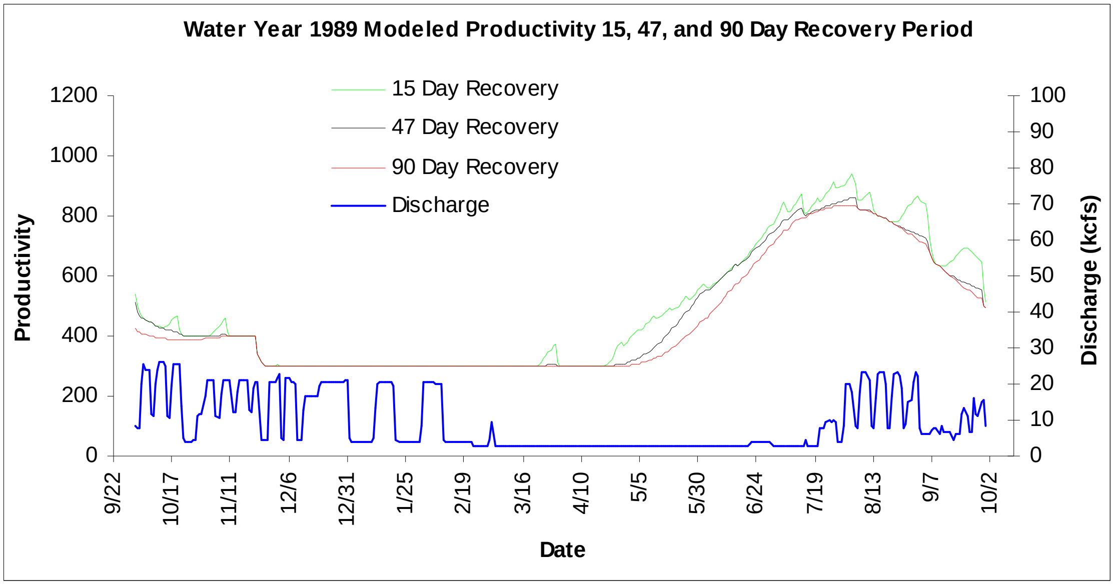


Figure 55. Comparison of water year 1989 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

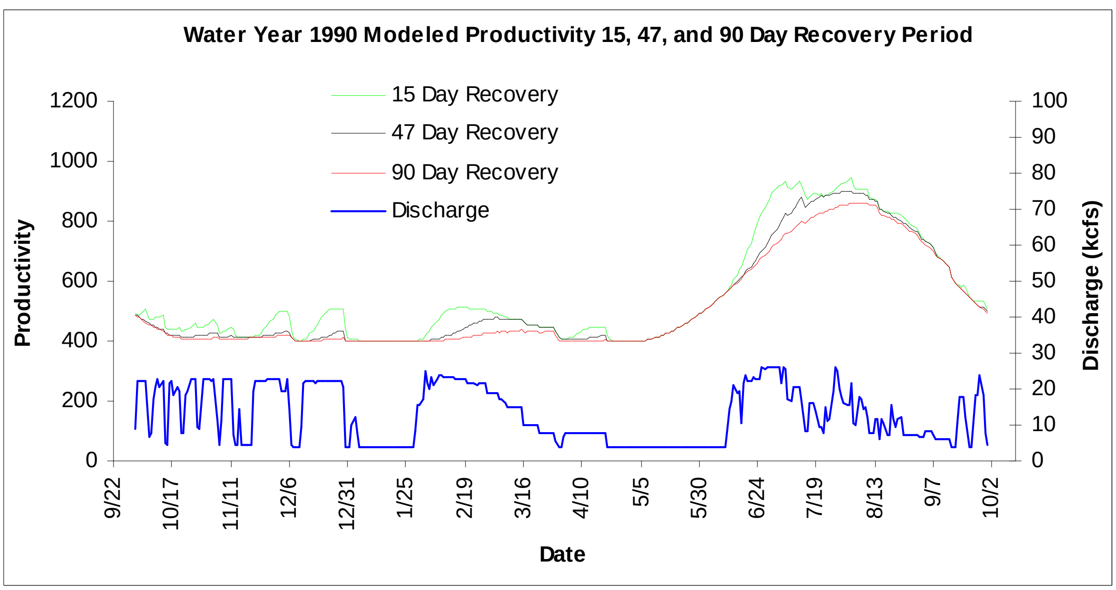


Figure 56. Comparison of water year 1990 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

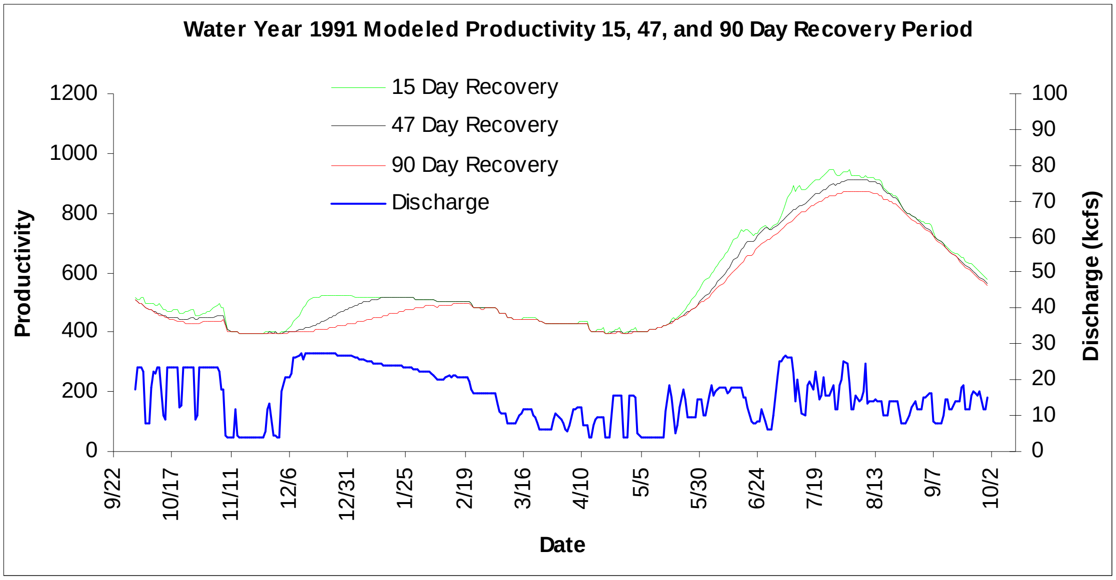


Figure 57. Comparison of water year 1991 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

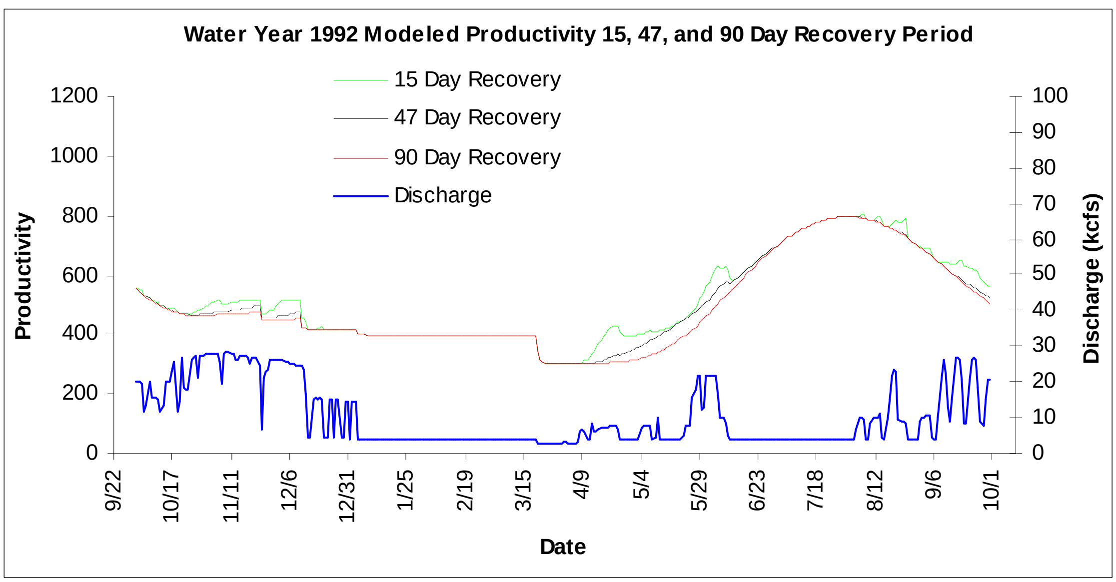


Figure 58. Comparison of water year 1992 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

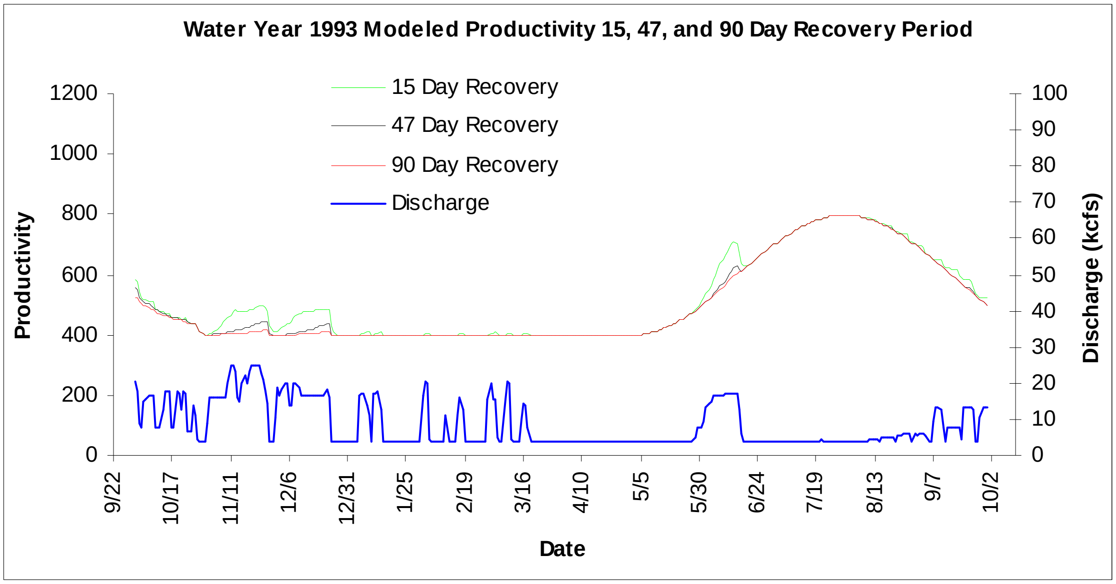


Figure 59. Comparison of water year 1993 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

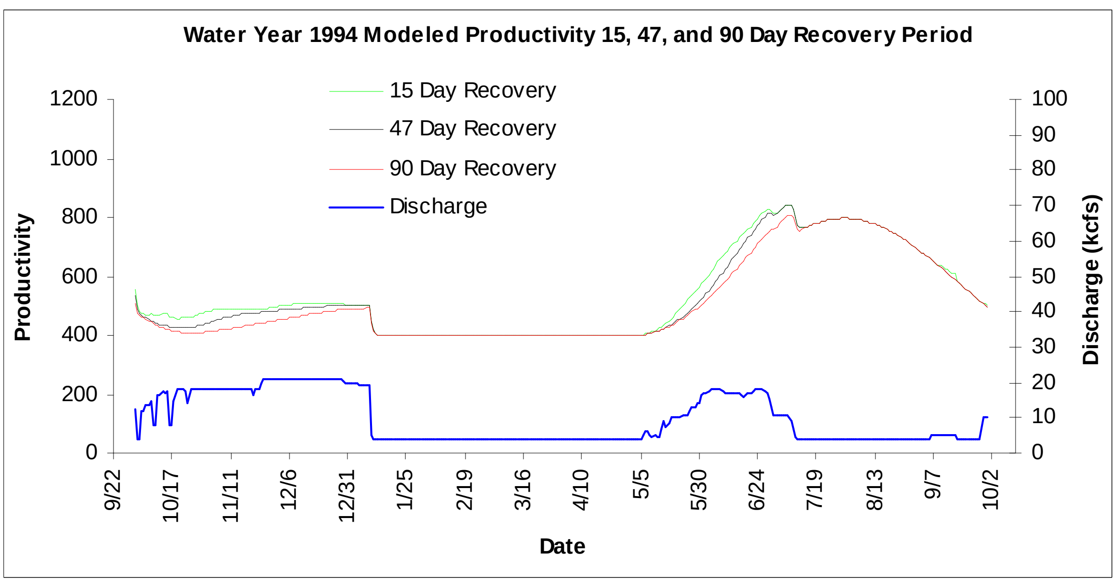


Figure 60. Comparison of water year 1994 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

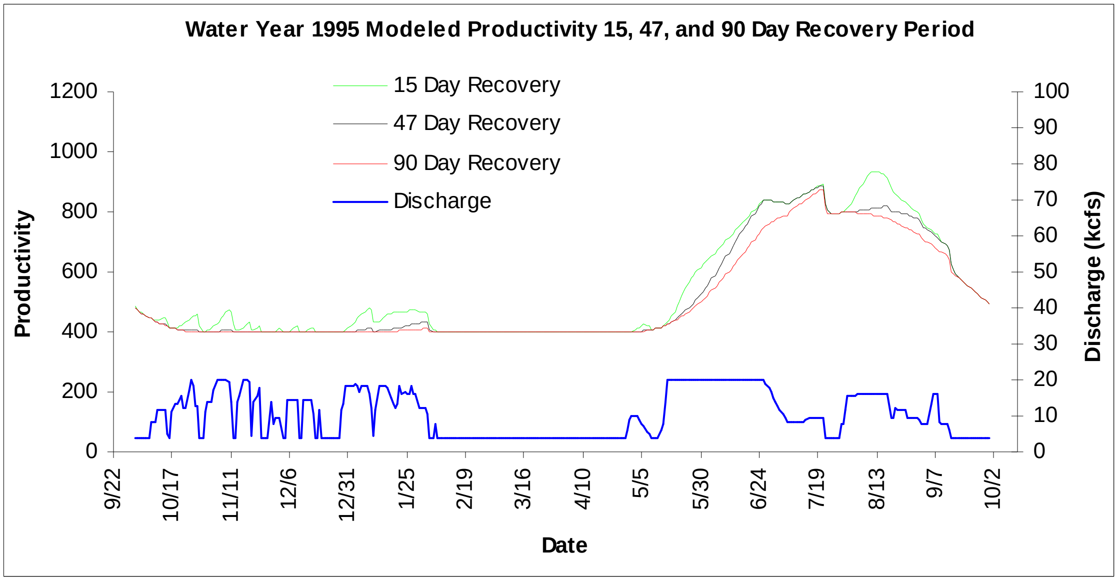


Figure 61. Comparison of water year 1995 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

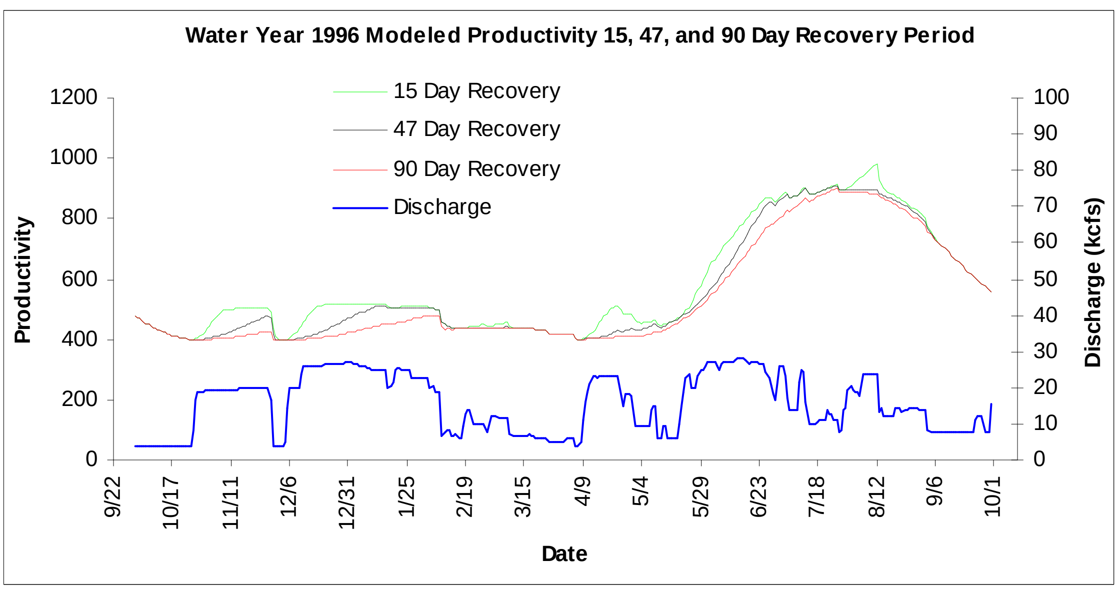


Figure 62. Comparison of water year 1996 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

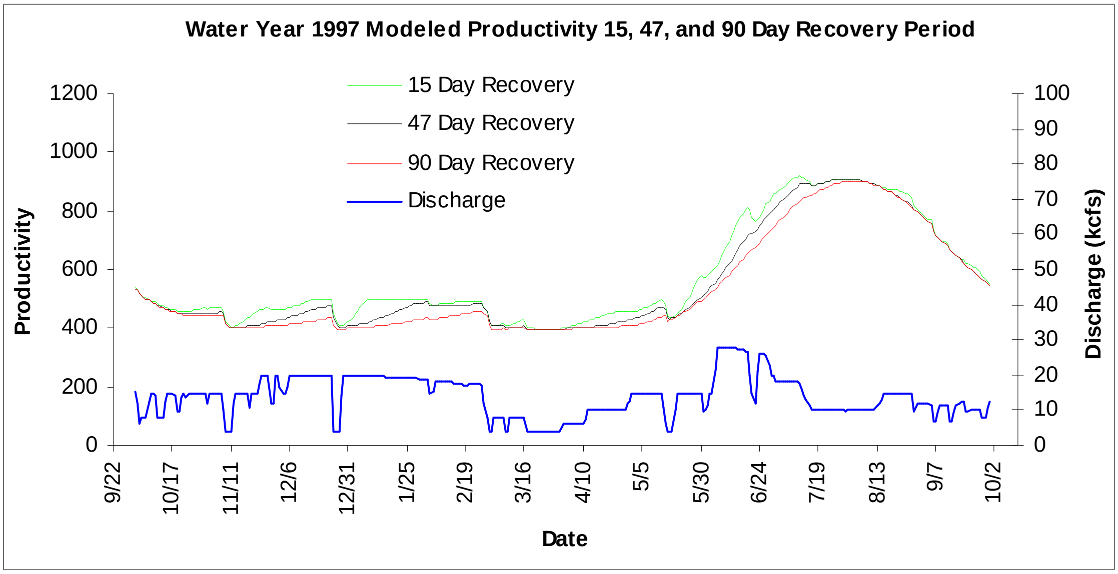


Figure 63. Comparison of water year 1997 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

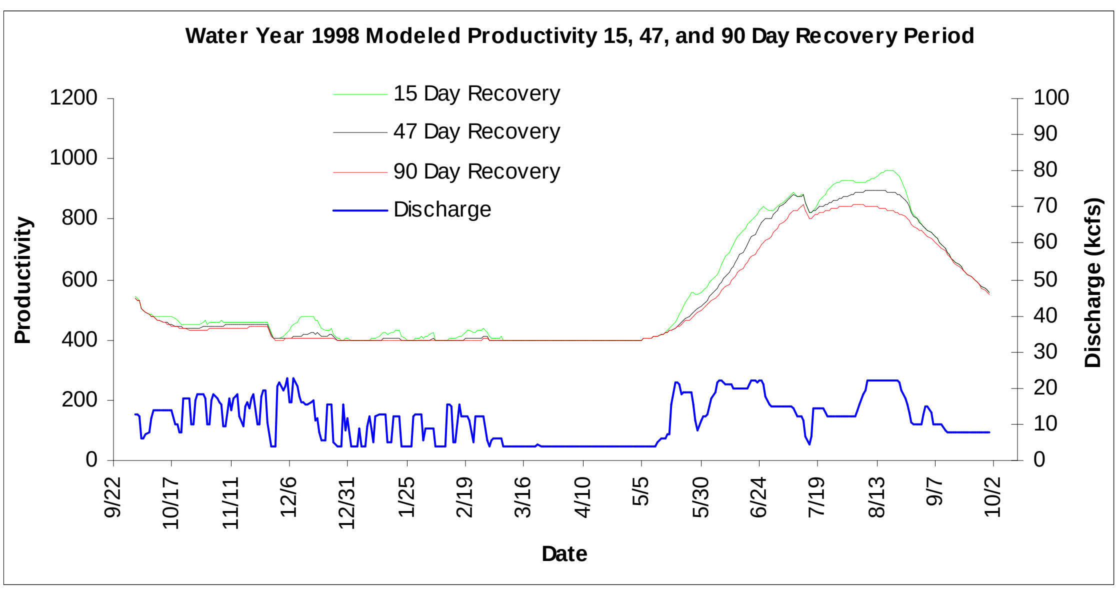


Figure 64. Comparison of water year 1998 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

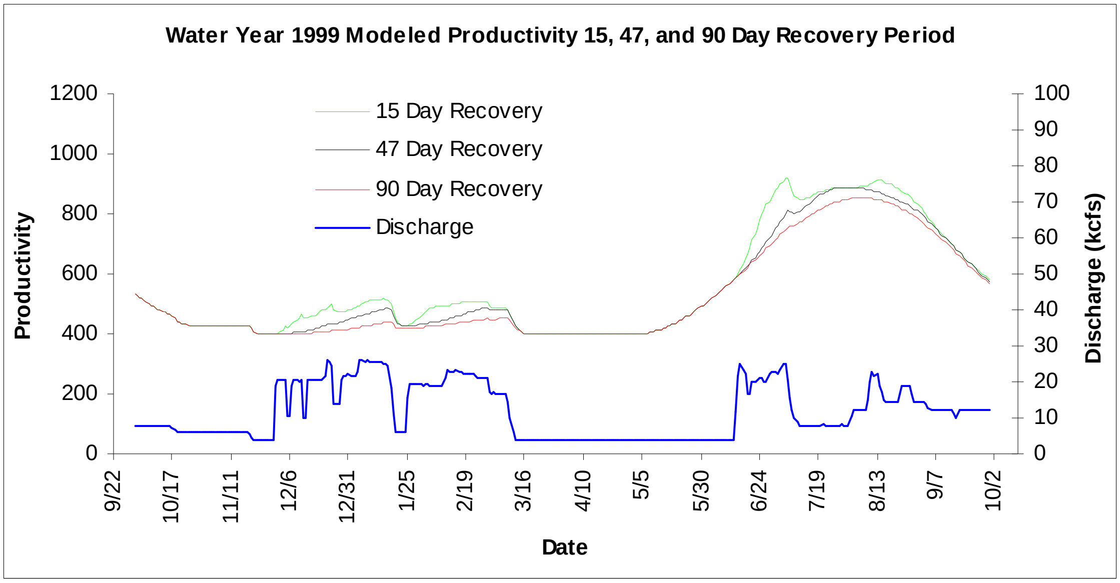


Figure 65. Comparison of water year 1999 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

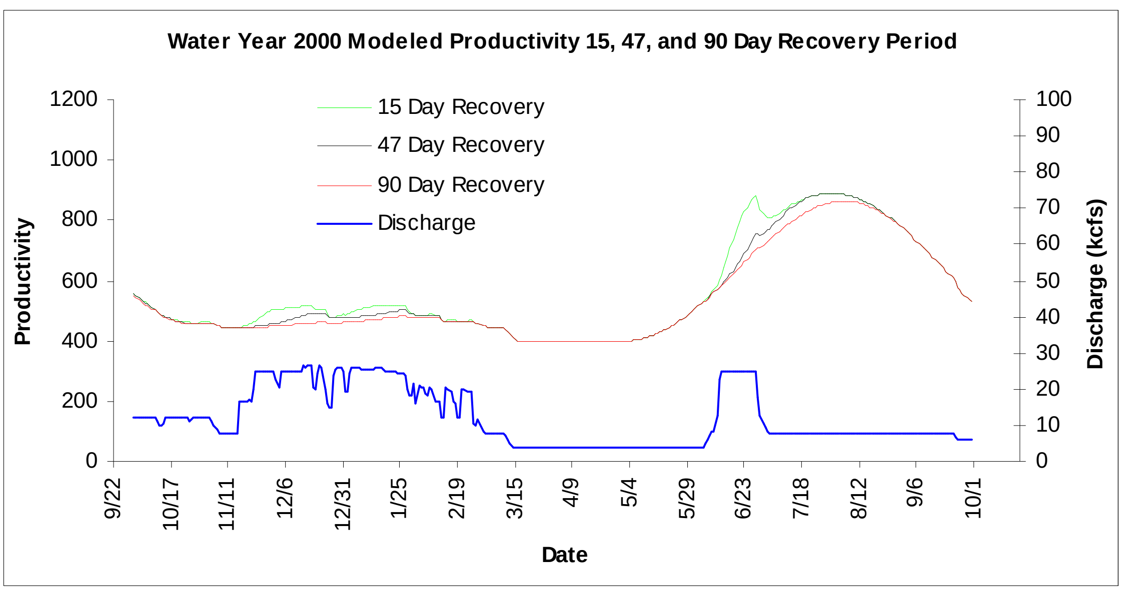


Figure 66. Comparison of water year 2000 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

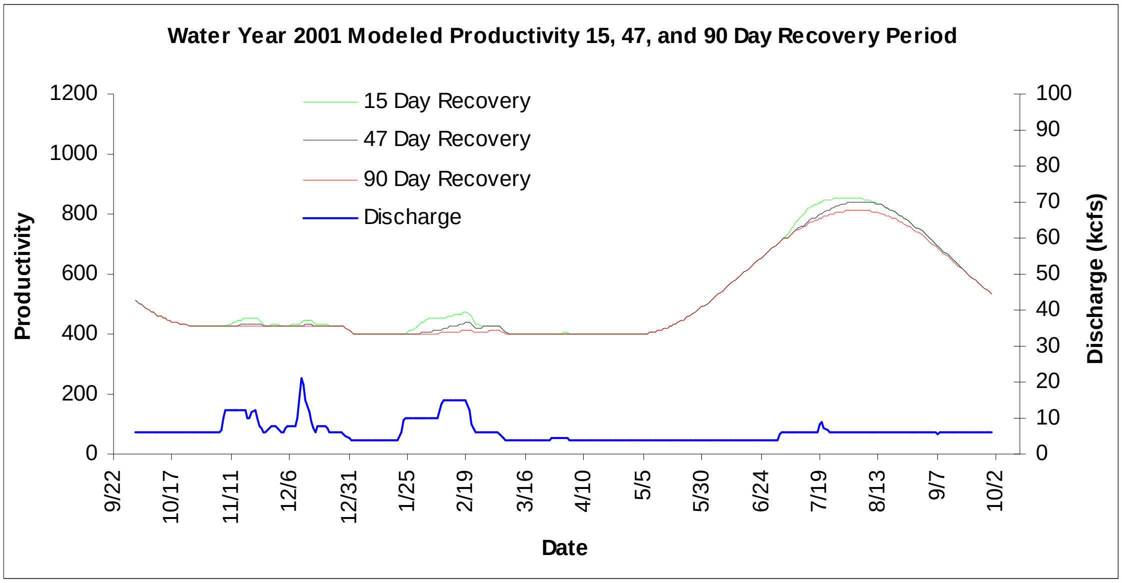


Figure 67. Comparison of water year 2001 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

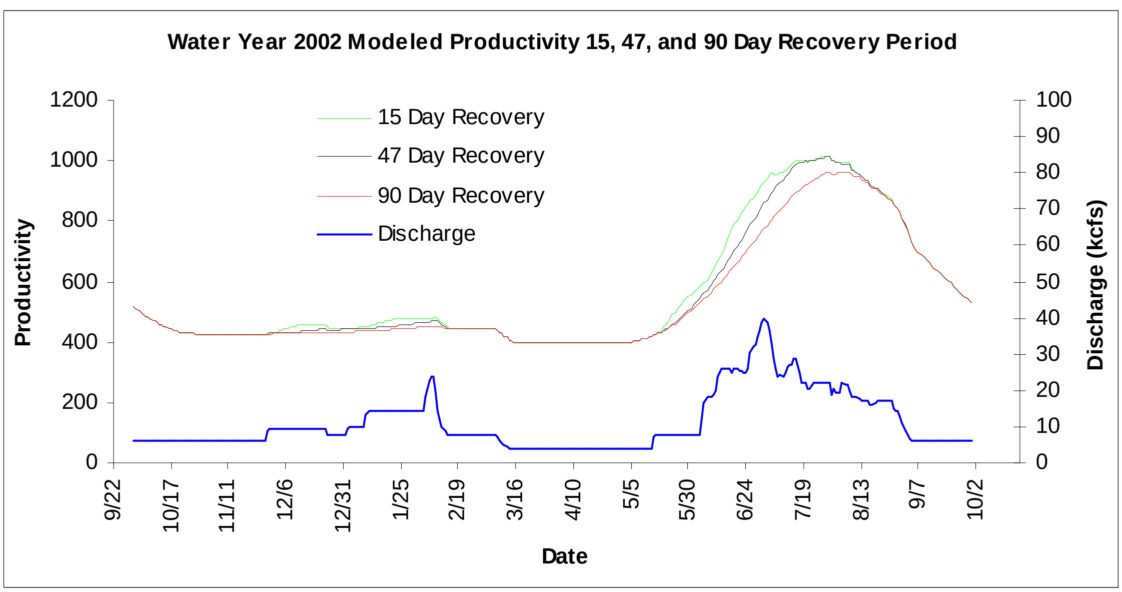


Figure 68. Comparison of water year 2002 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

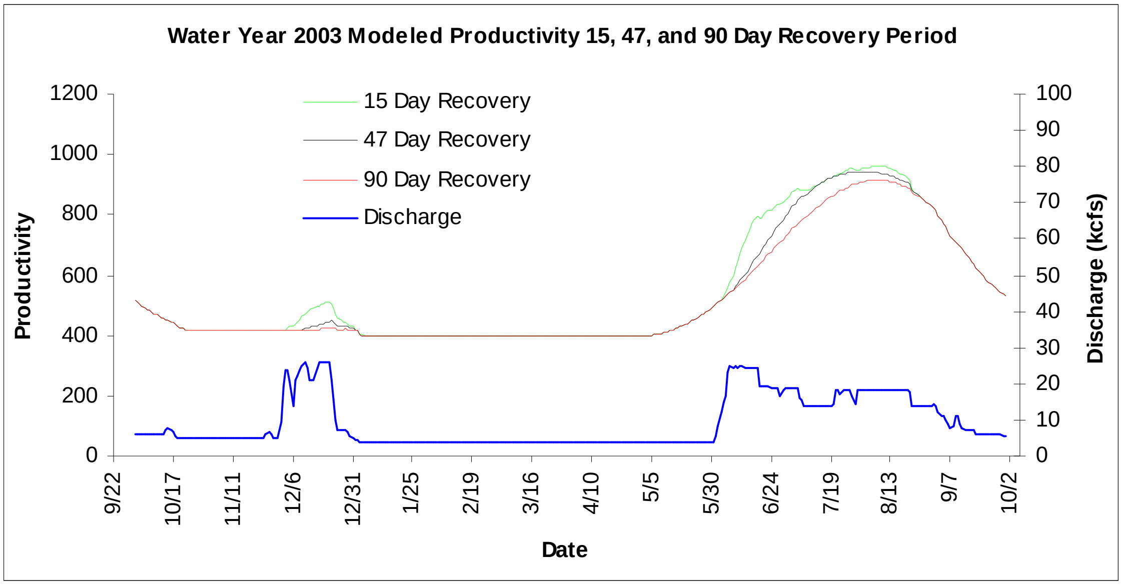


Figure 69. Comparison of water year 2003 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

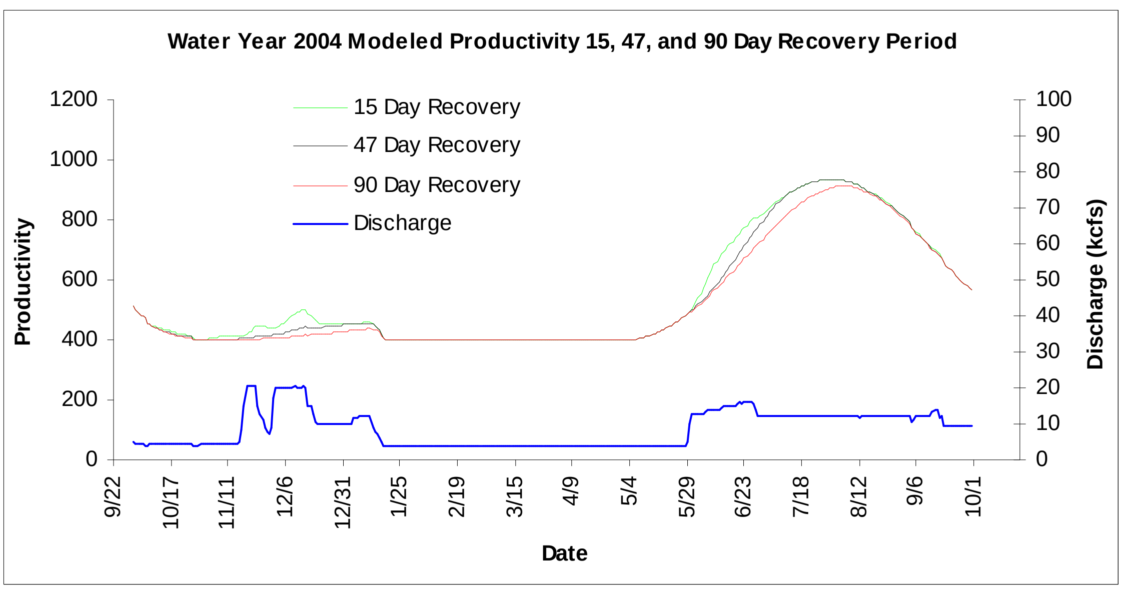


Figure 70. Comparison of water year 2004 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

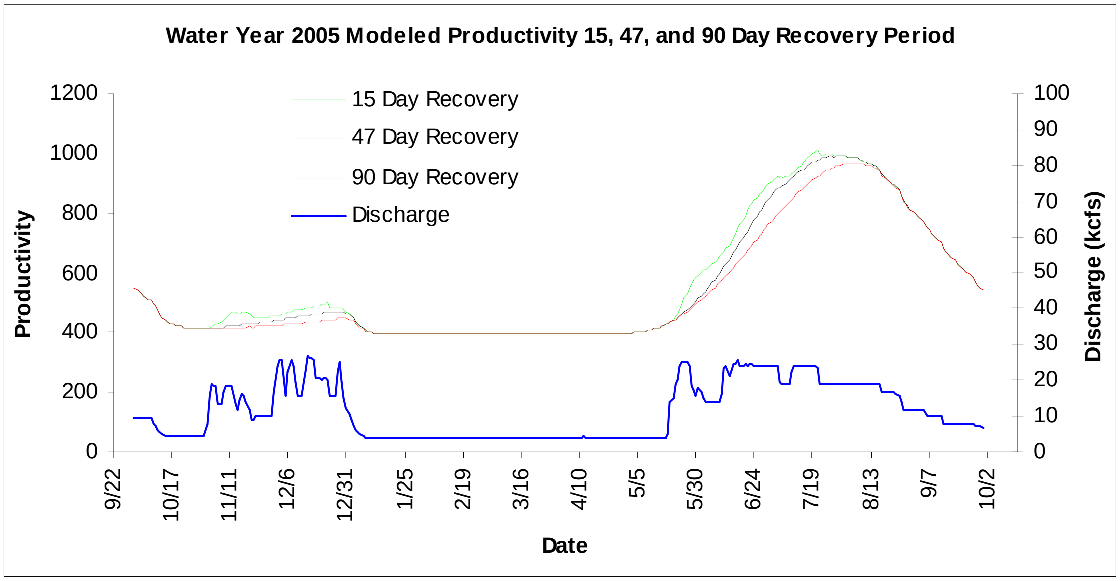


Figure 71. Comparison of water year 2005 benthic productivity by recovery period (15, 47, and 90-days) in the Kootenai River below Libby Dam.

Table 11. Percent differences in the monthly and annual potential productivity 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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
1977	6.8	2.9	3.1	2.9	18.5	2.8	10.6	6.9	2.2	24.3	3.7	0.3	7.0
1978	2.2	6.0	1.0	1.9	2.2	0.2	0.0	6.7	15.3	6.0	4.2	5.6	4.7
1979	1.7	4.8	4.5	2.0	1.1	0.0	1.0	0.0	11.9	0.6	3.9	18.9	4.4
1980	10.8	4.1	2.7	1.9	0.8	0.3	0.0	0.0	21.5	5.6	2.1	1.4	4.6
1981	4.1	8.7	8.9	11.3	7.6	0.0	0.0	0.6	21.0	7.4	0.9	1.0	6.0
1982	5.8	3.4	10.9	11.7	8.6	5.6	1.5	7.0	0.4	4.4	6.0	2.4	5.4
1983	5.4	11.1	1.7	8.8	5.8	0.6	1.5	0.4	0.0	5.6	4.3	0.7	3.8
1984	3.4	5.8	7.6	8.5	1.9	0.0	0.0	0.0	13.6	8.7	3.7	3.6	5.0
1985	13.1	36.6	6.8	6.2	0.3	0.0	9.3	29.1	68.9	80.9	22.9	37.8	22.0
1986	4.4	9.3	5.4	11.6	0.5	0.1	0.1	0.2	21.7	4.3	0.4	5.3	5.3
1987	7.9	0.9	0.4	4.1	2.1	1.3	0.0	0.0	8.2	12.0	3.1	4.2	4.4
1988	4.1	0.6	1.2	9.4	0.7	0.1	0.0	0.0	0.0	0.0	1.7	22.9	3.8
1989	1.9	2.0	0.1	0.0	0.0	3.3	4.9	16.9	1.5	4.2	4.9	11.5	4.7
1990	5.7	4.7	11.8	0.3	13.1	1.1	3.5	0.0	8.0	5.8	1.7	0.9	4.5
1991	4.3	2.1	12.8	1.6	0.1	0.2	1.0	2.7	6.5	5.1	1.0	1.9	3.3
1992	1.2	5.6	4.4	0.0	0.0	0.0	14.3	4.8	3.6	0.0	1.4	5.5	3.0
1993	1.1	9.6	9.0	0.5	0.2	0.5	0.0	0.2	5.7	0.0	0.4	2.5	2.3
1994	6.6	4.4	2.0	0.0	0.0	0.0	0.0	4.6	5.7	0.0	0.0	0.6	2.0
1995	3.1	4.9	0.9	11.0	1.1	0.0	0.0	8.1	5.0	0.1	8.5	0.4	3.7
1996	0.5	11.6	12.1	2.8	0.7	0.7	8.8	3.9	7.8	0.3	3.2	0.2	4.0
1997	1.5	6.0	6.0	10.5	1.4	1.3	5.6	5.7	9.5	1.8	1.0	1.1	4.0
1998	2.5	1.4	7.0	2.1	3.4	0.4	0.0	4.9	7.9	2.5	4.8	0.0	3.3
1999	0.0	0.0	9.2	5.2	8.6	0.3	0.0	0.0	6.8	4.7	3.0	0.6	3.3
2000	0.5	2.6	5.3	4.1	0.6	0.0	0.0	0.0	10.7	1.5	0.0	0.0	2.1
2001	0.0	2.0	1.1	1.2	7.0	0.1	0.2	0.0	0.0	3.4	0.4	0.0	1.2
2002	0.0	0.0	2.9	2.7	0.9	0.0	0.0	3.3	9.2	2.4	0.1	0.0	1.9
2003	0.0	0.0	8.1	0.1	0.0	0.0	0.0	0.0	11.8	1.5	1.5	0.0	2.1
2004	0.8	4.1	6.6	0.3	0.0	0.0	0.0	0.1	8.7	0.5	0.2	0.3	1.8
2005	0.0	5.6	4.3	0.1	0.0	0.0	0.0	4.1	9.0	2.2	0.0	0.0	2.2

Table 12. Percent differences in the monthly and annual potential productivity 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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
1977	3.2	1.2	1.7	1.3	7.8	1.8	4.6	1.4	0.4	8.8	2.5	0.0	2.9
1978	0.4	1.0	0.1	0.4	0.3	0.0	0.0	1.3	8.1	2.6	1.3	2.1	1.7
1979	0.7	2.1	1.5	0.7	0.3	0.0	0.2	0.0	3.0	0.1	0.7	7.8	1.5
1980	5.3	1.5	1.2	0.4	0.1	0.0	0.0	0.0	8.7	2.6	0.5	0.3	1.8
1981	1.6	4.2	4.9	3.4	5.7	0.0	0.0	0.1	10.8	3.7	0.5	0.2	3.0
1982	1.9	0.9	5.6	6.9	5.1	2.6	0.3	3.8	0.1	0.8	2.7	0.9	2.4
1983	1.9	5.1	1.2	4.6	2.7	0.6	0.2	0.1	0.0	1.5	2.9	0.1	1.7
1984	1.1	1.5	4.6	3.4	1.6	0.0	0.0	0.0	5.5	4.8	1.1	1.7	2.3
1985	3.5	15.1	4.1	2.7	0.1	0.0	2.0	5.7	12.3	29.8	16.1	18.8	9.1
1986	2.1	3.5	3.0	5.9	0.0	0.0	0.0	0.0	10.7	2.3	0.1	1.4	2.4
1987	3.9	0.9	0.1	0.8	0.4	0.3	0.0	0.0	2.0	6.8	1.6	1.3	1.9
1988	2.3	0.3	0.5	4.3	0.6	0.0	0.0	0.0	0.0	0.0	0.3	10.5	1.7
1989	0.6	0.4	0.0	0.0	0.0	0.6	1.0	9.6	0.6	1.3	1.6	3.2	1.7
1990	1.6	1.4	3.4	0.0	6.2	1.1	1.2	0.0	2.4	3.6	0.6	0.3	1.8
1991	1.5	0.6	5.8	1.6	0.0	0.0	0.2	0.6	3.6	2.2	0.5	0.5	1.5
1992	0.3	2.6	2.1	0.0	0.0	0.0	5.1	3.4	1.1	0.0	0.3	1.8	1.2
1993	0.6	4.1	4.9	0.1	0.0	0.1	0.0	0.0	1.7	0.0	0.1	0.6	0.9
1994	3.2	2.9	1.3	0.0	0.0	0.0	0.0	1.6	3.6	0.0	0.0	0.1	1.0
1995	0.7	0.8	0.2	3.1	0.7	0.0	0.0	2.3	4.1	0.0	3.8	0.4	1.5
1996	0.1	6.1	5.2	2.4	0.2	0.2	2.9	1.9	4.8	0.1	1.2	0.1	1.9
1997	0.5	2.0	3.4	5.6	0.9	0.3	2.3	2.4	4.4	0.8	0.2	0.2	1.8
1998	0.9	0.8	2.5	0.5	0.9	0.0	0.0	1.4	4.4	1.0	2.3	0.0	1.4
1999	0.0	0.0	3.8	2.4	4.4	0.3	0.0	0.0	1.9	3.2	1.3	0.5	1.5
2000	0.2	0.7	3.1	2.2	0.2	0.0	0.0	0.0	3.8	1.3	0.0	0.0	1.0
2001	0.0	0.5	0.2	0.2	3.7	0.1	0.0	0.0	0.0	1.6	0.4	0.0	0.6
2002	0.0	0.0	1.4	1.2	0.8	0.0	0.0	0.9	4.7	1.8	0.0	0.0	1.0
2003	0.0	0.0	3.1	0.1	0.0	0.0	0.0	0.0	5.3	1.2	0.7	0.0	1.0
2004	0.4	1.7	3.0	0.2	0.0	0.0	0.0	0.0	4.4	0.5	0.1	0.1	0.9
2005	0.0	2.3	2.1	0.1	0.0	0.0	0.0	0.9	4.9	1.5	0.0	0.0	1.1

Table 13. Percent differences in the monthly and annual potential productivity 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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
1977	-1.5	-1.6	-2.1	-0.6	-3.1	-3.3	-1.5	-0.4	-0.1	-3.3	-3.9	0.0	-1.9
1978	-0.1	-0.3	0.0	-0.1	-0.1	0.0	0.0	-0.4	-4.6	-2.6	-0.4	-0.5	-1.0
1979	-0.3	-1.0	-1.2	-1.0	-0.1	0.0	0.0	0.0	-0.9	0.0	-0.2	-2.9	-0.7
1980	-2.6	-2.4	-0.7	-0.1	0.0	0.0	0.0	0.0	-3.3	-3.5	-0.1	-0.1	-1.2
1981	-0.3	-1.4	-1.8	-0.7	-3.2	-0.7	0.0	0.0	-5.3	-4.1	-1.0	0.0	-1.8
1982	-0.6	-0.1	-2.3	-2.7	-2.7	-1.0	-0.4	-2.1	-0.2	-0.2	-1.1	-1.2	-1.1
1983	-0.6	-2.1	-2.1	-2.7	-3.0	-1.3	-0.1	0.0	0.0	-0.5	-1.8	-0.1	-1.1
1984	-0.3	-0.5	-3.3	-1.8	-0.5	0.0	0.0	0.0	-1.9	-4.6	-1.0	-1.3	-1.5
1985	-0.6	-6.5	-5.7	-1.1	-0.1	0.0	-0.6	-1.6	-3.6	-11.8	-15.1	-8.6	-5.3
1986	-1.4	-1.6	-1.5	-1.9	0.0	0.0	0.0	0.0	-4.8	-3.9	-0.1	-0.4	-1.5
1987	-1.5	-1.9	0.0	-0.2	-0.1	-0.1	0.0	0.0	-0.6	-5.0	-1.5	-0.6	-1.3
1988	-1.4	-0.5	-0.4	-1.9	-1.5	0.0	0.0	0.0	0.0	0.0	-0.1	-5.1	-1.0
1989	-1.1	-0.1	0.0	0.0	0.0	-0.2	-0.3	-5.9	-1.8	-0.9	-0.4	-1.0	-1.1
1990	-0.7	-0.5	-1.0	0.0	-2.6	-2.0	-0.3	0.0	-0.7	-2.6	-0.3	-0.1	-1.0
1991	-0.8	-0.3	-2.3	-3.0	0.0	0.0	0.0	-0.2	-2.2	-1.2	-1.0	-0.2	-1.0
1992	-0.2	-1.3	-0.9	0.0	0.0	0.0	-1.7	-4.1	-0.4	0.0	-0.1	-0.6	-0.7
1993	-0.4	-1.4	-1.0	0.0	0.0	0.0	0.0	0.0	-0.5	0.0	0.0	-0.2	-0.3
1994	-1.4	-2.8	-1.0	-0.2	0.0	0.0	0.0	-0.5	-2.8	-0.2	0.0	0.0	-0.8
1995	-0.2	-0.2	0.0	-1.1	-0.3	0.0	0.0	-0.7	-3.8	-0.2	-1.7	-1.1	-1.0
1996	0.0	-2.9	-1.9	-3.3	-0.1	-0.1	-1.0	-1.3	-3.0	-0.5	-0.5	-0.1	-1.2
1997	-0.2	-0.7	-2.7	-3.9	-2.0	-0.1	-0.9	-1.8	-3.2	-0.7	-0.1	-0.1	-1.3
1998	-0.3	-0.7	-0.7	-0.1	-0.3	0.0	0.0	-0.4	-2.9	-0.9	-1.8	0.0	-0.8
1999	0.0	0.0	-1.6	-2.1	-2.2	-1.0	0.0	0.0	-0.6	-2.2	-0.6	-0.6	-1.0
2000	-0.1	-0.2	-1.9	-1.0	-0.3	0.0	0.0	0.0	-1.3	-1.6	0.0	0.0	-0.6
2001	0.0	-0.1	-0.1	-0.1	-1.8	-0.3	0.0	0.0	0.0	-0.7	-0.8	0.0	-0.4
2002	0.0	0.0	-0.6	-0.7	-0.6	0.0	0.0	-0.3	-2.8	-2.2	0.0	0.0	-0.8
2003	0.0	0.0	-1.1	0.0	0.0	0.0	0.0	0.0	-2.1	-2.0	-0.2	0.0	-0.6
2004	-0.1	-0.6	-1.9	-0.5	0.0	0.0	0.0	0.0	-2.0	-1.4	0.0	0.0	-0.6
2005	0.0	-0.9	-1.7	0.0	0.0	0.0	0.0	-0.3	-3.2	-1.4	0.0	0.0	-0.7

Table 14. Percent differences in the monthly and annual potential productivity 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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
1977	-2.5	-3.0	-3.9	-1.8	-5.0	-8.0	-4.4	-0.6	-0.2	-5.4	-8.9	-0.6	-4.0
1978	-0.2	-0.5	0.0	-0.2	-0.1	0.0	0.0	-0.6	-7.9	-6.8	-0.9	-0.8	-2.0
1979	-0.6	-1.7	-2.5	-2.7	-0.1	0.0	-0.1	0.0	-1.4	0.0	-0.3	-4.7	-1.2
1980	-4.0	-5.7	-1.5	-0.2	-0.1	0.0	0.0	0.0	-5.3	-8.0	-0.6	-0.1	-2.5
1981	-0.5	-2.3	-3.2	-1.1	-5.7	-1.8	0.0	0.0	-9.0	-9.9	-2.1	-0.1	-3.6
1982	-1.0	-0.1	-3.7	-4.3	-3.1	-1.8	-0.8	-3.6	-0.5	-0.3	-1.8	-2.1	-1.8
1983	-1.0	-3.6	-4.6	-4.8	-5.4	-2.5	-0.1	0.0	0.0	-0.7	-3.4	-0.8	-2.1
1984	-0.5	-0.7	-6.2	-3.8	-0.9	0.0	0.0	0.0	-3.2	-9.4	-2.7	-2.2	-2.9
1985	-0.9	-10.7	-13.5	-2.9	-0.1	0.0	-0.9	-2.5	-5.8	-19.5	-27.7	-15.4	-9.8
1986	-2.8	-2.8	-2.4	-3.1	0.0	0.0	0.0	0.0	-8.0	-9.5	-0.6	-0.7	-3.0
1987	-2.5	-4.3	0.0	-0.4	-0.2	-0.1	0.0	0.0	-1.0	-9.3	-4.4	-1.1	-2.6
1988	-2.7	-1.2	-0.8	-3.1	-3.6	-0.2	0.0	0.0	0.0	0.0	-0.1	-8.6	-1.8
1989	-3.9	-0.2	0.0	0.0	0.0	-0.3	-0.4	-10.3	-5.6	-1.5	-0.6	-1.6	-2.2
1990	-1.0	-1.2	-1.6	0.0	-4.2	-4.6	-1.1	0.0	-1.2	-4.9	-1.1	-0.3	-1.9
1991	-1.3	-0.8	-3.8	-7.0	-0.4	0.0	-0.1	-0.3	-3.8	-2.4	-2.2	-0.3	-2.0
1992	-0.3	-2.0	-1.1	0.0	0.0	0.0	-2.8	-8.6	-1.4	0.0	-0.1	-1.0	-1.3
1993	-0.8	-2.3	-1.6	0.0	0.0	0.0	0.0	0.0	-0.8	0.0	0.0	-0.3	-0.5
1994	-2.4	-5.8	-2.4	-0.5	0.0	0.0	0.0	-0.9	-5.4	-0.9	0.0	-0.1	-1.6
1995	-0.3	-0.3	-0.1	-1.8	-0.5	0.0	0.0	-1.1	-7.2	-1.1	-2.8	-2.2	-1.8
1996	0.0	-4.7	-3.2	-7.2	-0.6	-0.1	-1.5	-2.7	-5.3	-1.6	-1.0	-0.2	-2.3
1997	-0.3	-1.2	-4.9	-6.1	-5.0	-0.4	-1.5	-2.9	-5.3	-2.3	-0.1	-0.1	-2.4
1998	-0.5	-1.5	-1.3	-0.2	-0.4	0.0	0.0	-0.7	-5.3	-2.4	-3.8	-0.4	-1.8
1999	0.0	0.0	-2.7	-4.5	-3.7	-1.8	0.0	0.0	-0.9	-4.1	-1.7	-1.4	-1.9
2000	-0.3	-0.3	-3.3	-2.1	-0.4	0.0	0.0	0.0	-2.0	-3.5	-0.4	0.0	-1.2
2001	0.0	-0.2	-0.1	-0.1	-3.0	-0.7	0.0	0.0	0.0	-1.1	-2.0	-0.1	-0.7
2002	0.0	0.0	-1.0	-1.6	-1.0	0.0	0.0	-0.4	-5.0	-5.2	-0.4	0.0	-1.6
2003	0.0	0.0	-1.8	0.0	0.0	0.0	0.0	0.0	-3.4	-4.8	-0.6	0.0	-1.2
2004	-0.2	-0.9	-3.7	-1.4	0.0	0.0	0.0	0.0	-3.3	-3.8	-0.1	-0.1	-1.3
2005	0.0	-1.5	-3.5	-0.2	0.0	0.0	0.0	-0.4	-5.8	-3.8	-0.3	0.0	-1.6

Table 15. Percent differences in the monthly and annual potential productivity 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	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Total
1977	-3.1	-3.8	-4.8	-2.8	-6.2	-11.7	-7.3	-0.8	-0.2	-6.6	-12.9	-2.8	-5.7
1978	-0.2	-0.6	-0.1	-0.2	-0.2	0.0	0.0	-0.7	-10.0	-11.0	-2.0	-1.0	-3.0
1979	-0.8	-2.1	-3.1	-3.6	-0.2	0.0	-0.1	0.0	-1.7	-0.1	-0.3	-5.7	-1.5
1980	-5.5	-9.5	-2.5	-0.2	-0.1	0.0	0.0	0.0	-6.5	-11.7	-2.4	-0.1	-3.9
1981	-0.6	-2.9	-4.3	-1.5	-7.2	-2.8	0.0	-0.1	-11.1	-15.1	-4.1	-0.1	-5.1
1982	-1.2	-0.2	-4.6	-5.3	-3.3	-2.2	-1.2	-4.5	-0.6	-0.4	-2.2	-2.3	-2.2
1983	-1.2	-4.4	-6.4	-5.8	-6.1	-3.1	-0.2	0.0	0.0	-0.9	-4.5	-2.0	-2.8
1984	-0.7	-0.9	-8.0	-4.7	-1.1	0.0	0.0	0.0	-3.8	-13.0	-5.2	-2.5	-4.1
1985	-1.1	-13.1	-20.3	-5.7	-0.1	0.0	-1.1	-3.0	-6.9	-24.0	-37.4	-25.6	-13.8
1986	-3.9	-3.5	-2.9	-3.8	0.0	0.0	0.0	0.0	-9.9	-14.6	-2.6	-0.8	-4.4
1987	-3.1	-6.2	0.0	-0.4	-0.2	-0.2	0.0	0.0	-1.2	-12.0	-8.2	-1.5	-3.8
1988	-3.8	-1.8	-1.0	-4.0	-5.5	-0.7	0.0	0.0	0.0	0.0	-0.2	-10.7	-2.5
1989	-7.5	-0.5	0.0	0.0	0.0	-0.3	-0.5	-13.1	-9.9	-2.4	-0.7	-1.9	-3.4
1990	-1.3	-1.8	-2.0	0.0	-5.2	-6.7	-1.5	0.0	-1.4	-6.5	-2.5	-0.4	-2.7
1991	-1.6	-1.1	-4.6	-10.2	-2.0	0.0	-0.1	-0.3	-4.9	-3.6	-3.1	-0.6	-2.9
1992	-0.5	-2.5	-1.2	0.0	0.0	0.0	-3.4	-12.0	-3.9	0.0	-0.1	-1.2	-1.9
1993	-1.6	-2.8	-2.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0	0.0	-0.3	-0.6
1994	-3.1	-8.1	-4.6	-0.8	0.0	0.0	0.0	-1.0	-7.1	-1.6	0.0	-0.1	-2.3
1995	-0.3	-0.4	-0.1	-2.3	-0.7	0.0	0.0	-1.4	-9.5	-2.5	-3.5	-2.9	-2.5
1996	0.0	-5.8	-3.9	-10.2	-2.1	-0.1	-1.9	-3.8	-7.1	-2.8	-1.5	-0.3	-3.3
1997	-0.4	-1.5	-6.2	-7.3	-7.5	-0.8	-1.8	-3.7	-6.6	-4.1	-0.3	-0.1	-3.2
1998	-0.6	-2.2	-1.7	-0.3	-0.5	0.0	0.0	-0.8	-6.9	-4.2	-5.6	-1.2	-2.6
1999	0.0	0.0	-3.3	-6.3	-4.9	-2.4	0.0	0.0	-1.1	-5.4	-3.1	-2.0	-2.6
2000	-0.6	-0.4	-4.2	-3.3	-0.5	0.0	0.0	0.0	-2.5	-4.9	-1.3	0.0	-1.7
2001	0.0	-0.3	-0.1	-0.1	-3.8	-0.9	0.0	0.0	0.0	-1.4	-3.0	-0.5	-1.0
2002	0.0	0.0	-1.3	-2.3	-1.5	0.0	0.0	-0.5	-6.5	-8.1	-1.4	0.0	-2.4
2003	0.0	0.0	-2.2	0.0	0.0	0.0	0.0	0.0	-4.2	-7.0	-1.7	0.0	-1.8
2004	-0.2	-1.1	-4.9	-2.3	0.0	0.0	0.0	0.0	-4.1	-6.0	-0.9	-0.1	-2.0
2005	0.0	-1.8	-4.9	-0.4	0.0	0.0	0.0	-0.5	-7.4	-6.5	-1.0	0.0	-2.4

Objective 6 – Estimate annual survival and mortality of salmonid cohorts in the mainstem Kootenai and South Fork Flathead Rivers

The number of rainbow and cutthroat trout in the Flower-Pipe section of the Kootenai River during the 1970's and early 1980's was estimated to be about 100 fish per thousand feet. Beginning in the late 1980's, the number of fish increased to an average of about 400 fish per thousand feet (Figure 72). The highest numbers of fish occurred in 2002 at about 800 fish per thousand feet. A spill event occurred in June and July 2002, and the fish population estimate in 2003 was almost half of that seen pre-spill estimate in 2002. The mechanism for this decline is not known, but possible causes could be normal population fluctuation or spill induced mortality or displacement.

The number of *Oncorhynchus* spp. per thousand feet in the Reregulation section (200 fish per 1000 feet) of the Kootenai has been consistently about half of the Flower-Pipe section estimate (Figure 80). High flows in 2002 did not allow recapture sampling in the Reregulation section, although fish had been marked. For this reason, the effects of the spill on fish populations in the summer of 2002 cannot be assessed due to a gap in estimate data. Highest estimated fish abundance in the Reregulation section occurred in 2006, at about 250 fish per thousand feet. In general, there are many more small fish (i.e., < 8 inches) in the Flower-Pipe section, and these small fish account for most of the differences in fish numbers between the Flower-Pipe and Reregulation sections (Tables 16 and 17; Figures 72 through 80; Figure 81). Fish from each year need to have ages estimated to generate age frequencies and the subsequent mortality and survival estimates for each cohort.

The bull trout population below Libby Dam was stable from 2004 to 2005, with a population estimate of about 1000 fish from Libby Dam to the Fisher River confluence. In 2006, the population appeared to decline with an estimate of less than 200 fish (Figure 81). Potential reasons for this decline include natural mortality of older fishes or some other environmental or health factor. Genetic samples of 61 fish were collected in the spring of 2006 and will be analyzed for genetic origin (i.e., above or below Libby Dam) pending final analysis and approval of a previous Libby Mitigation project study. Most bull trout captured have a total length of 500 to 900 mm, but a few fish are captured outside this length range (Figure 82). The low abundance of subadult bull trout captured during the population estimates may indicate limited recruitment into the mainstem population from Libby Dam to the Fisher River, low survival of subadults in the mainstem river once they outmigrate, limited outmigration from natal tributaries, or sampling bias. Outmigrants from tributaries may reside in other unsampled sections of the Kootenai River, as few subadult bull trout are captured in the Reregulation and Flower-Pipe sections. The origin of the bull trout below the dam is currently unknown at this time.

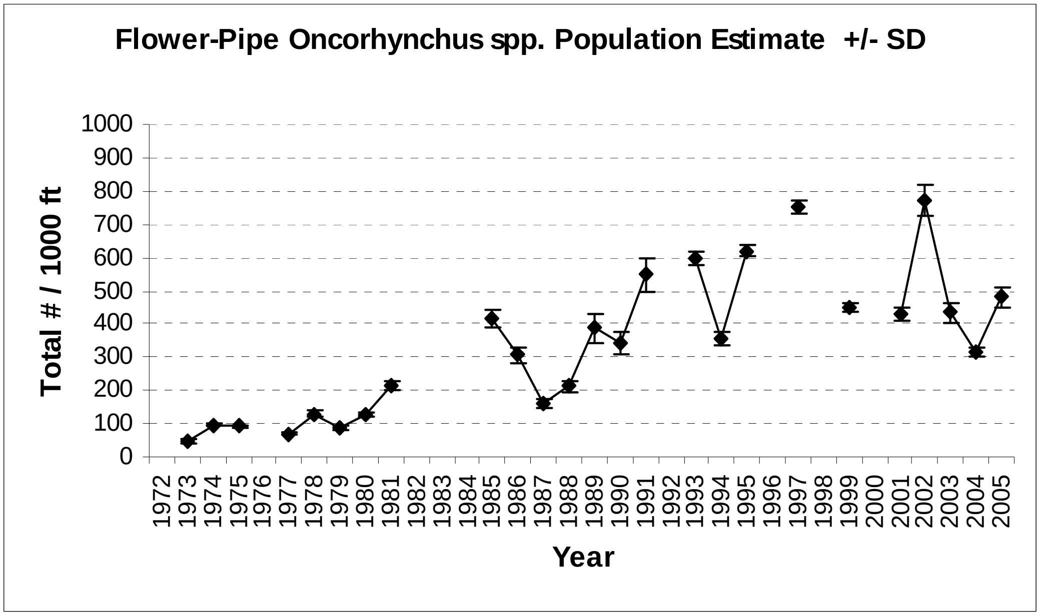


Figure 72. Population estimate of rainbow trout and cutthroat trout, as the number of fish per 1000 feet, in the Flower-Pipe (1973-2005) section of the Kootenai River below Libby Dam, Montana.

Table 16. Population estimate by length of fish in the Flower-Pipe section of the Kootenai River. An asterisk (*) indicates a lumped estimate for that length group and all longer length groups.

	Length Group (in)																			
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
1973	0	0	0	0	0	0	0	1	2	3	7	13	9	13*						49
1974	0	0	0	0	5	10	12	5	5	4	12	14	10	7	4	3	1	3*		95
1975	0	0	0	0	3	1	1	2	2	5	20	24	17	5	3	2	6			92
1976																				
1977	0	0	0	0	1	1	4	4	3	6	10	7	8	8	2	3	2	2	10*	70
1978	0	0	0	0	0	4	4	4	7	14	24	34	22	9	2	0	2	5*		130
1979	0	0	0	0	0	0	0	1	5	13	22	20	9	3	5	4	2	3*		88
1980	0	0	0	0	1	2	3	3	5	13	40	31	13	4	5	10*				129
1981	0	0	0	0	1	1	3	11	37	62	54	18	12	6	9*					214
1982																				
1983																				
1984																				
1985	0	0	0	0	2	2	59	122	79	36	29	39	46*							415
1986	0	0	0	0	0	0	34	69	70	60	29	24	10	10*						306
1987	0	0	0	0	0	1	4	19	38	35	18	15	16	15*						161
1988	0	0	0	0	0	1	9	53	57	48	14	12	11	8*						213
1989	0	0	0	0	0	4	54	111	140	43	18	17*								387
1990	0	0	0	0	0	0	79	134	73	20	15	15	7*							343
1991	0	0	0	0	4	26	91	142	131	70	21	23	38*							547
1992																				
1993	0	0	0	0	6	86	169	164	87	41	18	10	4	5	4	2	2*			598
1994	0	0	0	0	0	46	94	80	61	25	12	14	13	12*						356
1995	0	0	0	0	3	10	30	110	197	152	64	17	15	13	6	3	0*			620
1996																				
1997	0	0	0	3	1	19	110	242	207	80	30	20	18	20*						751
1998																				
1999	0	0	0	0	30	92	108	55	35	29	37	30	19	7	10*					450
2000																				
2001	0	0	0	0	27	87	99	69	58	33	19	13	9	15*						429
2002	0	0	0	0	0	33	252	264	143	46	18	9	4	2	5*					774
2003	0	0	0	0	2	14	36	126	108	58	46	26	11	8*						434
2004	0	0	0	0	2	2	23	34	69	86	53	20	12	16*						317
2005	0	0	0	0	1	6	47	135	137	65	31	26	19	14*						481

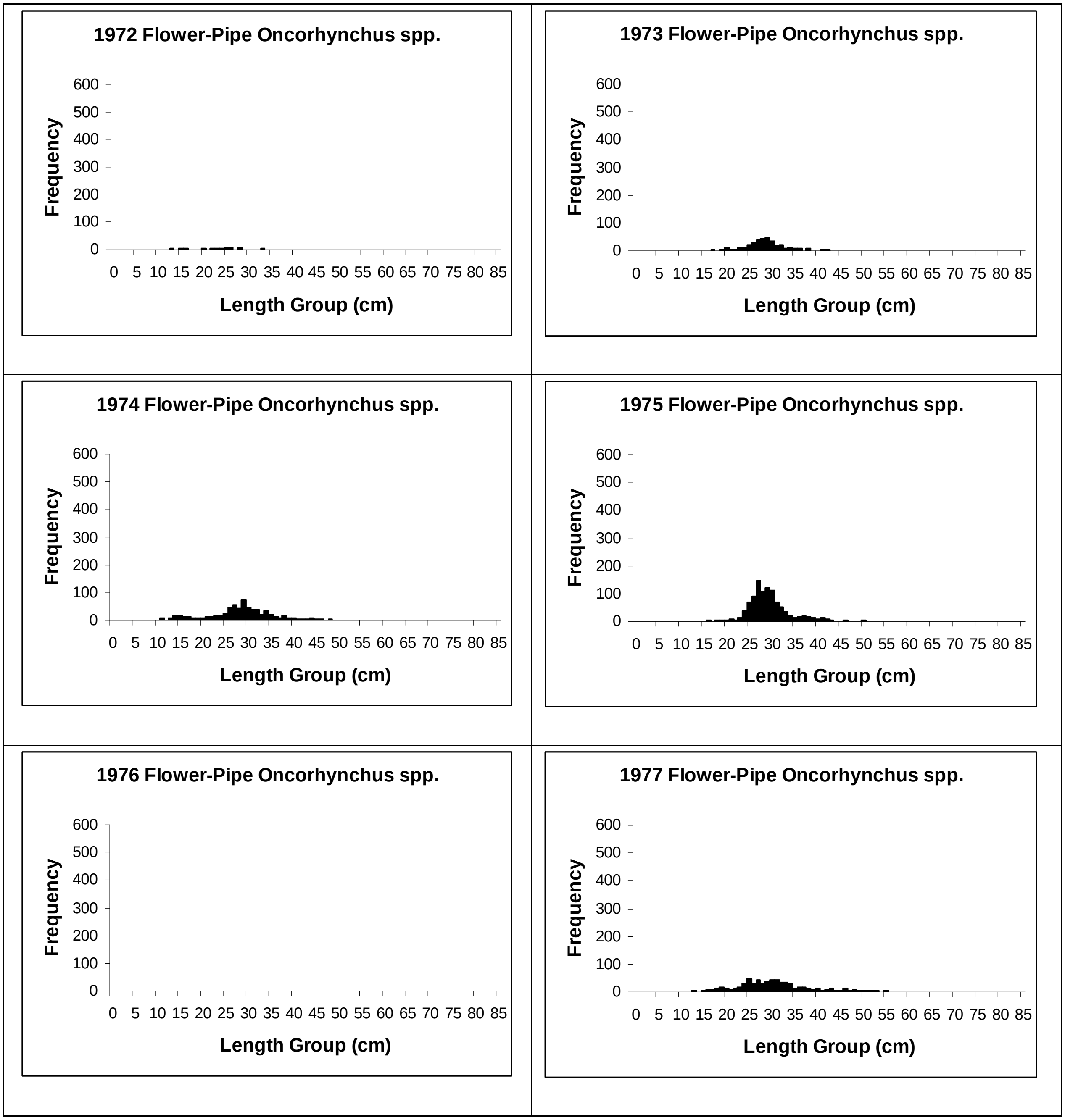


Figure 73. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 1972-1977. No estimate was obtained during 1976.

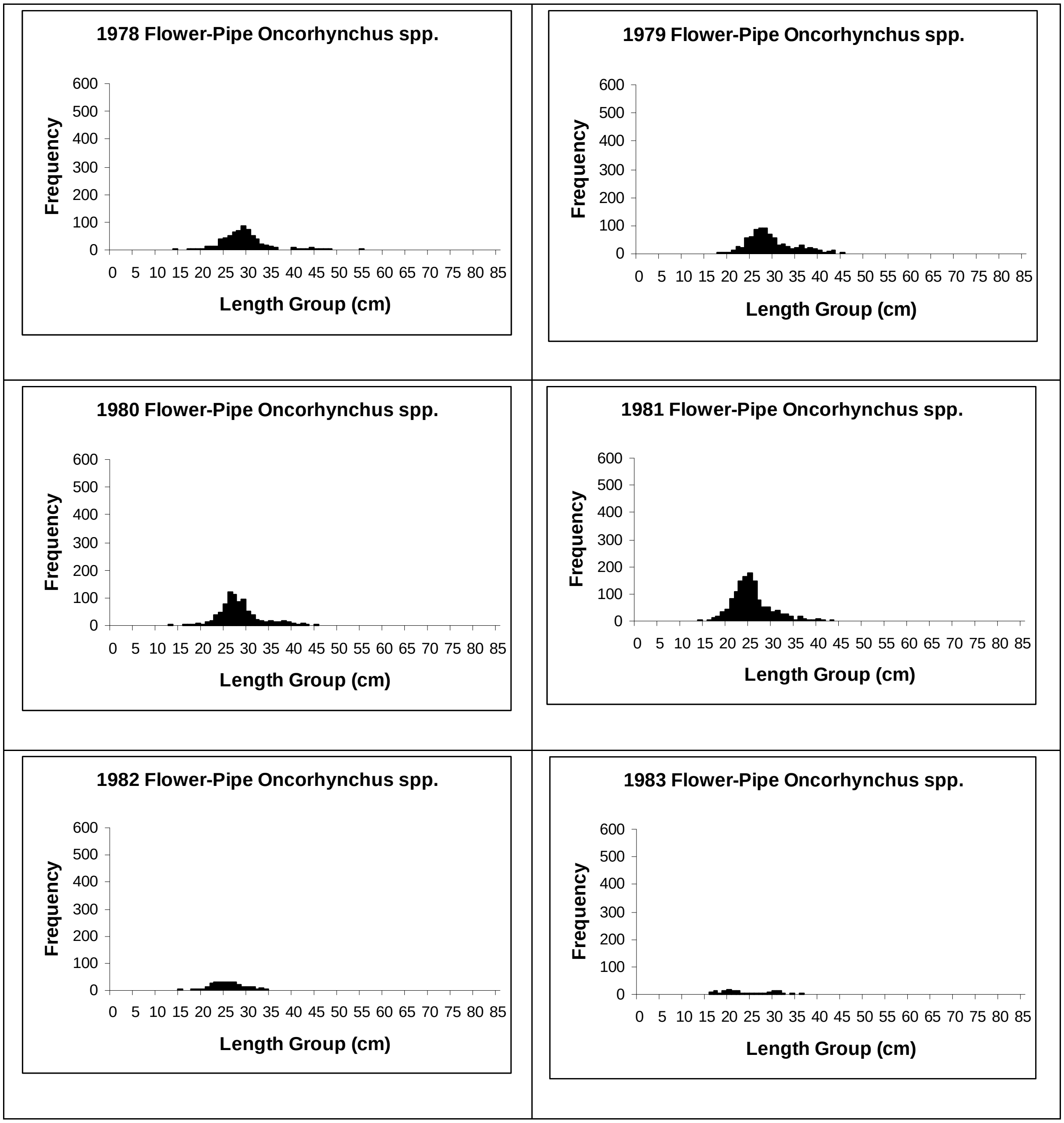


Figure 74. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 1978-1983.

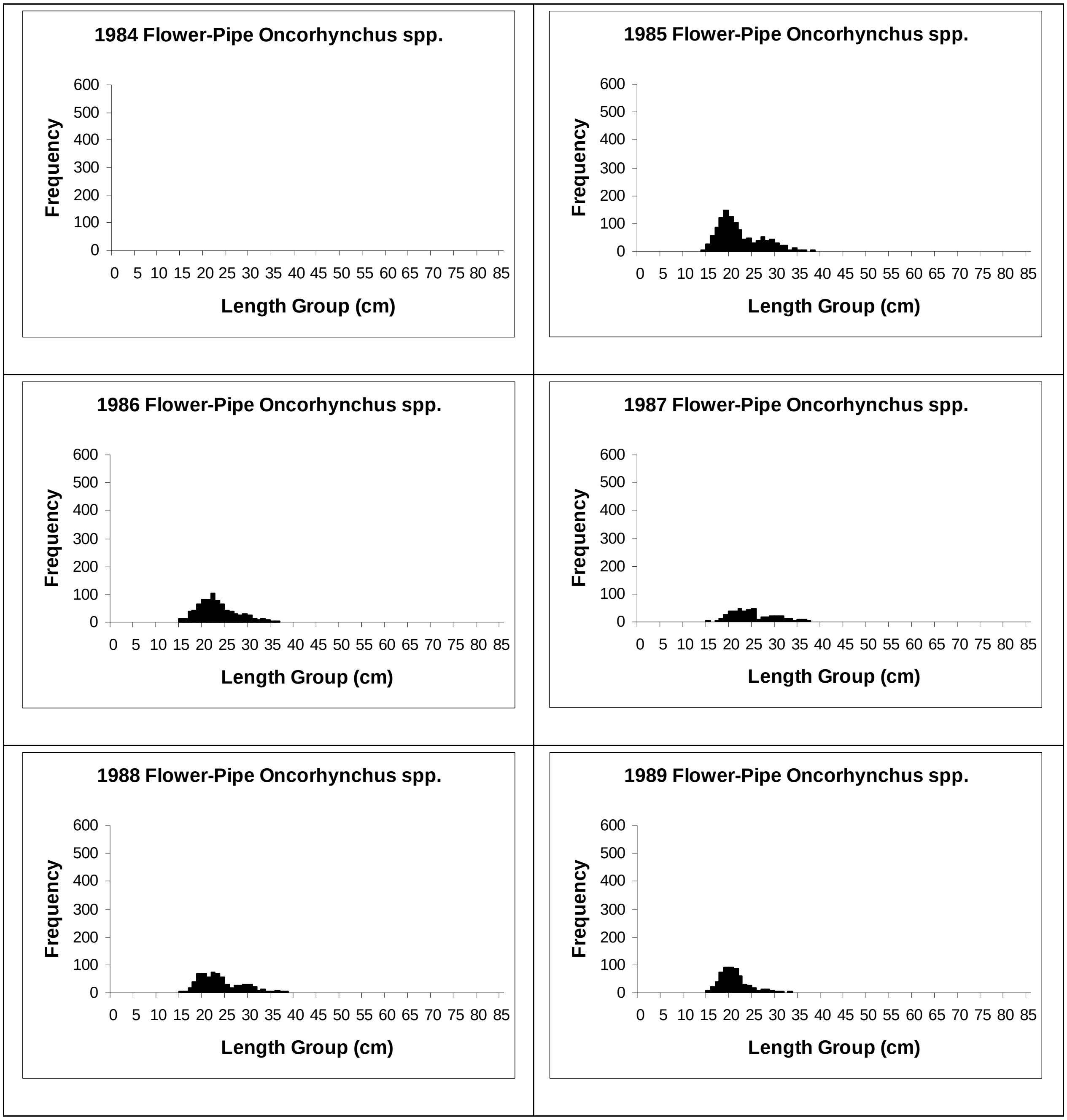


Figure 75. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 1984-1989. No estimate was obtained during 1984.

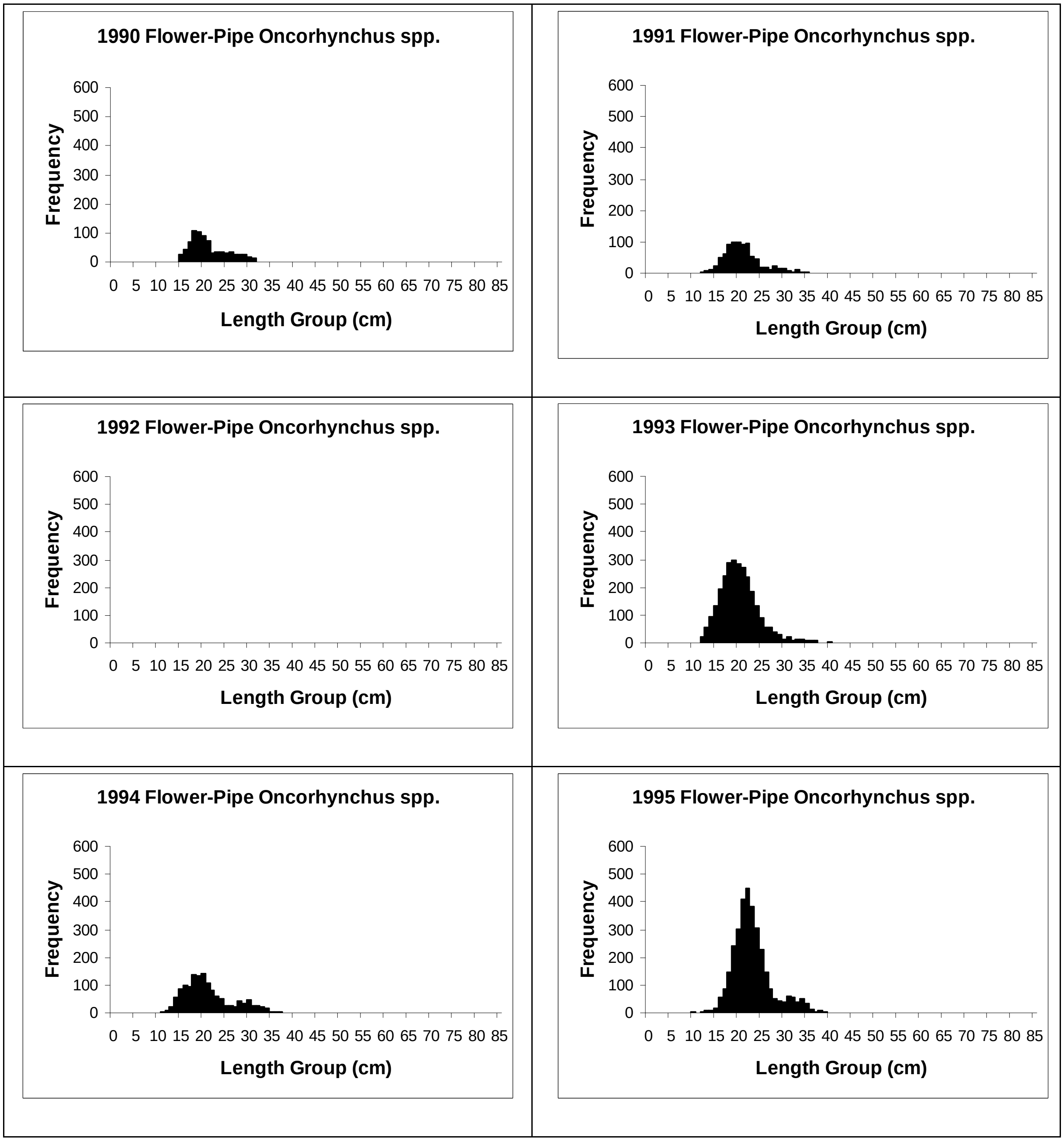


Figure 76. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 1990-1995. No estimate was obtained during 1992.

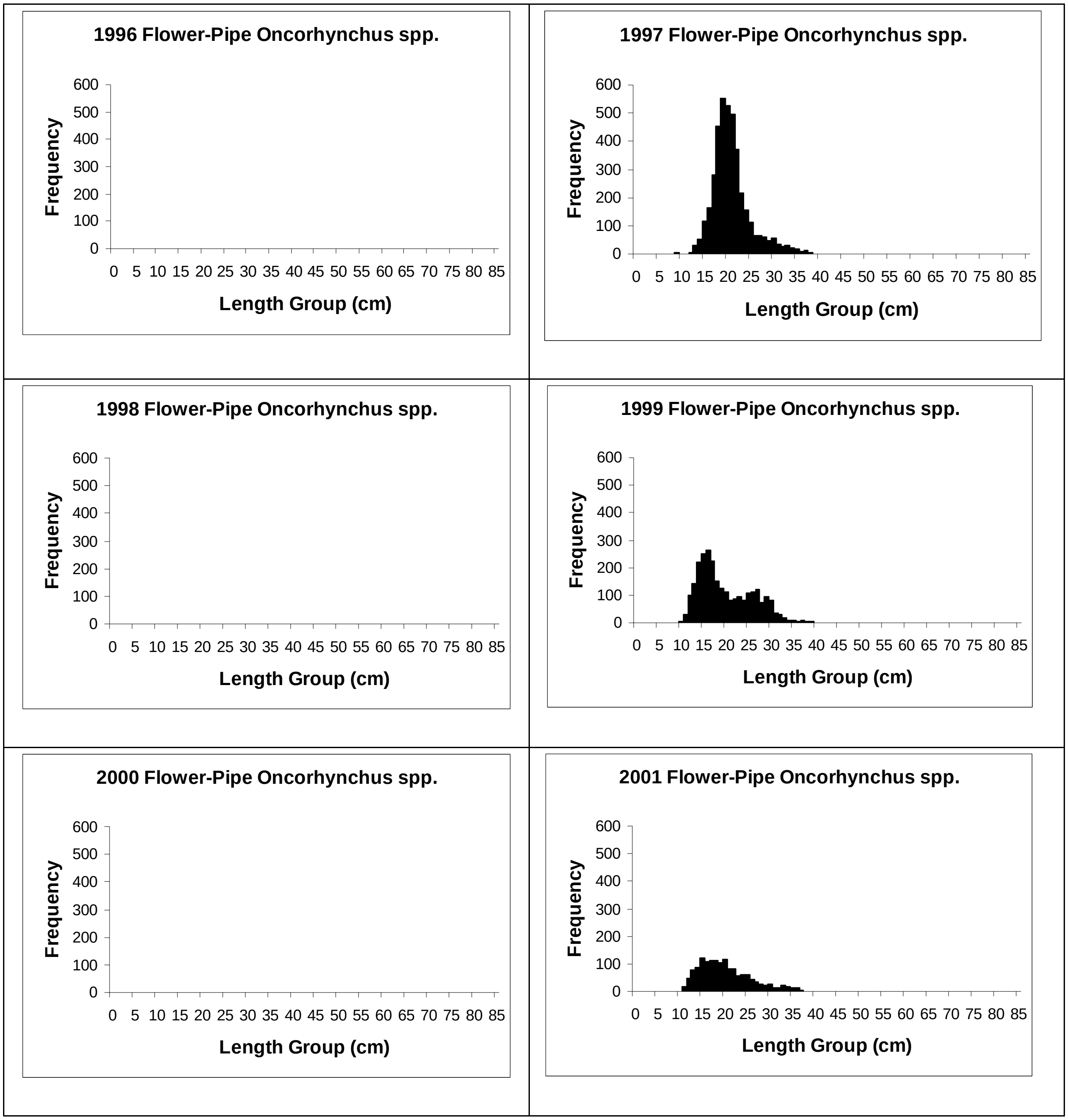


Figure 77. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 1996-2001. No estimates were obtained during 1996, 1998, and 2000.

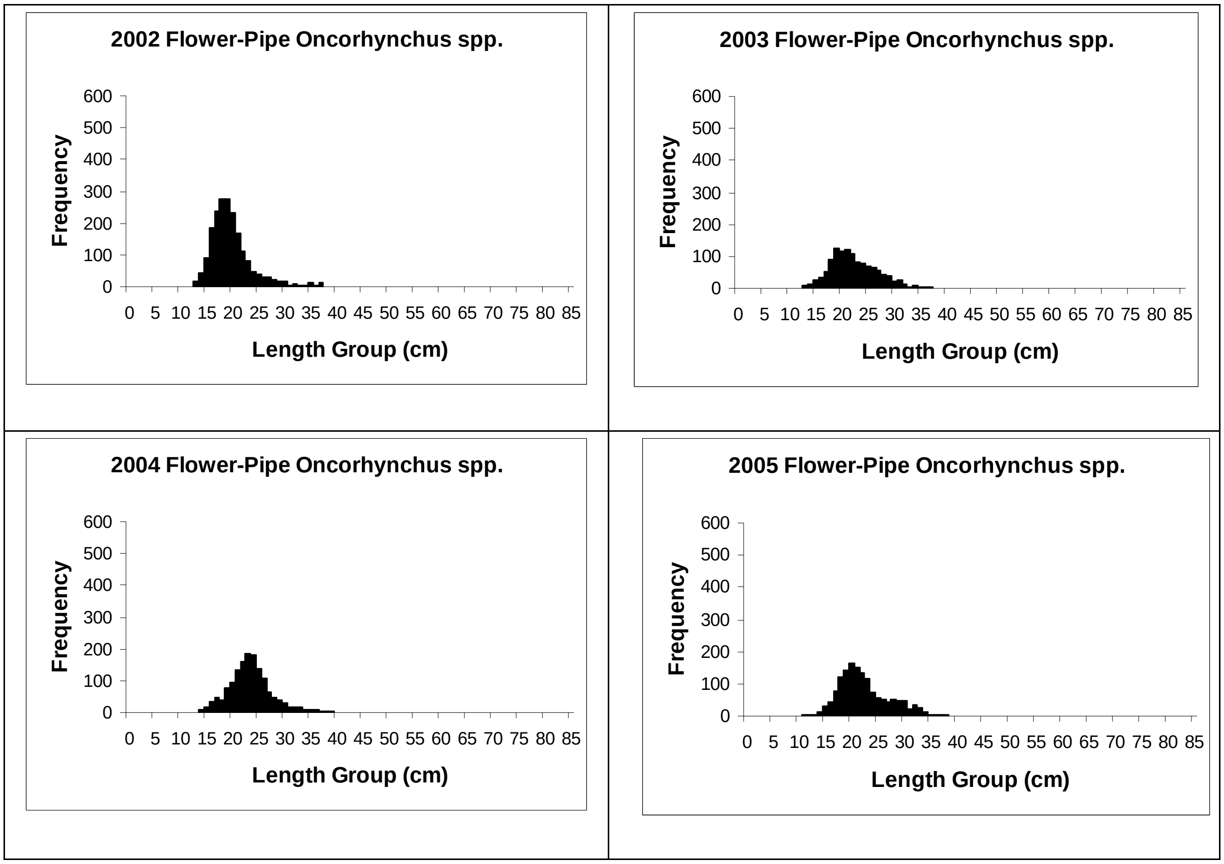


Figure 78. Length frequencies of Oncorhynchus spp. in the Flower-Pipe section of the Kootenai River collected during annual population estimates from 2002-2005.

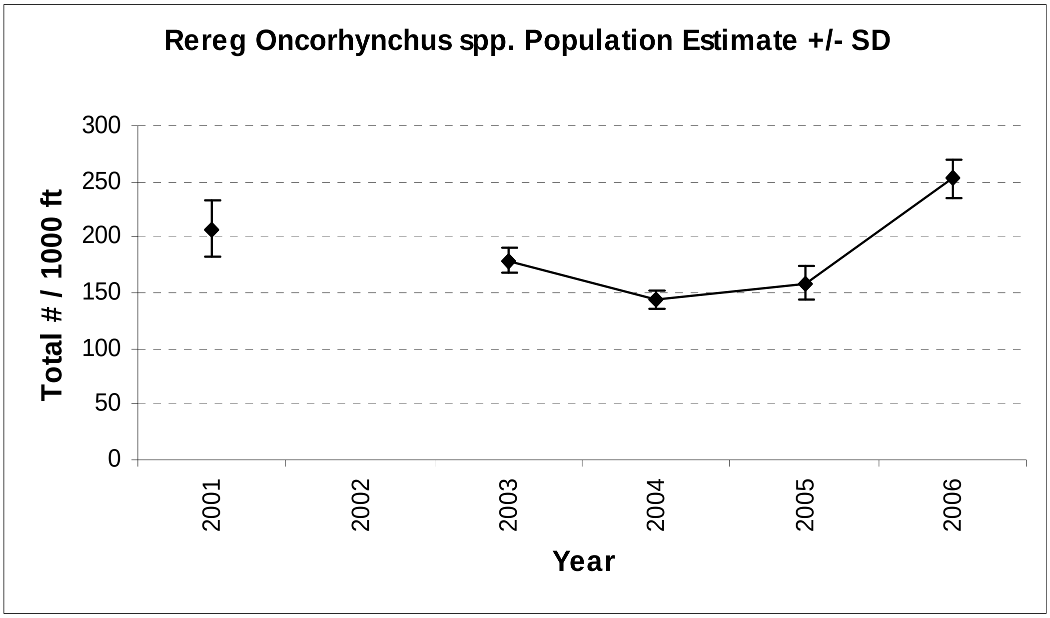


Figure 79. Population estimate of rainbow trout and cutthroat trout, as the number of fish per 1000 feet, in the Reregulation (2001-2005) section of the Kootenai River below Libby Dam, Montana.

Table 17. Population estimate by length group of fish in the Reregulation section of the Kootenai River from 2001-2006. 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.

	Length Group (in)																			
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
2001	0	0	0	0	4	36	38	49	23	20	2	4	10	10	5	3	4*			207
2002																				
2003	0	0	0	0	8	1	35	40	50	22	8	4	2	2	7*					179
2004	0	0	0	1	19	18	8	17	25	16	10	7	10	14*						144
2005	0	0	0	0	0	3	4	14	20	27	25	19	17	31*						159
2006	0	0	0	0	15	16	16	37	55	37	25	18	19	16*						253

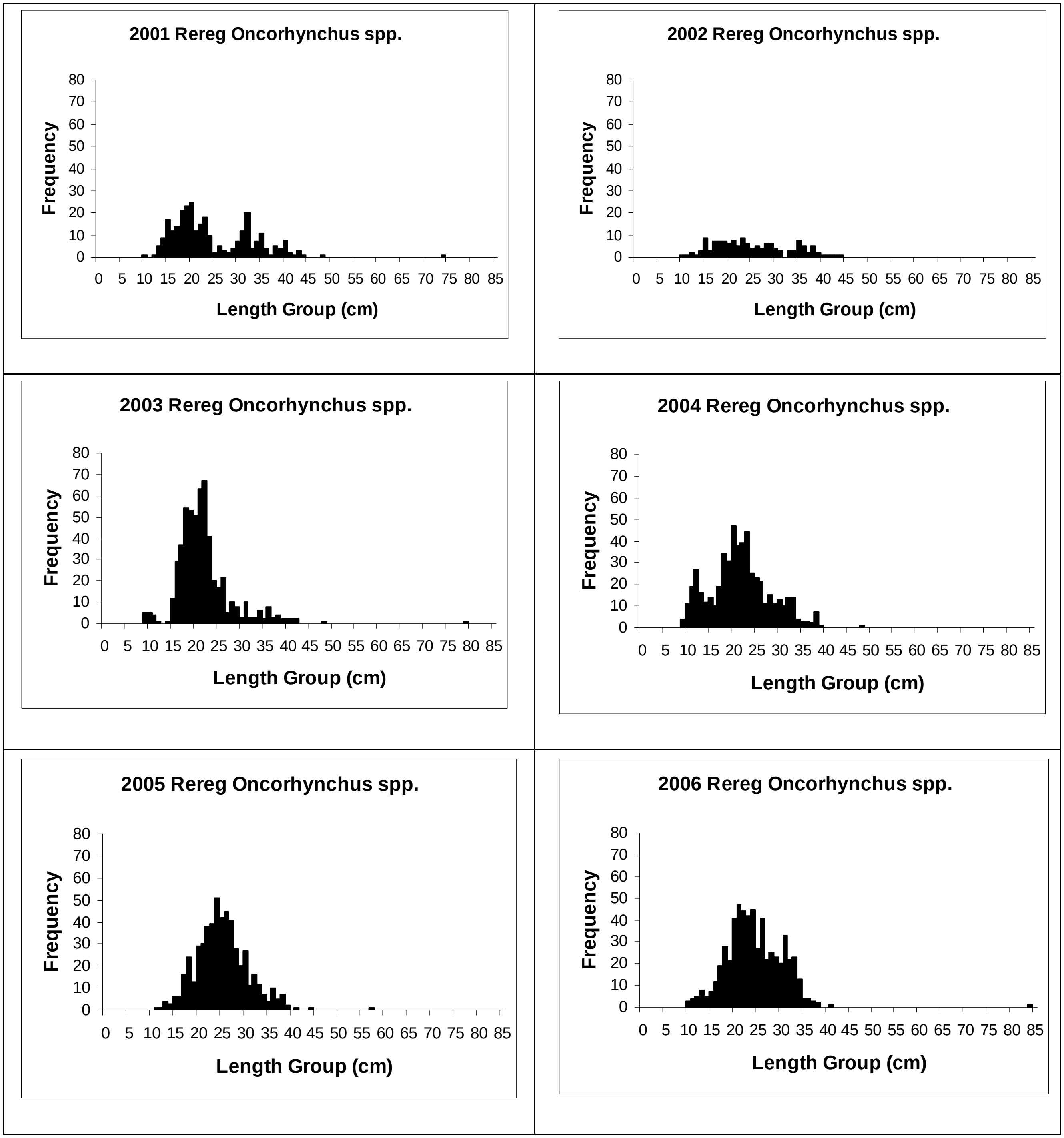


Figure 80. Length frequencies of Oncorhynchus spp. in the Reregulation section of the Kootenai River collected during annual population estimates from 2001-2006. Only a mark run was performed in 2002, high flows did not allow a recapture run, thus no estimate could.

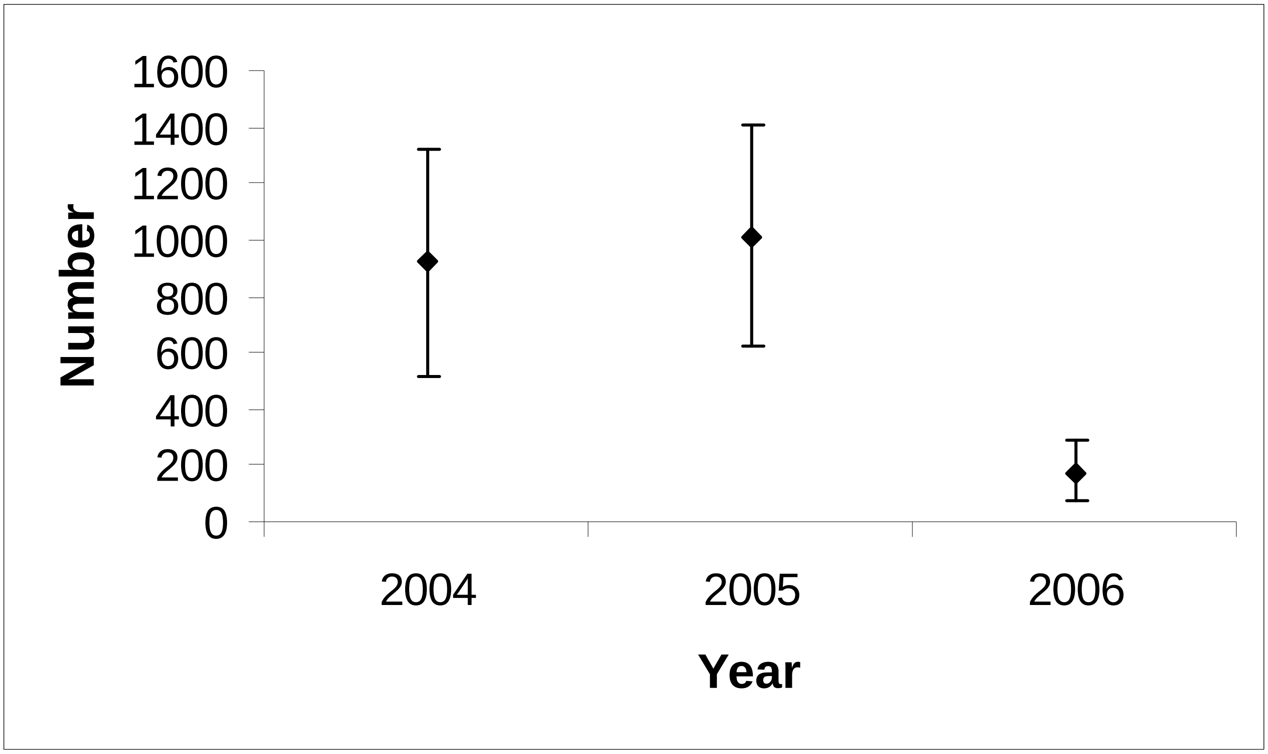
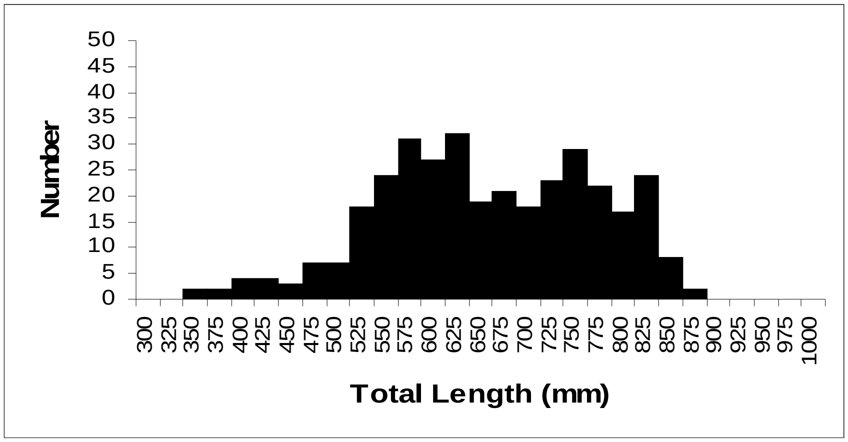
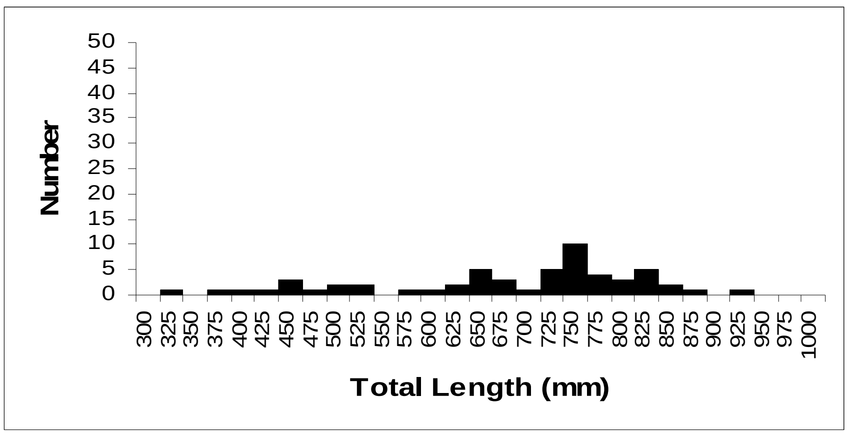


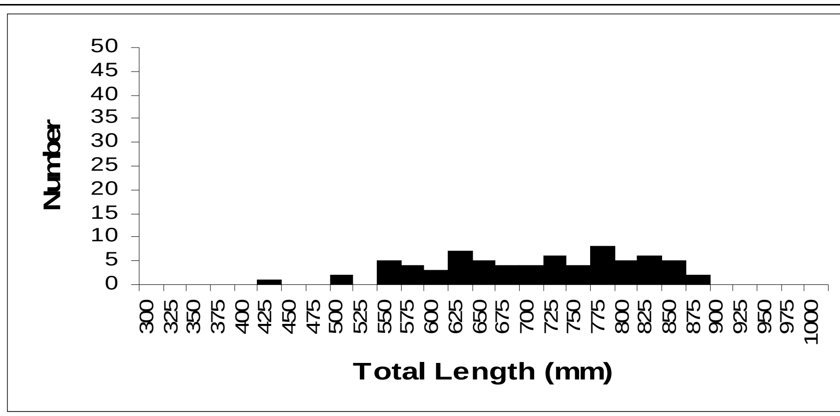
Figure 81. Bull trout population estimate (+/- 95% CI) from Libby Dam to the Fisher River confluence, approximately 3.5 river miles below Libby Dam, Montana.



A – 2004



B – 2005



C - 2006

Figure 82. Length frequency of bull trout below Libby Dam captured during annual population estimates collected from 2004 (panel A, *N* = 344), 2005 (panel B, *N* = 56), and 2006 (panel C, *N* = 71).

Objective 7 – Radio telemetry

No work has performed on this Objective do date due to staffing limitations.

Objective 8 – Assess how tributary conditions affect salmonid populations (i.e., survival, growth, and numbers of adults spawning in selected tributaries

No work has been performed on this Objective to date. Equipment specifications and cost estimates are being developed with Biomark, Inc.

Objective 9 – River age, growth, and condition of fishes in the mainstem Kootenai and South Fork Flathead Rivers

Condition of rainbow trout in the Flower-Pipe section of the Kootenai River for substock to stock length fish has remained near 100 throughout the history of work in the section from 1972-2005 (Figure 83). Stock to quality length fish typically have a lower mean relative weight with values averaging around 90 and quality to preferred length fish have shown more variation in their mean relative weight, with values ranging from 75 to 105 (Figure 79). Few fish larger than quality to preferred length are captured in the Flower-Pipe section of the Kootenai River, as evidenced by a lack of a mean relative weight since 1990. Rainbow trout in the Reregulation section of the Kootenai River have low average Wr values of 70-90 for substock to stock, stock to quality, and quality to preferred length (Figure 84). On occasion, large rainbow trout (>500 mm) are captured in the Reregulation section, and these fish are typically in good condition (i.e., relative weight value >100) with the exception of the 2006 trophy length fish, which had a low relative weight (<60). The Reregulation section is sampled in the spring and potentially reflects overwinter and post spawn conditions, compared to the Flower-Pipe section, which is sampled in the fall, when fish should be in better condition. Approximately 400 PIT tags were injected into rainbow trout, westslope cutthroat trout, and bull trout in the spring of 2006. These tagged fishes will be used to assess growth and survival of fish in sections of the Kootenai River and associated with environmental and biological conditions in each section of river. Tagged fish will be used to assess movements between sections of the Kootenai River, between the Kootenai River and tributaries, and how these movements relate to high discharges, spill, spawning, and other factors.

Growth of recaptured bull trout in the Kootenai River has been variable among the limited number of recaptured fish. In terms of length, bull trout have grown from less than 0.1 mm/day to greater than 0.4 mm/day (Figure 85). Growth appears to decrease with increasing length at initial tagging. Growth in terms of weight does not appear to follow the same pattern and appears to be more variable than length, with one fish losing weight and another averaging almost 10 grams per day of weight gain. Weight gained per day was evenly distributed among different lengths of bull trout (Figure 86).

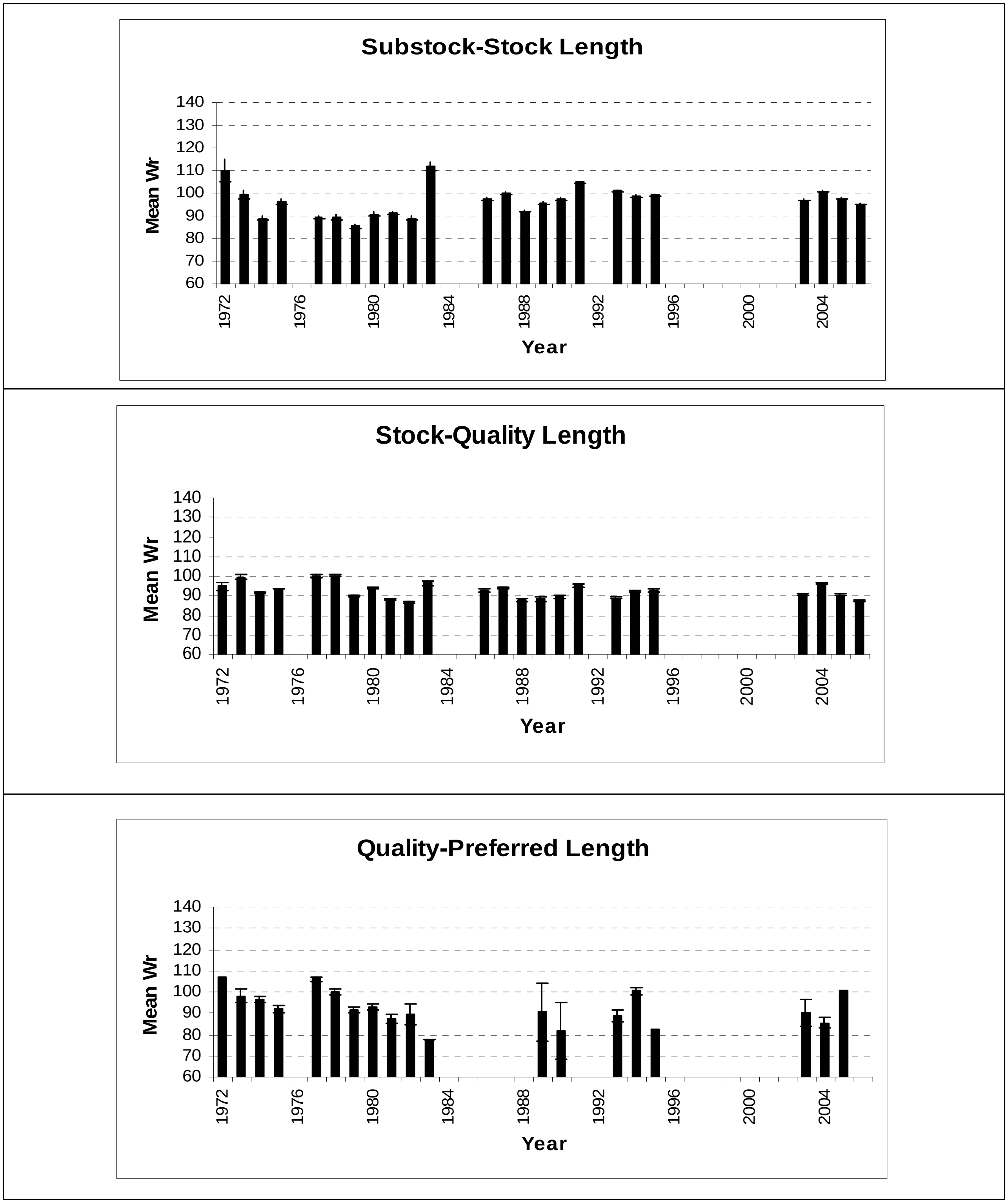


Figure 83. Mean relative weight of rainbow trout (+/- SE) in the Flower-Pipe section of the Kootenai River by length group from 1973-2005.

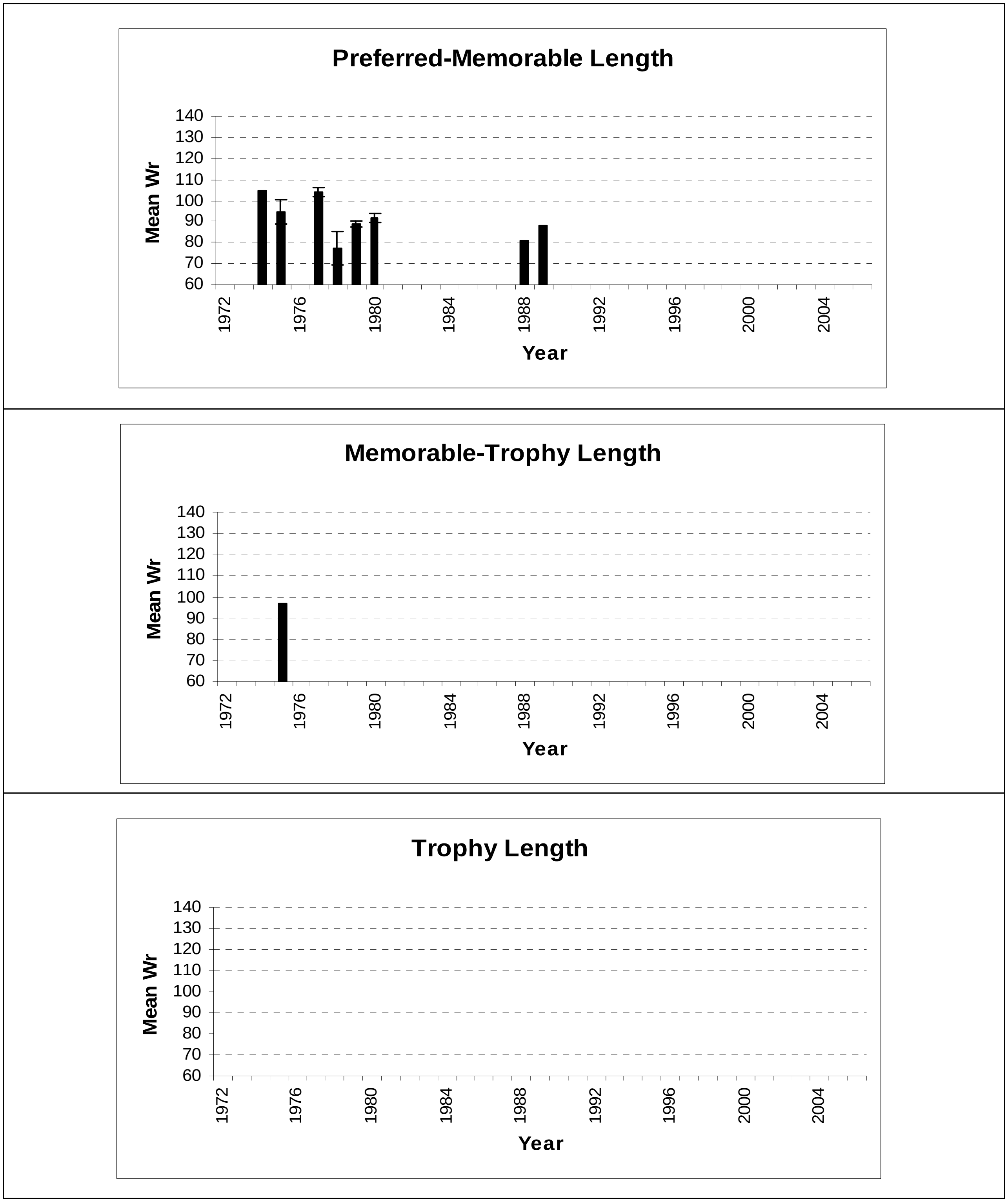


Figure 83 continued. Mean relative weight of rainbow trout (+/- SE) in the Flower-Pipe section of the Kootenai River by length group from 1973-2005.

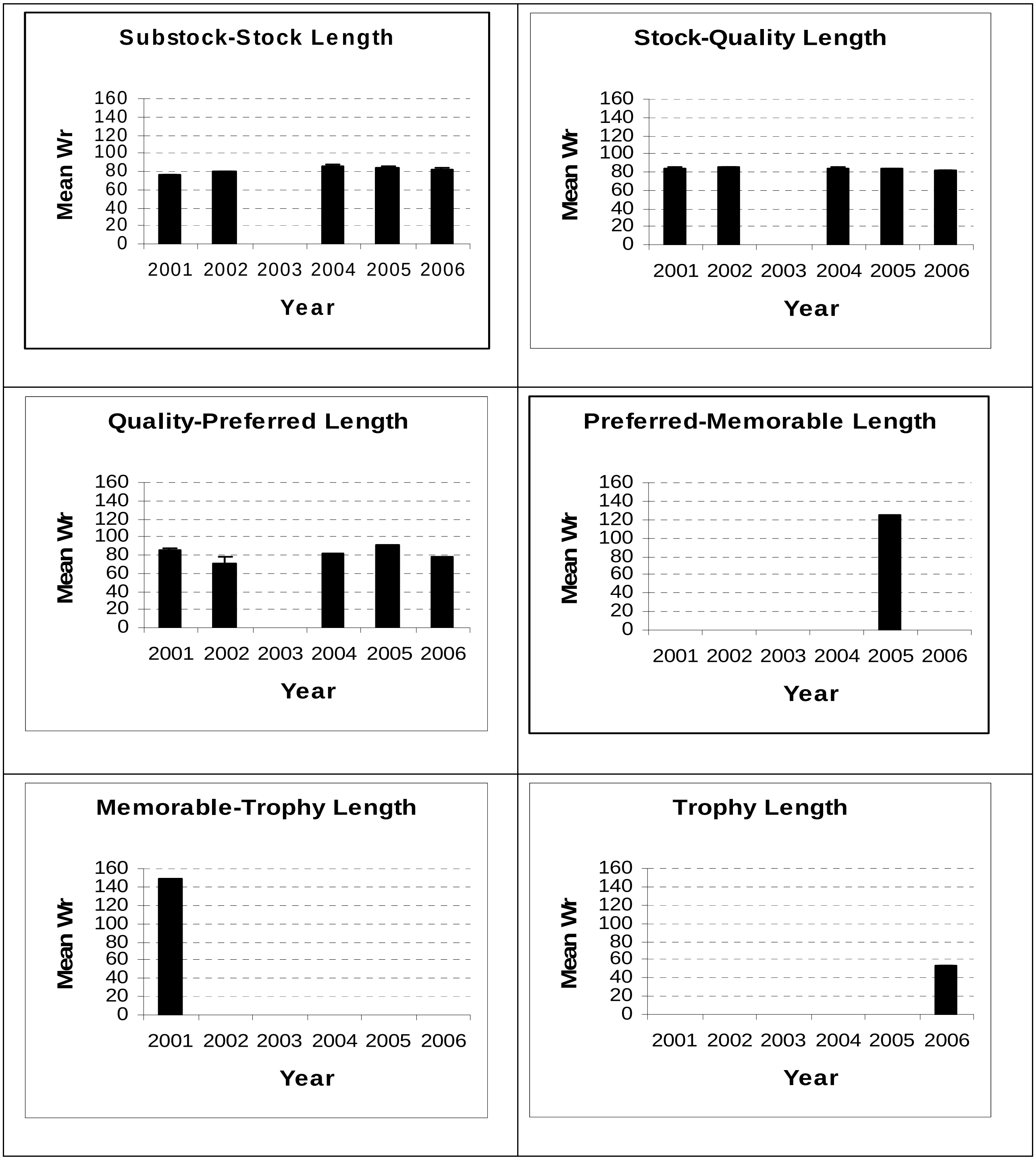


Figure 84. Mean relative weight (+/- SE) of rainbow trout in the Reregulation section of the Kootenai River by length group from 2001-2006.

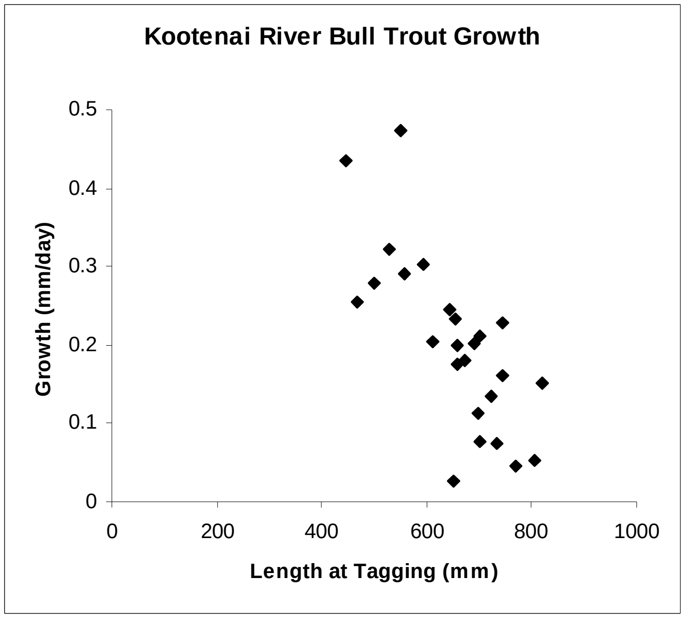


Figure 85. Growth of recaptured bull trout (mm/day) in the Kootenai River below Libby Dam from 2004 to 2006.

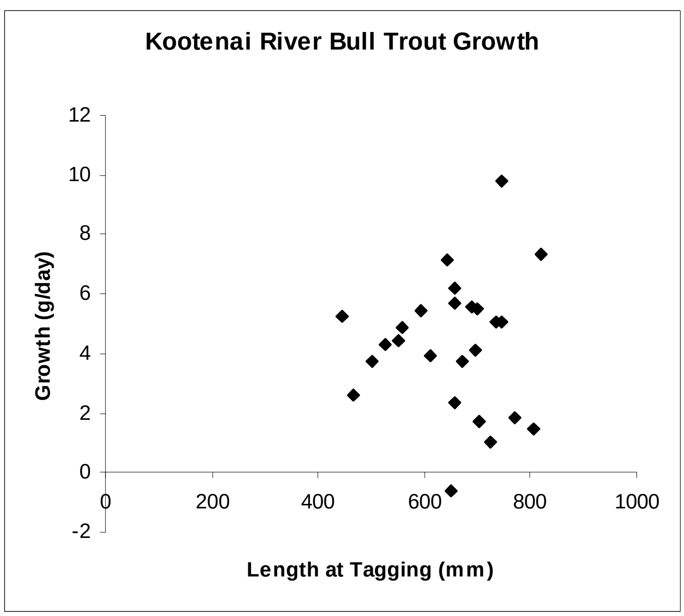


Figure 86. Growth of recaptured bull trout (g/day) in the Kootenai River below Libby Dam from 2004 to 2006.

DISCUSSION

Objectives 1 – 4: Reservoir Modeling, Age, Growth, and Condition

Reservoir conditions have changed since the construction of Libby Dam and subsequent filling of Lake Koocanusa. The fish community has changed in terms of abundance and species composition. Lake Koocanusa contains more kokanee than during the pre-dam and early post dam system. Mean length of kokanee continues to decrease, and approximately 6-year cyclical peaks in mean length have been observed. The cause of this decline in mean length may be increased competition for food resources, along with changes in the reservoir productivity and nutrient levels. Kokanee attained lengths greater than 400 mm after first being introduced into Lake Koocanusa. Bull trout numbers above Libby Dam have also increased, as shown by increased catch per net and increased redd counts in tributaries above Lake Koocanusa. A large landslide partially blocked fish passage in the Wigwam River in 2005, and redd counts above the landslide decreased from 2,133 in 2004 to 642 in 2005 (Herb Tepper, personal communication). It is not known whether bull trout spawned below the landslide and the effects of fewer redds on the population may not be noticeable for several years.

Lake Koocanusa drawdown currently has a maximum of about 40 to 50 feet per year, much less than conditions in the 1980's and 1990's, when the reservoir was drawn down several hundred feet. This should provide for higher productivity at lower trophic levels and may lead to higher condition of fishes. Dam operations have likely changed the thermal structure of the reservoir and may account for some of the discrepancies between model simulations and actual isotherms of the reservoir. Currently, we have not tried to assess how recent operations and selective withdrawal may have affected the reservoirs temperature regime, but on average, the reservoir now maintains a larger volume of water which should heat up and cool more slowly than in previous years. Moderated temperature change should affect all trophic levels.

Objectives 5 – 9: Mainstem River Age, Growth, Condition, Movement, and Survival, and Tributary Fish Population Dynamics and Environmental Influences

In recent years, river conditions have become more stable as power peaking is less frequent now below Libby Dam. Relative weight data shows that most rainbow trout in the Kootenai River are not at their optimal weight. Mean relative weights for most length categories of rainbow trout range from 80-90. Seasonal differences in relative weight will be assessed in the future. Current dam operations now mimic natural conditions more closely than earlier operations and should provide better conditions for fish survival, growth, and productivity. Despite mimicking natural conditions, the spring peak discharge remains well below the pre-dam peak, summer flows remain high, and winter flows and temperature conditions are higher than pre-dam conditions. Higher summer flows may lead to higher productivity of the benthic fauna but availability of benthic fauna to fish may be less because preferred fish habitat may be reduced.

FUTURE RESEARCH NEEDS and DIRECTION

The Mainstem Amendment has not yet been implemented. If they are not implemented by the start of the next water year, statistical comparisons between years of existing data will look for significant differences between specific operational strategies before Mainstem Amendment implementation. A Fisheries Biologist should be hired in order to begin work in the Flathead River system in the spring or summer of 2007. Filling this position will increase the rate and which work and analysis can be completed in portions of the Flathead River drainage. A Technician was hired in the Kootenai River portion of the project, which will increase the amount of fieldwork that can be completed and increase project productivity.

The productivity of Lake Koocanusa was assessed from 1972 to 1980 (Woods 1982) and again from 1986 to 1987 (Chisholm1989). Woods (1982) reported daily areal productivity rates ranging from 0.4 to 420 mg $C/m^2/d$ and Chisholm et al. (1989) reported rates ranging from 63.9 to 588.0 mg $C/m^2/d$. Model simulations (RIVBIO and LRMOD) assume relatively constant reservoir conditions regarding inflow and outflow parameters as well as nutrient levels. If the productivity of Lake Koocanusa has changed since the development of the HRMOD and LRMOD reservoir models, this change in productivity may help to explain discrepancies between model simulations and observed trends in biological metrics above and below Hungry Horse and Libby Dams. Productivity of Lake Koocanusa should be reevaluated within the next 5 years using similar methods as previous investigators.

Spatial temporal analyses of precipitation data, juvenile fish population estimate data, redd counts, and core sample data will be explored to help explain various mechanisms (i.e., abiotic or biotic) influencing the bull trout populations in selected tributaries of the Kootenai River system.

ACKNOWLEDGEMENTS

We would the Bonneville Power Administration for funding the opportunity to evaluate the effects of the Mainstem Amendment and dam operations on fisheries upstream and downstream of Libby and Hungry Horse Dams, Montana. We would also like to acknowledge all previous researchers that have worked or are currently working within the Columbia River basin, and in the Kootenai and Flathead River drainages. This body of work, information, and time is invaluable. Specific thanks go to B. Stephens, J. Tohtz, J. Dunningan, M. Hensler, C. Muhlfeld, N. Benson, M. Benner, L. Garrow, C. Sinclair, J. DeShazer, T. Ostrowski, and J. Lampton for collaboration on aspects of this project and assistance with field data collection. Additional thanks are extended to Cecilia Brown, Joe DeHerrera, and Mark Shaw for comments on this project.

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APPENDICES

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

CRC = peamouth
CSU = largescale sucker
BT = 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
NOP = northern pike
NSQ = northern pikeminnow
PUMP = pumpkinseed
RBT = rainbow trout
RSS = redside shiner
WCT = westslope cutthroat trout
YEP = yellow perch

Units or statistical abbreviations used in the text and tables of this report:
acre-ft = acre-feet
CI = confidence interval
cfs = cubic feet per second
cm = centimeter
ft = foot or feet
ft^2 = square foot
ft^3/s = cubic feet per second
in = inch
km = kilometer
km^2 = square kilometer
m = meter
mg/l = milligrams per liter
mi = mile
mi^2 = square mile
m^2 = 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:

spp. = species (refers to multiple species within the same genus)
W_r = relative weight
W_s = standard weight