PART 2. Narrative

Project ID: New resident fish monitoring project called for by NPCC' Mainstem Amendment

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

Section 9 of 10. Project description

a. Abstract

In 2003, the Northwest Power and Conservation Council (Council) directed the Pacific Northwest region to implement, and evaluate specific dam operating strategies at Columbia River dams. This proposal includes research and monitoring protocols to assess biological and physical responses in Montana associated with the Council's plan. Beginning in the summer 2004, water released from Hungry Horse and Libby Dams will be limited to 10 feet from full pool (elevations 3550 and 2449, respectively) during the months of July through September 30. This limit applies to all years except the lowest 20^{th} percentile water supply; during drought years, the draft could be increased to 20 feet from full pool by September 30. This dam operation strategy also stabilizes the release of water to the Flathead and Kootenai Rivers during the July through September period. These actions were designed to protect aquatic resources in headwater reservoirs and rivers, while providing suitable conditions for anadromous species recovery in the lower Columbia River. Previous research by Montana Fish, Wildlife & Parks provided empirical data and methods to assess potential impacts of dam operations, including power, flood control and flow augmentation. Historic data provide an environmental base line for comparison with alternative operating strategies. This proposal offers methods to compare the biological response to alternative dam operations.

b. Technical and/or scientific background

Populations of Kootenai white sturgeon (*Acipenser transmontanus*) are listed as endangered and native bull trout (*Salvelinus confluentus)* are listed threatened under the Endangered Species Act (ESA). Westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and redband trout (*O. mykiss*) have also declined due to dam construction and operation, negative interactions with nonnative species (e.g. predation, competition, genetic introgression), and anthropogenic factors (e.g. channel alterations and sedimentation). Methods for isolating the effects of various factors affecting fish populations are especially important now that many Columbia Basin fish species have been listed, or proposed for listing, under ESA. Changes in dam operation for recovery of lower Columbia River fish stocks have been shown to impact resident fish in the headwaters (ISAB 1997) and must be balanced to benefit all native species.

The Council directed the Pacific Northwest region to test, implement, and evaluate an interim summer operation for Columbia River dams. They requested MFWP to develop a monitoring plan to evaluate the effects of their operating strategy on resident fish in Montana. The plan implements, in the summer 2004, new drafting limits at Hungry Horse and Libby Dams (Figures 1 and 2). Under the new operations, summer drafting for flow augmentation would be limited to 10 feet from full pool by September 30 (elevations 3550 and 2449, respectively). This applies to all years except the lowest 20^{th} percentile water supply; during drought years, the summer draft could be increased to 20 feet from full pool by September 30. Reservoirs will be drafted conservatively to maintain the minimum flow established for the rivers during all years. During the same period, dam discharges to the Flathead and Kootenai Rivers will be stabilized to enhance aquatic ecosystems immediately affected by the dams.

The Council also directed resource managers in the Columbia River to evaluate physical and biological changes that occur in the lower Columbia River from McNary Dam to downstream of Bonneville Dam that result from the modified drafting strategy at Libby and Hungry Horse Dams. Physical evaluations should compare available flows and velocities during summer 2004 with historic flows and velocity measurements from years with similar runoff volumes. This analysis can be conducted using available hydrosystem modeling by the Council, Army Corps of Engineers (ACOE) and Bonneville Power Administration (BPA). Physical and biological evaluations will be addressed by other proposals.

Montana Fish Wildlife & Parks proposes to use quantitative biological models and field research to assess the biological consequences of various dam operation strategies on aquatic resources in Montana (Marotz et al. 2002). The original models and published field research provide some of the tools required to assess biological impacts of operational changes called for by the Council's Mainstem Amendments. Our proposed monitoring strategies expand on the existing models using additional empirical data to assess alternative operations in greater detail.

Model simulations of reservoir trophic responses and riverine habitat availability will provide the most immediate comparisons for assessing the biological consequences of the Council's operation strategy. The existing models require only minor modifications to provide results needed to inform policy within the first year. Additional field research to calibrate and verify the reservoir models could be accomplished within three years. Conversely, the proposed field research required to assess fisheries responses at the population level would require a longer-term monitoring program. Monitoring operational effects on fish at the population level is far more complex and results will be confounded by independent factors unrelated to dam operation.

Reservoir Modeling

Reservoir assessments will be conducted using computer models developed for Hungry Horse Dam (HRMOD) and Libby Dam (LRMOD). The models were empirically calibrated using over 17 years of laboratory and field measurements of physical and biological parameters related to dam operations (Marotz et al. 1996). Reservoir biology

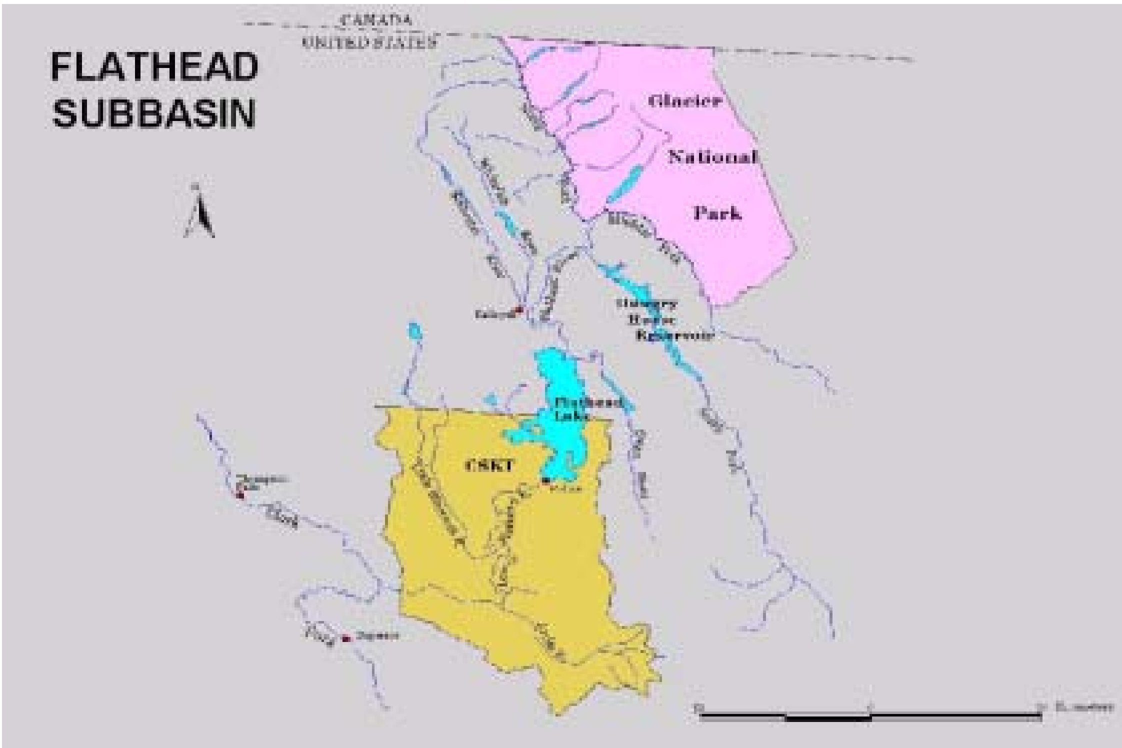

Figure 1. Map of the Flathead Watershed in Montana.

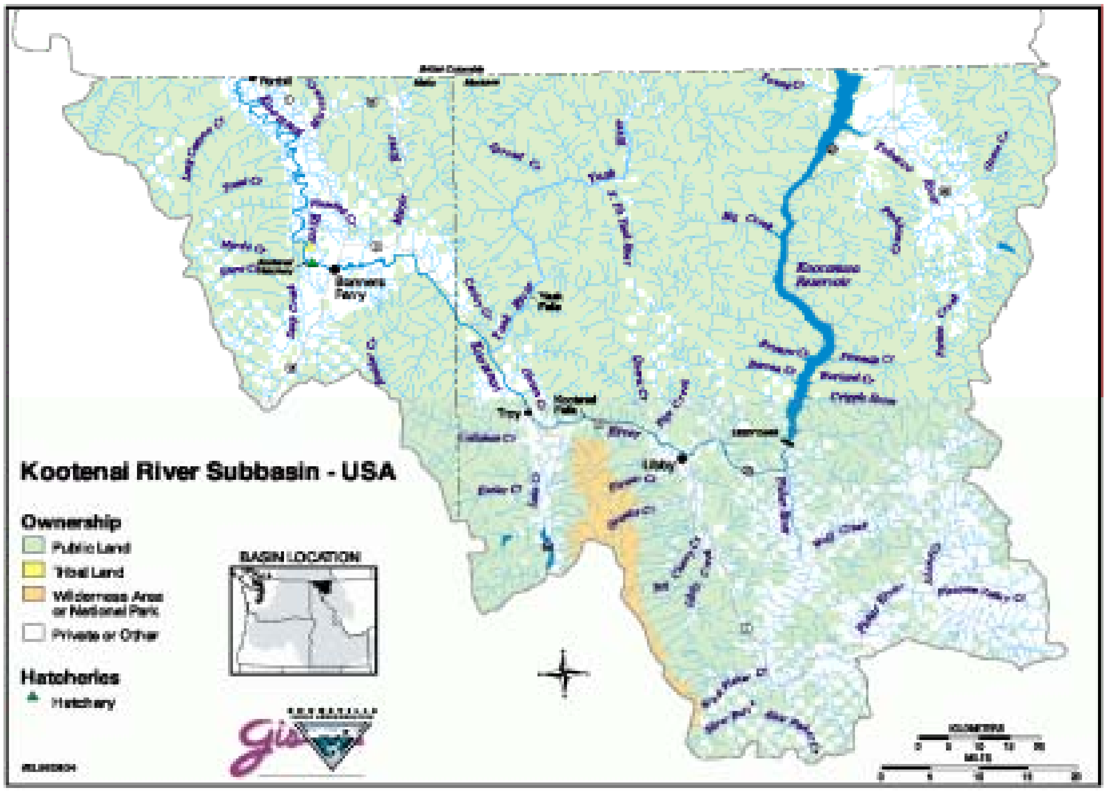

Figure 2. The Kootenai Watershed in Montana.

was assessed using field sampling for all trophic levels in Hungry Horse and Libby Reservoirs (Chisholm et al. 1989; May et al. 1988; Cavigli et al. 1998; Skaar et al 1996). The models were used to develop Integrated Rule Curves (IRCs) designed to limit the duration and frequency of deep reservoir drawdowns, improve reservoir refill probability and produce a more naturally shaped dam discharge hydrograph. Reduced drawdown protects aquatic food production in the reservoirs, assuring an ample springtime food supply for fish. Increased refill frequency improves biological production during the warm months. At full pool, the reservoir contains the maximum volume and biological productivity for fish growth and a large surface area for the deposition of terrestrial insects, an important summer fish food component, from the surrounding landscape. Refill timing also assures that passage into spawning and rearing habitats in tributaries is maintained for the threatened bull trout that begins its fall spawning run in July. Another species of special concern in Montana, the westslope cutthroat trout, ascends the spawning streams during April and May when the reservoirs are near the annual minimum elevation. Downstream of the dams, biological production in the river is protected by the more naturally shaped hydrograph. The naturalized spring freshet resorts and cleans river sediments and helps restore nutrient cycles and floodplain function. Normalized river flows benefit all species of special concern, including the endangered Kootenai white sturgeon, threatened Bull trout, westslope cutthroat and redband trout. River discharges from both projects then continue downstream to aid anadromous salmon smolt migration.

We propose to refine the reservoir models using field data compiled since the models were completed in 1996 and verify model results using directed field sampling. The hydrologic components of each model will also be updated using hydraulic measurements recorded since 1996. Conditions in the reservoirs resulting from various dam operation scenarios can be simulated by first calculating the hydrologic mass balance and thermal structure in the reservoir pool. Biological responses to various reservoir operations can be modeled at all trophic levels from primary producers (phytoplankton) through tertiary trophic levels (fish growth). Fish growth is correlated with survival, fecundity and reproductive success of individual fish (Chapman and Bjornn 1969). Model simulations will be corroborated with biological data from the reservoirs.

River Modeling

Power production and flood control operations have essentially reversed the annual hydrograph, resulting in storing water derived from spring runoff and releasing it during the fall and winter months when flows were historically low (Figure 3). Biological and physical habitat impacts in rivers immediately downstream of hydropower facilities are significant and well documented (Ward and Stanford 1979). Regulated flows perturb the river channel morphology affecting the environment of all life stages of aquatic organisms. Regulation of the Flathead and Kootenai Rivers has dramatically altered the physical characteristics of the riverine environment and biological community by affecting water quality and quantity, fish and insect habitat, and imposing barriers to fish migration (Stanford 1975; Stanford and Hauer 1978; Hauer and Stanford 1982;

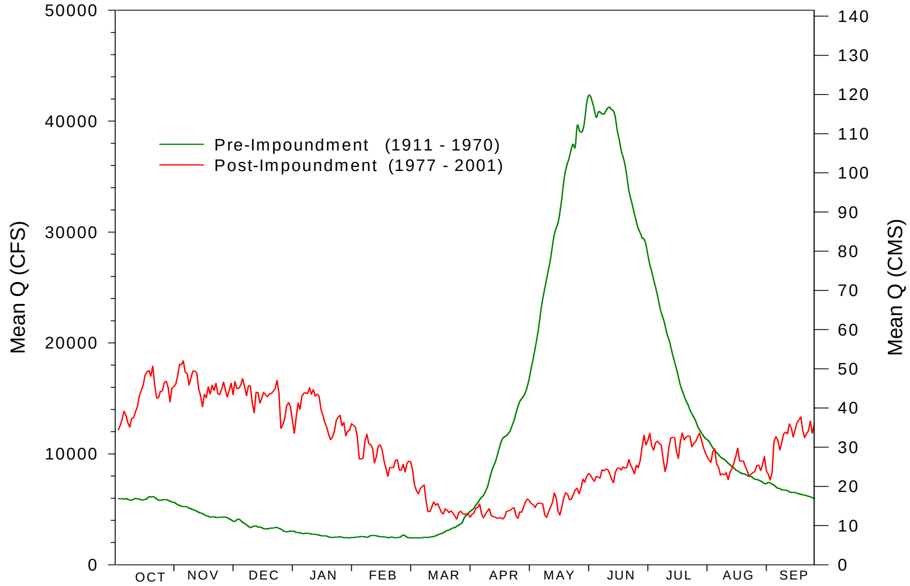

Figure 3. Example of flow regulation below headwater storage projects. These data compare the Kootenai River discharge prior to impoundment by Libby Dam (1911-1970) and regulated flows post-impoundment (1977-2001) in mean annual cubic feet per second (cfs) and cubic meters per second (cms).

Fraley and Graham 1982; Shepard et al. 1984; Fraley and Decker-Hess 1987; Hauer et al. 1994; Hauer et al. 1997; Christenson et al. 1996; Marotz et al. 1999; Muhlfeld et al. 2000). Reduction in natural spring freshets due to flood control has reduced the hydraulic energy needed to maintain the river channel and periodically re-sort river gravels. Collapsing riverbanks caused by intermittent flow fluctuation and lack of flushing flows have resulted in sediment build-up in the river cobbles, which is detrimental to insect production, fish food availability, and security cover.

The operation of Hungry Horse and Libby Dams increased the variability of river flows throughout the year (Figure 4). Rapid flow fluctuations modified the trophic dynamics in the Flathead and Kootenai River and reduced productivity of riverine algae, aquatic insects, and fish communities. Power peaking and load following cause the zone of water fluctuation, or *varial zone*, to widen and become biologically unproductive, diminishing system health. Rapid flow reductions desiccate the river margins, stranding insects, zooplankton, fish and fish eggs (Hauer and Stanford 1982; Perry 1984; Perry et al. 1986; Hauer et al. 1994; Hauer et al. 1997). Flow fluctuations during the low flow period, especially the productive warm months, are harmful to aquatic life (Marotz et al. 1996 and 1999). Since the implementation of flow augmentation for anadromous fish (NOAA-Fisheries 2000) flows below Libby Dam have exhibited a double summer peak during five of the nine previous summers (Figure 5).

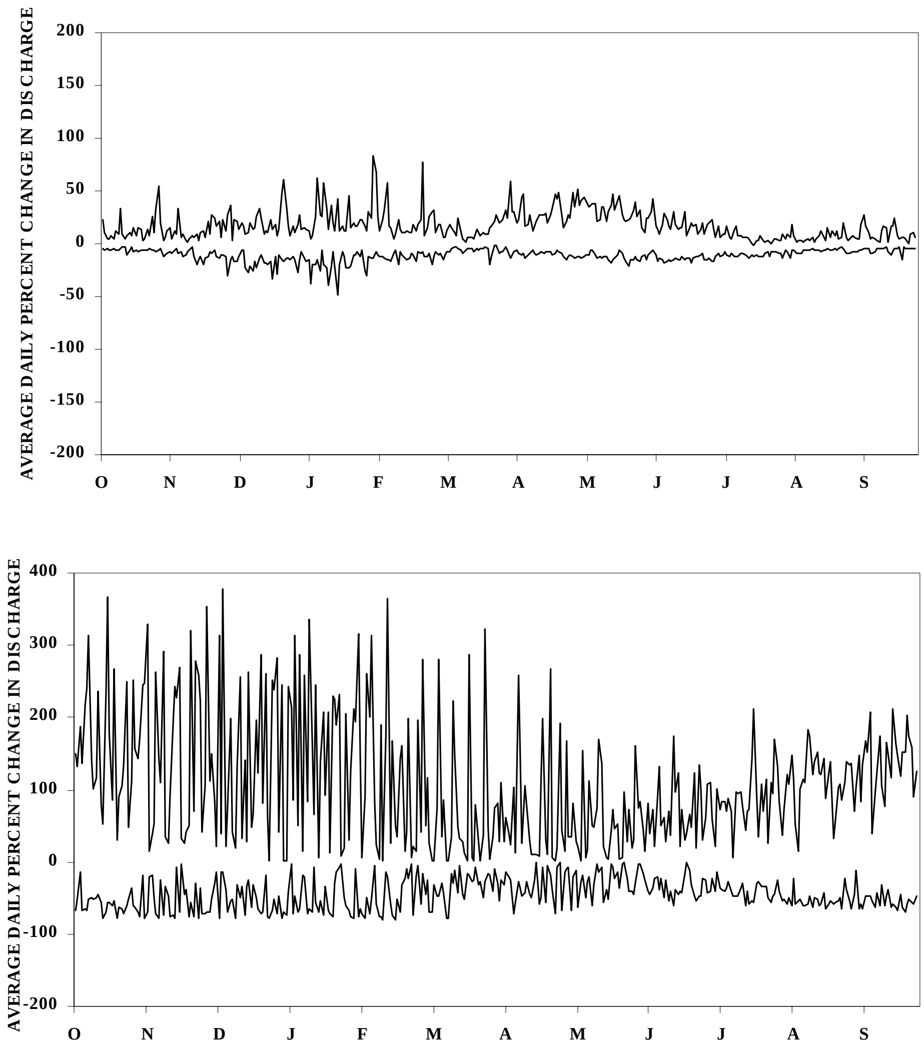

Figure 4. Range in daily change in discharge of the Kootenai River from water year 1952 through 1971 (top) and below Libby Dam from water years 1975 through 1995 (bottom) *in* Hauer 1997. Intermittent fluctuations create a wide varial zone that becomes biologically unproductive.

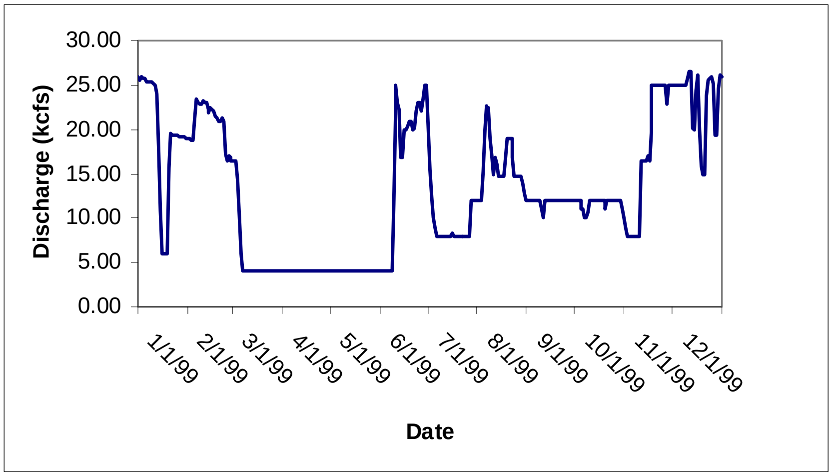

Figure 5. Example of an unnatural double summer peak operation downstream of Libby Dam. This discharge pattern occurred in the Kootenai River in 1999.

When flows fluctuate frequently, aquatic and terrestrial vegetation that would normally provide secure habitat along the river margins and stabilize soils cannot fully reestablish each summer, and fine sediment materials are more easily eroded and swept back into the channel. Sporadic flow fluctuations are especially harmful to bull trout that require shallow areas along the channel margins at night (Muhlfeld et al. 2003).

Unnatural pulses of water are not consistent with the normative river concept described by the Independent Scientific Advisory Board (ISAB 1997 b). However, if dam discharges are gradually ramped down from a normalized spring freshet and stabilized, flood plain function can be restored, reducing deleterious effects on biological production.

Instream Flow Incremental Methodology (IFIM) river research by MFWP provided researchers with tools to quantify available physical habitat and fish habitat use relative to changes in river discharge. Results substantiate restoring the most natural flow regime possible during summer to protect key ecosystem processes and restore native trout populations in the Flathead and Kootenai Rivers (Marotz et al. 2002). IFIM results influenced the US Fish and Wildlife Service's 2000 Biological Opinion (BiOp) on the operation of Hungry Horse and Libby Dams. As required in the USFWS 2000 Biological Opinion, we propose to study the effectiveness of flow ramping rates established for the restoration of bull trout in the Flathead and Kootenai Rivers. Site-specific IFIM models, verified with additional field research, will be used to assess biological consequences of the Council's river management strategy.

A selective withdrawl system was installed on Hungry Horse Dam in August 1996. The device allowed dam operators to control temperatures in the tailrace, thus resorting temperatures to near pre-dam conditions (Christenson et al. 1996; Marotz et al. 1996).

During 1995 and 1996, MFWP quantified zooplankton distribution in the reservoir forebay and entrainment through the device to provide a basis for operational recommendations (Cavigli et al. 1998). Thermal control and modified discharge ramping rates will likely influence invertebrate communities, and potentially fish growth, in the Flathead River downstream. Because the selective withdrawal system can control water temperatures in the dam discharge regardless of which dam operating plan is implemented, all model simulations will be configured to optimize thermal conditions in the tailwaters.

c. Rationale and significance to Regional Programs

Hungry Horse and Libby Dams are the only federal dam projects that can be reconfigured to provide flows and reservoir conditions needed to restore resident fish species immediately affected by the projects. For this reason, priority should be placed on fish species immediately affected by the dams.

Reservoir models for Hungry Horse and Libby Dams share data with other system models in the Columbia Basin. Simplified versions of the Montana reservoir models were used to evaluate impacts to other Columbia River storage reservoirs and develop solutions (SOR EIS 1985; Geist et al. 1996). The resident fish alternative (SOS#4) developed for the SOR EIS contained many of the operating strategies in the Council's mainstem amendment.

The flood control components of reservoir models were useful to the ACOE in developing their new variable flow, system flood control strategy called VARQ (ACOE 1999). Implementation of VARQ at Hungry Horse and Libby Dams was called for by the 2000 Biological Opinions (BiOp) on the operation of the Federal Columbia River Power System (FCRPS) by both the National Marine Fisheries Service (NOAA–Fisheries 2000) and U.S. Fish and Wildlife Service (USFWS 2000). VARQ has been implemented on an interim basis at Libby Dam by the ACOE and the US Bureau of Reclamation (BoR) has implemented VARQ flood control at Hungry Horse Dam. The ACOE is currently drafting an environmental impact statement (DEIS) on the long-term implementation of VARQ.

Changes in dam operation for recovery of lower Columbia River fish stocks have been shown to impact resident fish in the headwaters (ISAB 1997) and must be balanced to benefit all native species. Recent changes to dam operation called for in the 2000 BiOps on Kootenai white sturgeon, bull trout and listed anadromous species provide a better balance. The endangered Kootenai White Sturgeon Recovery Team adopted the IRC/VARQ operation for the Kootenai River in the white sturgeon recovery plan (USFWS 1999, also see appendices B & C). The original tiered flow strategy for augmenting flows to enhance white sturgeon spawning and recruitment were developed using LRMOD. Sturgeon flow targets at Bonners Ferry, ID were since converted by ACOE and USFWS to specified volumes to be released from Libby Dam.

d. Relationships to other projects

This proposal is a resident fish monitoring component of the regional monitoring plan prescribed by the Council. The Council also directed resource managers in the lower Columbia Basin to evaluate physical and biological changes that occur from McNary Dam to downstream of Bonneville Dam that result from the modified drafting strategy at Libby and Hungry Horse Dams. Physical evaluations should compare flows and velocities resulting from the Council's operating plan next summer, with previous years of similar runoff volumes. This anadromous fish analysis could be conducted using available hydrosystem modeling by the Council, Army Corps of Engineers (ACOE) and Bonneville Power Administration (BPA). Biological evaluations will require a new experiments in the lower Columbia River to directly assess flow and survival relationships. Biological research could be facilitated by marking Hanford Reach fall chinook either by trapping in the Hanford Reach or at McNary and extending the estimates of fall chinook survivals to Bonneville Dam and the Columbia River estuary.

This project will be closely linked to the ongoing fisheries mitigation projects at Hungry Horse and Libby Dams (199101903 and 199500400, respectively). MFWP works cooperatively with the Confederated Salish and Kootenai Tribes (CSKT) to complete projects identified in the Mitigation Plans (MFWP & CSKT 1991 and 1993, and MFWP, CSKT & KTOI 1998) and Subbasin Planning Documents. Projects in the Flathead parallel our projects in the Kootenai watershed. Model development progressed concurrently, using nearly identical methods and schedules. Equipment, personnel, data and techniques are typically shared between basins.

Concurrent with this project, MFWP will maintain annual monitoring, watershed assessment, and research components. Monitoring includes watershed-level monitoring of spawning substrate, redd counts, population estimates, and gill net monitoring series to assess direct and indirect effects of the program. We maintain this extensive monitoring program through a cooperative effort with MFWP Fisheries Management Staff and, to a lesser extent, other agencies.

e. Project history

Although this is a new project, the models and field research in this proposal have been used in other proceedings in the Columbia Basin that are relevant to this project.

The installation of Hungry Horse Dam in 1952 and Libby Dam in 1972 changed the physical and biological environment within in the reservoirs and Flathead and Kootenai Rivers downstream (Chisholm et al. 1989; May et al. 1988; Cavigli et al. 1998; Skaar et al 1996; Appert and Graham 1982; Fraley and Graham 1982; Fraley and Decker-Hess 1987; Fraley et al. 1989). Previous research conducted by MFWP provided site-specific quantitative data and techniques to assess the potential impacts of power generation, flood control and summer flow augmentation on the reservoir and river. Previous results provide an environmental base line for comparison with dam operations monitored by this proposal.

Computer models were used to develop integrated operational rule curves (IRCs) for Hungry Horse and Libby Reservoirs, Montana, (Marotz et al. 1996). The goal was to mitigate or enhance the fishery, while still providing for flood control and power production. Results showed that biological production in the reservoirs could be enhanced by limiting the maximum annual drawdown, improving reservoir refill, and by maintaining the reservoirs at or full pool during the productive summer months.

The Montana reservoir models were critically examined during the period 1991-1995, in the Columbia River System Operation Review (SOR) conducted by Bonneville Power Administration (BPA), U.S. Bureau of Reclamation (BOR), and U.S. Army Corps of Engineers (ACOE). State, tribes, and agencies represented on the SOR Resident Fish Workgroup assessed analytical tools available for biological assessments of various reservoir operation strategies. Our methodology was deemed appropriate for use in the SOR process. A simplified version of the Montana models was modified for use on the other storage reservoirs in the U.S. portion of the Columbia River System. Results were published in Appendix K of the Final Environmental Impact Statement (SOR EIS 1995). This "screening model" enabled researchers to evaluate compromises between resident fish species in the headwaters and salmon and steelhead in the lower Columbia. The IRCs and similar resident fish constraints at other storage projects formed the basis of SOS #4 which met the requirements of more work groups than the preferred alternative. Alternatives designed to improve anadromous fish survival with increased flow augmentation were found to have a negative effect on the reservoir fisheries (Geist et al. 1996).

Although the IRCs were adopted by the Northwest Power Planning Council in its Fish and Wildlife Program (Council 1994), they were not implemented in 1995 because of conflicting requirements in the NMFS 1995 Biological Opinion (BiOp). In general, the original IRC and BiOp were similar throughout the operating year but differed substantially during the summer. Whereas the IRCs attempted to fill the reservoirs in July and maintain elevations near full pool, the Biological Opinion attempts to fill the projects by June 30, then drafts the projects 20 feet by the end of August. The August release produced an unnatural second flow peak following the naturally timed spring freshet and differed from the natural hydrograph which historically declined gradually from a peak flow in early June to basal low flows by late July. Fundamental differences between the two plans sparked heated debate and at least one congressional hearing (Senate Subcommittee on Science, Technology, and Space, June 19, 1996). A technical analysis of Columbia River operating criteria, funded by NMFS and BPA, was initiated to find common ground and develop a compromise. The IRC concept was compared to the Biological Opinion and two other alternatives (Wright et al. 1996).

The original IRC elevational targets were later revised for compatibility with the various system models, and to improve conditions for the Kootenai white sturgeon, bull trout and other resident and anadromous fish species (Marotz et al 1999). In 1997, Montana revised the IRCs to allow for a 10 foot summer draft, shaped to reduce flow fluctuation in the rivers downstream. The four-year "critical period" method for dam operation, which drafted storage reservoirs consecutively deeper to maximize firm power production each year during an extended drought, was abandoned due to fishery-related changes in the operation of Columbia River dams. The reservoir models and IRC operation now assume that every year is designated “critical year one” to better mimic current operations. This revision improved reservoir refill probability and was consistent with Montana’s recommended operation.

Technical modelers of the Army Corps of Engineers (ACOE) Hydraulics Branch (ACOE 1999) critically examined the IRC strategy for flood control. ACOE modelers established that the IRC strategy was similar to a new system flood control strategy (called VARQ) developed by the ACOE. Differences between VARQ and IRCs during lower water years resulted from integrating power operations into the IRCs. Consequently, reservoir elevations defined by VARQ were higher than the IRCs in less than average water years. During average and higher years, the VARQ and IRCs were nearly identical. However, VARQ required approximately 10 feet more flood storage capacity in the highest 10 percentile of water years. In response, the IRCs were lowered to be consistent with VARQ. Montana views VARQ as flexibility to operate the reservoirs higher than the IRCs when it is economically feasible and safe (in terms of flood control) to do so. VARQ allows dam operators to store more water prior to runoff in less than average water years so that river flows can be augmented during spring without compromising reservoir refill probability. This flood control strategy is crucial to create a naturalized spring runoff (within flood constraints) while simultaneously protecting resident fish in the storage reservoirs.

Thermal modeling conducted by MFWP resulted in the installation of selective withdrawal structures on the four penstocks on Hungry Horse Dam (Christenson et al. 1996 and Marotz et al.1996). As a result of computer modeling, the selective withdrawal structure at Hungry Horse Dam was modified prior to installation to minimize zooplankton entrainment and protect the fishery in the reservoir. Duel control gates were designed to intake reservoir water from two depth strata simultaneously into each turbine penstock. This design allowed dam operators to control water temperature in the dam discharge by mixing water from above and below the layer containing the maximum density of zooplankton (Cavigli et al. 1998). The thermal component of the Libby Reservoir Model lead to refinements in the operation of the selective withdrawal gates at Libby Dam. The thermal models continue to be used to investigate various strategies for thermal control in the Kootenai and Flathead Rivers.

Entrainment of reservoir fish through Libby Dam turbines was estimated using the empirically calibrated entrainment model developed for Libby Dam by Skaar et al. (1996). Multiple regression analysis explained that most of the variation in fish entrainment rate (r^2=0.78) was explained by dam discharge, forebay fish density at 0-10 m above the withdrawal depth and vertical fish densities derived from seasonal hydroacoustic transects. Fish entrainment rate was also correlated with discharge (r^2=0.76). Skaar et al. (1996) found that kokanee (*Oncorhynchus nerka*) constituted over 98 percent of fish entrained at Libby Dam. Trends in fish density and vertical distribution can be extrapolated from sampling conducted from December 1990 through June 1993, or verified in real time using hydroacoustic sampling techniques. During spring, fish are concentrated near the surface associated with warmer water as thermal stratification begins to develop; nearly all sonic targets were found in the top 20 m.

During summer, fish densities are lower than in May and June, although densities are typically higher in August than in late fall and winter. Potential for entrainment is high in spring and summer when fish congregate near the depth where Libby Dam water withdrawals normally occur (Skaar et al. 1996).

Riverine habitat models were constructed to examine potential impacts of dam operations on riverine organisms. Previous research demonstrated that the Flathead and Kootenai Rivers provide critical rearing areas for native bull trout and westslope cutthroat trout populations (Shepard et al. 1984; Fraley and Shepard 1989; Muhlfeld et al. 2003 and 2003b). Therefore, MFWP conducted Instream Flow Incremental Methodology (IFIM) studies to determine how changes in river discharge (e.g., seasonal flow regimes and discharge change rates) influence the availability of suitable habitat for subadult and adult bull trout and westslope cutthroat trout. Radio-telemetry was used to identify seasonal location and movements of lake trout, bull trout, and westslope cutthroat trout in the drainage. Personnel built on the previous database to construct a biological layer to overlay on the physical framework of the IFIM study. Physical aspects of the IFIM project were directly contracted by BPA (project 199502500). MFWP used a modified Instream Flow Incremental Methodology approach (IFIM; Bovee 1982; Miller et al. 2003) using site-specific biological and physical data to quantify impacts on critical salmonid habitat.

Results of the IFIM studies showed that habitat area for native bull trout and westslope cutthroat trout is more available at lower discharges than higher discharges (Miller et al. 2003). Comparison of the pre and post-dam hydrology demonstrated that stable flow during both summer and winter low-flow periods provided more habitat than the highly variable flow regime caused by hydropower operations. Variation in weekly and daily flows under post-dam conditions first floods, then dewaters stream margins, which forces subadult bull trout to move from their habitat used during day and night. Further, channel margin habitats that are intermittently wet and dry (called the *varial zone*) provide little productivity for lower trophic levels and also become unproductive for fish, especially bull trout that use those areas at night and as flows increase. Muhlfeld et al. (2002) found that subadult bull trout moved from deep, mid-channel areas during the day, to shallow low-velocity areas along the channel margins without overhead cover at night. The authors recommended that resource managers who wish to protect overwintering habitat features preferred by subadult bull trout should employ natural flow management strategies that maximize and stabilize channel margin habitats.

The Independent Scientific Advisory Board (ISAB 1997 and 1997b) recommended that restoration of the most natural flow regime possible under the current management constraints will protect key ecosystem processes and maintain or restore bull trout populations in Montana and elsewhere in the Pacific Northwest (Independent Scientific Group 1999). IFIM research by MFWP supported previous literature showing that stable flow regimes are more productive than flow regimes with high weekly variation. The highly variable flows apparently stress native salmonids as they move from day to night habitat locations based on depth and velocity characteristics. Miller et al. (2003) provided a visual characterization of habitat and Arcview project data.

In December 2000, the U.S. Fish and Wildlife Service (USFWS) published their Biological Opinion (USFWS 2000) that addresses impacts of the Federal Columbia River Power System operations on bull trout and Kootenai white sturgeon. Montana's reservoir and river models were used to develop tiered flows for Kootenai River white sturgeon that are specified in the USFWS 2000 BiOp and Recovery Plan (USFWS 2000; USFWS1999) and subsequently modified by the USFWS and ACOE (Figure 6). The BiOp also included terms and conditions for flow ramping rates for Hungry Horse and Libby Dams, and requires that action agencies, in consultation with the USFWS, conduct a 10-year study to assess the biological effectiveness of these prescribed ramping rates beginning in 2001; this research has not been funded to date.

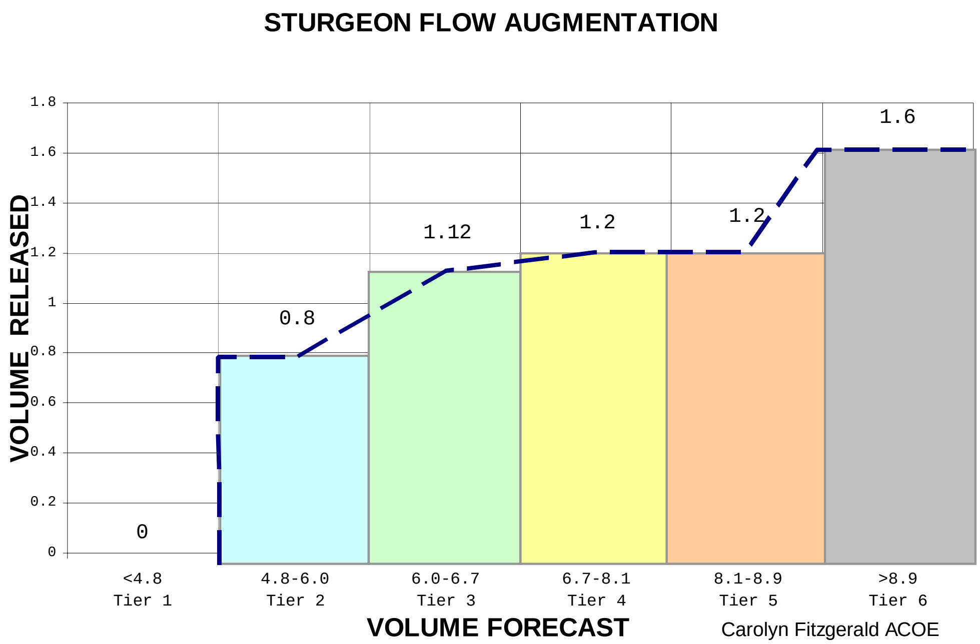

Figure 6. The volume of water to be released from Libby Dam to enhance Kootenai white sturgeon spawning and incubation is calculated based on the May inflow forecast for Libby Reservoir. The sturgeon volume within each tier increases with increasing water availability.

Proposal objectives, tasks and methods

The State of Montana proposed five main objectives for evaluating the Council's prescribed reservoir operation.

Objectives.

1. Evaluate the response of listed bull trout and resident fish to the Council's proposed reservoir drafting strategy.
2. Evaluate habitat changes associated with stabilized flows and velocities in the Flathead and Kootenai Rivers.
3. Evaluate the changes in survival for juvenile and adult salmon migrating through the Lower Columbia River.
4. Evaluate changes in flow during the fall and winter period that may affect chum salmon protection and survival improvements.
5. Evaluate changes in reservoir refill probability that may result from reducing the summer draft of the reservoirs.

This proposal addresses objectives 1 and 2 (above) as addressed by the following project objectives:

Objective 1. Evaluate the potential response of listed bull trout and resident fish resulting from the Council's reservoir drafting strategy.

Task 1. Use HRMOD and LRMOD to calculate the amount of physical habitat available for aquatic productivity resulting from reservoir drafts in the Mainstem Amendments at Hungry Horse and Libby Reservoirs.

Methods

Marotz et al. (1996) developed two computer simulation models for Hungry Horse (HRMOD) and Libby (LRMOD) Dams. The models simulate the physical operation of the dams including the water budget and flood concerns, and predict the resulting thermal structure of the reservoir and tailwater temperature. Physical habitat availability under alternative dam operating scenarios will be compared using model simulations.

The physical framework in the reservoir models were constructed by digitizing large scale topographic maps (1 inch = 400 feet) of the reservoir pool in 3.1 m (10 ft) depth increments. Conditions in the reservoirs resulting from various dam operation scenarios can be assessed beginning with the hydrologic mass balance and thermal structure in the reservoir pool. The models then calculate the amount of reservoir substrate that remains biologically productive under alternative operating strategies. Detailed methods used to construct MFWP's quantitative biological computer models of Hungry Horse Dam (HRMOD) and Libby Dam (LRMOD) were reported by Marotz et al. (1996).

Differing dam operation strategies will be contrasted using time series analyses of historic reservoir surface elevation data, correlated with seasonal measurements of biological productivity (phytoplankton and benthic dipteran production). Annual trends in euphotic zone depth and phytoplankton productivity were used to calibrate each reservoir model. Carbon fixation by phytoplankton was measured by C^{14} liquid scintillation samples from light/dark bottle arrays suspended along the reservoir's length. Depth profiles of Chlor α were used to describe seasonal trends in phytoplankton biomass. The reservoir models estimate phytoplankton production (metric tons of carbon fixed). Reservoir volume, surface area and seasonal trends in solar input, attenuation and aspect, largely control model output, which calculates an annual plot of primary productivity and an annual total. Phytoplankton washout through the dams (metric tons) was calibrated by chlor α vertical distribution within the reservoir and verified using entrainment sampling in the turbine outflow.

Observed rates of aquatic diptera colonization in newly inundated substrates, and larval mortality in desiccated areas, provide evidence for describing time lags in insect production following reservoir surface fluctuations. Model simulations will assume a five week lag for insect recolonization of new flooded habitat and a one week delay in insect mortality after substrate becomes dry. Calculations will be calibrated using data from dipteran larvae captured in dredge samples of reservoir substrate collected above and below pool elevation (May et al. 1988).

Task 2. Use HRMOD and LRMOD to calculate the biological responses resulting from reservoir drafts in the Mainstem Amendments at Hungry Horse and Libby Reservoirs.

The biological models were empirically calibrated using field measurements of physical and biological parameters as related to dam operations (Chisholm et al. 1989; May et al. 1988; Cavigli et al. 1998; Skaar et al. 1996; Marotz et al. 1996). The biological response to various reservoir operations can be modeled within trophic levels extending from primary producers (phytoplankton) through tertiary trophic levels (fish growth). Specifically, the two reservoir models estimate zooplankton production and washout, the deposition of terrestrial insects on the reservoir surface and body growth of major game fish. We will compare these model outputs for alternative operational strategies.

Total zooplankton production (metric tons) was calibrated on phytoplankton production and seasonal measures of carbon transfer efficiencies. The Hungry Horse Reservoir model partitions zooplankton production by genera, based on measured relative abundances in Wisconsin net tows and vertical distributions sampled using Schindler Traps.

Benthic production (metric tons of emergent insects) was calibrated on the depth distribution of insect larvae collected in benthic grab samples and emergence rates from insects captured in surface emergence traps.

Terrestrial insect deposition (percent of maximum) by insect order (coleoptera, hemiptera, homoptera, and hymenoptera) were calibrated using near shore (<100 m) and offshore surface insect tows.

Fish growth (end of year kokanee size at Libby and westslope cutthroat growth at Hungry Horse) in total length (TL) and weight (grams) were calculated through multivariate analysis on water temperature structure and food availability.

Task 3. Compile age-growth and condition factor data from annual gill net series to compare actual growth at age under varying reservoir operating strategies to long-term composite growth increments. Relate variation in growth increments to environmental conditions.

The method described by Weisberg (1986) will be used to back-calculate fish length at age using scale and otolith annuli from individual fish. Growth increments from individual salmonids age III to VI will be compared, by yearclass, with a composite growth rate at age from all samples, to test the null hypothesis that reservoir operation does not influence salmonid growth increments for salmonids within the reservoirs. Annual variation in growth rates can then be attributed to environmental conditions that fish experience during a given year. We acknowledge that growth increments may be confounded by density dependant growth and that maximizing individual fish growth does not necessarily maximize population yield. Nonetheless, the results from out study design outlined below may provide evidence for differentiating tertiary production under various reservoir operation strategies.

We propose to use two study designs to test the null hypothesis. The first will test if growth increments and length at age differ before and after the ten foot draw down amendment was implemented. We plan to use an analysis of variance for statistical analysis of the data. The second study design will assess whether the magnitude of the draw down influences the magnitude of incremental fish growth. This second study design will rely on multiple regression techniques. We propose to evaluate the efficacy of both study designs.

Task 4. Update the Libby Reservoir model using data from recent years to improve the predictive capability of the hydrologic model to better estimate the unregulated component of the flow via a regression on reservoir inflow.

The hydrologic component of each model will be updated using hydraulic measurements collected since the models were completed in 1996. Refinement of the hydrologic component using additional annual records will allow greater resolution in estimating river flows and water temperatures at incremental points downstream.

Additional flow/temperature modeling will require updating the Libby model using data from recent years to improve the predictive capability of the component that estimates the unregulated component of the flow via a regression on reservoir inflow. This will allow greater resolution in estimating river flows and water temperatures at incremental points downstream.

Objective 2. Evaluate alterations in native fish habitat associated with dam operations in the Flathead and Kootenai Rivers.

Task 1. Use IFIM models to estimate the biological responses resulting from river flow in the Mainstem Amendments in the Flathead and Kootenai Rivers.

The Instream Flow Incremental Methodology (IFIM) is the most widely applied methodology for developing instream flow recommendations in North America (Reiser et al. 1989). MFWP will use a modified Instream Flow Incremental Methodology approach (IFIM; Bovee 1982; Miller et al. 2003) to quantify changes in critical salmonid habitat resulting from alternative operating strategies. Our two-dimensional hydrodynamic modeling approach overcomes many limitations related to classical physical habitat simulation modeling (1-D; Leclerc et al. 1995), and the methodology was reviewed and approved by the ISRP during the 2000 Rolling Review Process. The IFIM models use a combination of empirical physical and biological data to quantify the total availability of various habitats for selected life stages of native fishes (Hoffman et al. 2002; Marotz and Muhlfeld 2000; Miller et al. 2003; Muhlfeld et al. 2001, 2002 and 2003b).

Habitat use and movement data were collected for each native target species (bull trout and westslope cutthroat trout) and life stage (juvenile and adult) by use of radiotelemetry and snorkel surveys in reaches affected by dam operations downstream of Hungry Horse and Libby Dams. Habitat suitability functions were developed using these data to ensure that the suitability criteria accurately reflected the habitat requirements of the species and life stage of interest. Further, radiotelemetry allowed researchers to accurately characterize selection of specific habitats during day and night surveys. Calculation of habitat suitability criteria for each two-dimensional hydraulic model required use of a bivariate analysis of depth-velocity paired data to calculate fish presence for depth and velocity in the stream reach. Muhlfeld et al. (2003b) found that depth and velocity were the most important habitat variable influencing habitat selection of subadult bull trout in the Flathead River.

Habitat utilization curves were developed using hundreds of observations on radio-tagged fish from summer 1999 to winter 2002 in the Flathead River and visual observations (SCUBA) from 1990 to 1998 in the Kootenai River. Observations were stratified by species, size-class, and season. Please see Muhlfeld et al. (2002) and Hoffman et al. (2002) for a detailed description of the methods and sample sizes used for development of suitability curves for the Flathead and Kootenai Rivers, respectively. Suitability curves were then combined with two-dimensional hydraulic simulations of river hydraulic characteristics (i.e., stream bed elevations, mean column velocity, habitat type) in a GIS analysis format to determine habitat area as a function of discharge. Model results will be corroborated with new radio telemetry relocations to ensure meaningful and defensible instream flow analyses.

Estimations of usable habitat from the calibrated IFIM models will be used to rank the alternative operating strategies based on the amount of available habitat for each target species and lifecycle stage of salmonids in the Flathead and Kootenai Rivers.

Using the IFIM models, estimates of total usable area will be obtained for each species and life stage for three specific operational strategies: historic (pre-dam), water budget flow augmentation for anadromous fish recovery, and the proposed Mainstem Amendments. Regression and time-series analyses will be used to correlate total usable area under various operational strategies as related to river discharge. For each operational strategy, five representative water years will be selected to quantify suitable habitat at low (lowest 40th percentile), medium (average ± 10 percentile), and high (top 40th percentile) flow conditions, which will provide a mean and range of conditions. Historic flow records compiled by the U.S. Geological Survey will be input to the model to calculate habitat conditions on a weekly, daily, and seasonal basis. Operations since the water budget was implemented to augment river flow for anadromous fish recovery will be quantified with specific emphasis of more recent years where flow augmentation was released during the second half in August, creating a double peak. Finally, suitable habitat availability will be estimated for conditions following the proposed Mainstem Amendment strategy, which is designed to release stable flows from July through September. The Mainstem Amendments follow a sliding scale for flat flows at low, medium and high water years. Water releases will be calculated by adding the volume within top 10 ft of each reservoir and reservoir inflow (tributaries) divided by number of days during the period of July and September. ANOVA (mixed model) will be used to test the null hypothesis that suitable habitat availability does not differ between control (historic) and treatment groups for each flow regime. Regression analyses will assess the relationship between habitat availability (dependent variable) and river discharge (independent) for each operational strategy and flow regime to identify flows that maximize critical habitat.

Task 2. Estimate annual salmonid cohort survival, and relate that survival to environmental variables including weekly and daily summer flow variation (tributary and river phase).

Understanding population productivity and survival are key components to fisheries management and may be especially useful for assessing the biological responses to dam operations. Estimates of fish survival in relation to dam operations are available for anadromous salmonids in the lower Columbia River. Connor et al. (1998) first provided an index of subyearling Chinook salmon survival at lower Granite Dam by tagging individuals with passive integrated transponders upriver in the Snake River. Further, Connor et al. (2003) developed a multiple regression model to predict cohort survival for summer flow augmentation based on temperature and flow conditions. These studies provide population level information to assess whether summer flow augmentation was a beneficial recovery measure to enhance survival of subyearling chinook salmon in the Snake River.

To the best of our knowledge, however, no peer-reviewed studies have estimated population production, or the rate of change, for migratory bull trout and westslope cutthroat trout populations as related to dam operations in the headwaters of the Columbia River Basin. Estimating the effects of hydropower operation on the survival of resident fishes in headwater areas is difficult due to the complexity of life history strategies (e.g. resident, fluvial and adfluvial) and the lack of fish counting stations that are available for anadromous fish research elsewhere in the Columbia River system. Resident fish live above and between dams where no fish counting facilities exist, and salmonid populations exhibit complex movement patterns throughout the upper Flathead River and Kootenai River systems. Further, within a species, individual fish of one life history strategy are generally not visually distinguishable from those of another life history.

Native westslope cutthroat trout and bull trout exhibit both resident (i.e., remaining in natal streams throughout life) and migratory life history strategies (Shepard et al. 1984; Liknes and Graham 1988; Fraley and Shepard 1989; Muhlfeld et al. 2003b). Migratory westslope cutthroat trout rear in their natal stream for 1-4 years, and then migrate downstream as subadults to a lake (e.g., adfluvial) or the remain in the river (e.g., fluvial). Adult westslope cutthroat trout generally overwinter in the mainstem river or lake, and then migrate long distances upstream (up to 250 km) during high spring flows to access natal spawning streams in the headwaters. Similarly, juvenile bull trout emigrate from tributaries to the river or lake during early summer through winter. Adult adfluvial bull trout migrate from Flathead Lake into the Flathead River and move toward staging areas in early summer (April-July); move into spawning tributaries generally in August; and move rapidly back downstream to the river or lake during September (Shepard et al. 1984). Thus, at any time of the year, different salmonids, life histories, and age groups are migrating throughout the river system. These conditions complicate using mark-recapture methodologies and the standardization of the timing of annual monitoring surveys.

Montana Fish, Wildlife & Parks has a lengthy history of detailed monitoring of the fish populations in the Kootenai and Flathead Rivers downstream of the dams. Population estimates (Peterson mark-recapture; Ricker 1975; Zar 1996) by age class for rainbow and westslope cutthroat trout have been completed annually since 1973 on the Kootenai River. In addition, mountain whitefish population estimates by age class were also completed annually on the Kootenai River from 1971-1981 and then approximately every three to four years since 1981. Similarly, population estimates (Peterson mark-recapture; Ricker 1975; Zar 1996) have been completed for rainbow trout in the Flathead River from 1979-1981 and annually since 1997 (Deleray et al. 1999; Muhlfeld et al. 2000, 2001 and 2002). Using telemetry, Muhlfeld et al. (2000, 2001, and 2002) found that rainbow and hybrid trout occupy small home ranges in the dam-influenced portion of the Flathead River during summer, fall, and winter, and spawn in tributaries during high spring flows (Muhlfeld et al. 2000, 2001 and 2002). Thus, this life history pattern makes it possible to obtain accurate and reliable population estimates using a mark-recapture methodology. Age and length/weight information also accompanies the population estimates. These data, and the continued collection of similar data will be a critical component of our study plan to evaluate the river operation changes proposed by the current Mainstem Amendments.

We propose to estimate cohort survival for salmonid populations downstream of Hungry Horse and Libby Dams using consecutive annual population estimates. Mark-recapture population estimates collected prior to the implementation of the Mainstem Amendments during the summer of 2004 will serve as a basis for comparison. Subsequent annual population estimates will allow researchers estimate annual survival and then use these data to test the null hypothesis that that river operation (weekly and daily summer flow variation) does not influence salmonid survival in the river. We will also use multiple linear regression analyses to evaluate cohort annual survival in relation to environmental conditions such as total summer discharge, daily and weekly discharge variation, and water temperature. Also, prior to commencing sampling after the implementation of the Mainstem Amendments, we will conduct a series of power analyses to determine the level of precision needed to detect population level responses to hydrosystem operations Finally, we may also explore the efficacy of using alternative estimators such as the maximum likelihood estimator for our cohort survival estimates.

Task 3. Use radio telemetry to assess fish locations and movement associated with river flows. Verify IFIM model simulations by using radio telemetry to assess fish locations and movement associated with river flows.

Now that the habitat models are completed, we have the opportunity to combine the IFIM model with radio-telemetry and model simulations to determine the effectiveness of flow ramping rates (up and down) as prescribed in the BiOp (tables 1 and 2.).

Existing and new radiotelemetry relocations will be overlaid on IFIM model results to assess the predictive capability of the IFIM models. Detailed relocations of up to 30-40 radio tagged fish at a variety of flows will provide us with hundreds of locations to compare to IFIM model preferred (predicted) locations for each given discharge which the observation was recorded. This is a conservative approach designed to least impact our target bull trout and cutthroat trout populations. The proposed relocations will only be used to verify the predictive capability of the IFIM models and will not be incorporated into the model unless different results are detected. Locations of radio-tagged fish will be associated with flow ramping, and will be used to assess the effects of flow fluctuation on fish movements. Therefore, we propose to evaluate the effectiveness of the prescribed ramping rates by use of radio-telemetry during summer. The goal of this study is to assess whether hourly and daily flow ramping rates influence movements and habitat use by westslope cutthroat trout, rainbow trout and bull trout implanted in the South Fork Flathead River and main-stem Kootenai River.

This fieldwork is designed to test the null hypothesis that hourly and daily discharge variation does not influence fish movement. Field sampling will require close coordination with dam operators to ensure that radio telemetry observations are collected at appropriate times relative to changes in discharge within the Kootenai and Flathead Rivers. We anticipate that a before-after and control comparison could be used as the experimental design to test the null hypothesis. Specifically, we propose to compare the standardized distance (e.g. distance per unit time) a radio tagged fish moves during a flow

Table 1. Daily and hourly maximum ramp up rates for Hungry Horse Dam (as measured by daily flows, not daily averages, restricted by hourly rates).

Ramp Up Rates - Hungry Horse Dam		
Flow Range (measured at Columbia Falls)	**Ramp Up Unit (Daily Max)**	**Ramp Up Unit (Hourly max)**
3,500 - 6,000 cfs	Limit ramp up 1,800 cfs per day	1,000 cfs/hour
> 6,000 - 8,000 cfs	Limit ramp up 1,800 cfs per day	1,000 cfs/hour
> 8,000 - 10,000 cfs	Limit ramp up 3,600 cfs per day	1,800 cfs/hour
> 10,000 cfs	No limit	1,800 cfs/hour

Ramp Down Rates - Hungry Horse Dam		
Flow Range (measured at Columbia Falls)	**Ramp Down Unit (Daily max)**	**Ramp Down Unit (Hourly max)**
3,500 - 6,000 cfs	Limit ramp down to 600 cfs per day	600 cfs/hour
> 6,000 - 8,000 cfs	Limit ramp down to 1,000 cfs per day	600 cfs/hour
> 8,000 - 12,000 cfs	Limit ramp down to 2,000 cfs per day	1,000 cfs/hour
> 12,000 cfs	Limit ramp down to 5,000 cfs per day	1,800 cfs/hour

Table 2. Daily and hourly maximum ramp up rates for Libby Dam (as measured by daily flows, not daily averages, restricted by hourly rates).

Ramp Up Rates - Libby Dam			
Flow Range	**Ramp Up Unit (Daily max)**	**Ramp Up (Hourly max) 1 Oct – 30 Apr**	**Ramp Up (Hourly max) 1 May – 30 Sep**
4,000 - 6,000 cfs	Limit ramp up to one unit per day (approx 5,000 cfs per day)	2,000 cfs/hr	1,000 cfs/hr
6,000 - 9,000 cfs	Limit ramp up to one unit per day (approx 5,000 cfs per day)	2,000 cfs/hr	1,000 cfs/hr
> 9,000 - 17,000 cfs	Limit ramp up to one unit per day (approx 10,000 cfs per day)	3,500 cfs/hr	2,000 cfs/hr
> 17,000 cfs	No limit	7,000 cfs/hr	3,500 cfs/hr

Ramp Down Rates - Libby Dam			
Flow Range	**Ramp Down Unit (Daily Max)**	**Ramp Down (Hourly max) 1 Oct – 30 Apr**	**Ramp Down (Hourly max) 1 May – 30 Sep**
4,000 - 6,000 cfs	Limit ramp down to 500 cfs per day	500 cfs/hr	500 cfs/hr
> 6,000 - 9,000 cfs	Limit ramp down to 1,000 cfs per day	500 cfs/hr	500 cfs/hr
> 9,000 - 17,000 cfs	Limit ramp down to 2,000 cfs per day	1,000 cfs/hr	1,000 cfs/hr
> 17,000 cfs	Limit ramp down to one unit per day (approx 5,000 cfs per day)	5,000 cfs/hr	3,500 cfs/hr

ramping period to standardized movements during period of stable flow (control). Sampling period would be stratified into sampling period based on the flow ranges listed in Tables 1 and 2. This information will provide a tool for decision-makers to design flow regimes that mutually benefit native resident fish, power demands, and salmon recovery efforts in the lower Columbia River basin. We expect that the same radio tagged fish could be used to assess several tasks in this objective.

Task 4. Use migrant trapping (i.e., screw and box traps) and Passive Integrated Transponder (PIT) tagging to estimate survival and growth of cutthroat trout and rainbow trout populations.

The productivity of bull trout and westslope cutthroat trout populations is influenced to a large degree by food and space limitations in natal tributaries (Chapman 1966; Chapman and Bjornn 1969). Age-specific abundance, survival, growth and age at emigration will be monitored in selected spawning and rearing streams in the Flathead River system by examining juvenile emigration and adult escapement. We will use migrant weirs and remote PIT tag detection weirs to capture juvenile and adult rainbow trout and cutthroat trout from the following spawning and rearing streams in the North Fork Flathead River from 2004 through 2005: Langford Creek, Meadow Creek, and Ivy Creek (rainbow trout streams), and Ketchikan Creek, and Colts Creek (westslope cutthroat trout streams) (Figure 7).

Bi-directional migrant traps and remote PIT tag detection weirs will be installed near the mouths of spawning and rearing streams to capture and tag juvenile emigrants and adult spawners during spring, summer, fall, and possibly winter (depending on snow and ice conditions). In 2004, weirs will be installed in Meadow, Langford, Ketchikan, and Colts Creek and deployed through 2006. Subsequent recapture information will be obtain by use of remote PIT tag detection weirs through 2010. All captured trout will be anesthetized with MS-222, abdominally implanted with individual PIT tags, and examined for marks including PIT tags. Juvenile and adult fish will also be marked with an adipose fin clip to estimate tag retention in recaptured fish. Scales and tissue samples will be collected from each fish to estimate size and age-class structure, fish growth, and genetic composition (Kanda et al. 2001). In addition, tissue samples will be collected from individual fish to quantify elemental signatures in the scales to estimate natal origin and life history (Wells et al. 2003; Muhlfeld et al.- *In review*). Further, we will examine the scale chemistry data to identify potential elemental signatures that represent the environmental history of recaptured fish. This information will be used to determine if residence time was spent in dam-influenced portions of the river. Genetics and scale chemistry results may also be used to estimate straying rates for each stream. However, we do not expect adult spawners to stray because the remote PIT tag detection weirs will be installed using large antennas (1m x 1 m) and natural cover (i.e., LWD and boulders) to decrease the probability of thwarting fish to nearby spawning tributaries. In 2003, Muhlfeld et al. (2004) did not detect trap avoidance by adult spawners in Langford, Meadow, and Cyclone Creeks.

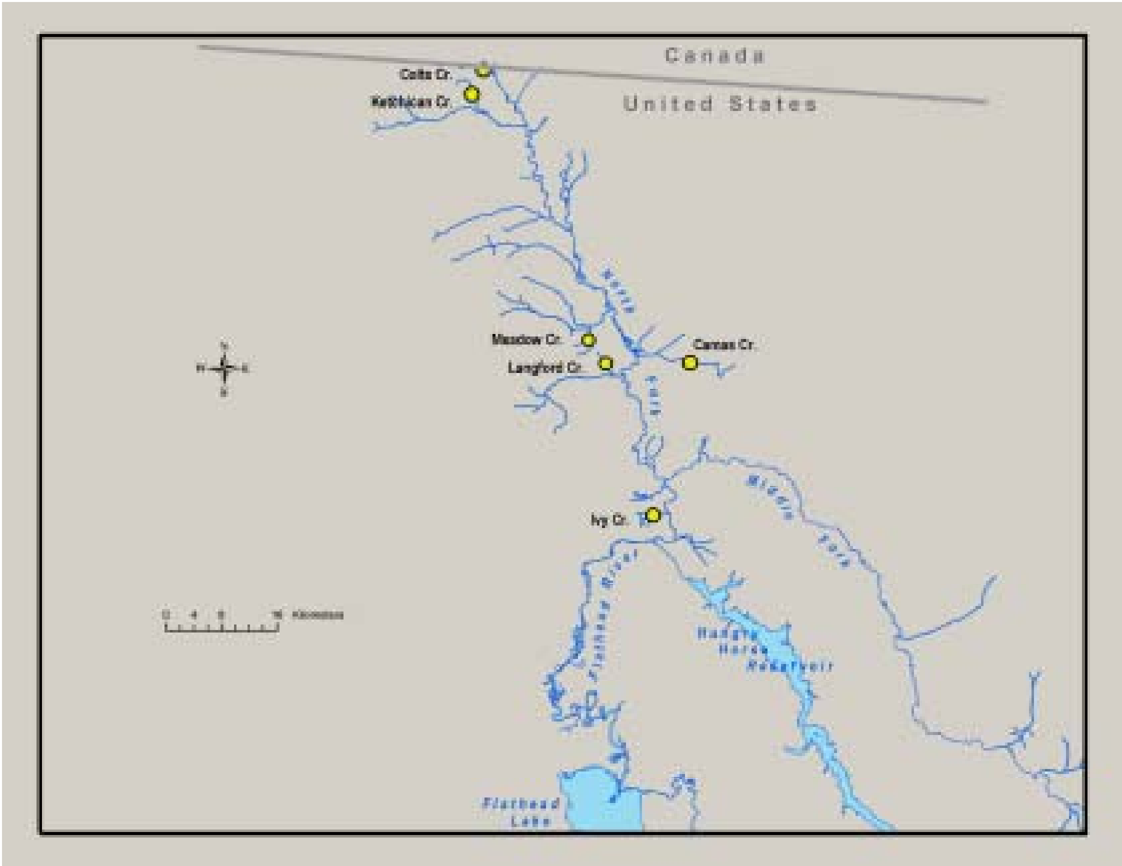

Figure 7. Location of tributaries in the North Fork and mainstem Flathead River where remote PIT tag detection weirs will be used to capture juvenile and adult rainbow trout and cutthroat trout.

A mark-recapture technique will be used to estimate capture efficiency for juvenile emigrants during stratified time-periods. Marked fish captured in the emigrant traps will be relocated approximately 100 m upstream of the trap to estimate trap efficiency. The proportion of recaptured fish will provide an estimate of trap efficiency, which will then be used to estimate fish number of unmarked fish moving past the trap during a particular time period (week, month, or season). Ratios of marked versus unmarked fish will be used to obtain population estimates using a simple Peterson mark-recapture estimator (Roper and Scarnecchia 1999). Recruitment from index streams will be estimated using remote PIT tag detectors. If sufficient numbers of adult fish can be recaptured during subsequent years (bull trout and cutthroat trout typically spawn at 5-7 years of age; Shepard et al. 1984; Liknes and Graham 1988; Fraley and Shepard 1989), we will quantify juvenile to adult survival.

In each study steam, population estimates will be conducted seasonally to estimate abundance, size and age structure, and percent emigration. Population estimates will be conducted using a multiple-pass technique in two 150-m sections upstream of each trap (Zippin 1958), and the backpack electrofishing apparatus will be configured to avoid damage to native fishes (Dwyer et al. 1993; Dwyer and Erdahl 1995). All captured trout will be anesthetized with MS-222, abdominally implanted with individual PIT tags, and examined for marks including PIT tags for each survey. Population estimates will be used to estimate tributary survival and emigration coupled with the weir trap data. Also, we will use a systematic survey to locate PIT tags each time a population estimate is performed throughout each study stream to quantify movements and to locate missing fish (Morhardt et al. 1999).

Snow and ice conditions may preclude winter trapping and winter conditions may significantly influence survival and subsequent recruitment from natal tributaries (Cunjak et al. 1998). Therefore, we will use telemetry to monitor movements and habitat use of juvenile fish to obtain estimates of juvenile emigration during winter months. Surveys will be conducted using aerial and ground surveys on a weekly basis. Muhlfeld et al. (2001) provides a detailed description of the telemetry methods and analysis.

After fish emigrate from their natal tributaries, we will assess the influence of dam operation on survival and growth of subadult and adult fish. Juveniles marked in tributary streams will be recaptured in the river systems using boat-mounted electrofishing apparatus and mobile PIT tag detectors. Results will be used to estimate of subadult survival in the river and lake system during subsequent years and to provide evidence to link potential factors (density dependent and independent) influencing age-specific survival.

> Task 5. Compare length at age and growth increments of rainbow, westslope cutthroat and bull trout captured below Libby and Hungry Horse Dams via electrofishing to compare alternative system operation strategies.

One potential method to infer population-level responses to proposed summer flow conditions in the Flathead and Kootenai Rivers is to evaluate changes in fish growth and condition factor. We therefore propose field research to test the null hypothesis that river operation (seasonal, weekly, and daily flow variation) does not influence salmonid growth increments for salmonids within the Kootenai and Flathead rivers. We recognize that this direct evaluation will be confounded by factors unrelated to dam operation. Otoliths and scales from fish captured during annual electrofishing surveys will be used to determine age at emigration and subsequent growth increments. We will estimate growth rates by back-calculating fish length at age using annuli and growth increments (Weisberg 1986; Weisberg and Frie 1987). The method described by Weisberg (1986) will be used to back-calculate fish length at age using scale and otolith annuli from individual fish. Growth increments from individual salmonids age I to VI will be compared, by year class, with a composite growth rate at age from all samples. Annual variation in growth rates can then be attributed to environmental conditions that fish experience during a given year. Total length and girth will be measured to determine condition factor. This approach will compare growth and condition factor information from years with high and variable summer flows to data collected during the proposed system change. We propose to use multiple linear regression to evaluate annual variation in growth rates and condition factor to environmental conditions such as total summer discharge, daily and weekly discharge variation, and temperature.

Although hydropower effects on water temperature and river flow influence food and space relations, growth and condition of juvenile and adult fish may be influenced by density dependent factors. Less abundant populations may have high average growth and condition factors due to reduced fish density and competition, but relatively low productivity on a unit area basis. Size and age at emigration, which are controlled by environmental factors in natal tributaries that are unrelated to dam operation (Boss and Richarson 2002), influence annual growth of juvenile fish after they emigrate from their natal tributaries. Therefore, even though growth and condition of individual fish may be correlated with survival, fecundity and reproductive success (Chapman and Bjornn 1969), the growth of fish in a population can not be used to directly predict the productivity of the affected fish population.

g. Facilities and equipment

Offices, equipment, and facilities are located at the MFWP regional headquarters in Kalispell, Montana and the Libby Area MFWP Office in Libby, Montana. The regional headquarters is a 5 acre complex, built in 1990 , that houses ~55 MFWP employees in addition to our project personnel. Facilities include several boat sheds, a machine shop, wet laboratory, field prep room, storage buildings for project equipment, and office space for all staff. Other specialized equipment includes a 22 ft boat with inboard motor, 14 ft boat with outboard motor, Bobcat skid-steer loader with backhoe (shared with Libby Dam Mitigation Project), backpack and bank electrofishing units, GPS units, laser level and surveying equipment, microscopes, cameras, and project vehicles from the MFWP motor pool. Fisheries management and Parks Divisions have other specialized equipment available when occasionally needed for projects: boom trucks, dump trucks, trailers, additional boats and vehicles, etc.

We have sufficient computer and communications equipment. In addition, our office houses the Geographic Information Services Unit (GIS support) for the state. This group frequently assists our project in GIS, GPS, and mapping applications. They also manage the Montana River Information System (MRIS).

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Section 10 of 10. Key personnel

BRIAN MAROTZ

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Education

Louisiana State University - Baton Rouge, Louisiana.
Master of Science – Fisheries Management. Focus: Estuarine Biology

University of Wisconsin - Stevens Point, Wisconsin.
Bachelor of Science – Biology. Focus: Aquatic Science

15 Credits: Gulf Coast Research Institute Ocean Springs, Mississippi.
Marine Biology

16 Credits: S.E.A. Semester at Sea, Boston University at Woods Hole, Massachusetts
Marine Science

Professional experience

1991-Present Fisheries Program Manager, Montana Fish, Wildlife & Parks. Kalispell, Montana.
Duties: Supervise Special Projects Office, Libby and Hungry Horse Mitigation. Co-Leader of Flathead and Kootenai Subbasin Planning.

1989 – 1991 Fisheries Biologist, Montana Fish, Wildlife & Parks. Kalispell, Montana.
Duties: Hungry Horse Mitigation Program, Field sampling and computer modeling of Flathead and Kootenai Watersheds to develop Integrated Rule Curves (IRCs) for Montana Reservoirs.

1985 – 1989 Fisheries Biologist, Montana Fish, Wildlife & Parks. Libby, Montana.
Duties: Libby Reservoir Research, Kootenai Instream Flow Project, Field sampling and computer modeling of Flathead and Kootenai Watersheds to develop Biological Rule Curves (BRCs) for Montana Reservoirs.

1984 – 1985 Research Associate, Louisiana State University - Baton Rouge, Louisiana.
Duties: Estuarine Research to develop an operating plan for water control structures to control salt water intrusion, yet allow catadromous migrations of fish and crustaceans to and from coastal marsh habitats.

Publications

Pertinent Publications Listed in this Document

Awards
1994 Governor's Award for Excellence in Performance as an Employee of the State of Montana

1994 Director's Award for Excellence as an Employee of Montana Fish, Wildlife & Parks

1989 Certified Fisheries Scientist
American Fisheries Society

Clint C. Muhlfeld
Fisheries Research Biologist

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Education and Experience

1994	BS, University of Montana, Missoula, Aquatic Biology
1999	MS, University of Idaho, Moscow, Fisheries Resources
1999-present	Fisheries Research Biologist, Montana, Fish, Wildlife, and Parks
1997-1999	Graduate Research Assistant, University of Idaho
1994-1996	Fisheries Technician, Montana, Fish, Wildlife, and Parks

Interest Areas
My interest is to use applied research and innovative mitigation techniques for conservation and management of native fishes. My specific interests are:

Stream salmonid research and management
Watershed and stream habitat restoration
Fish-habitat relationships
Population dynamics
Conservation of native fishes
Life history of fishes (scale and otolith chemistry)
Hydroelectric dams and fish mitigation
Fluvial geomorphology and hydrology

Current Projects

- Using trace element compositions and stable isotopes of juvenile westslope cutthroat trout scales to determine stream origin and understand life history.
- Influence of winter and summer flow augmentation and flow ramping rates on native salmonid populations and associated critical habitats in the upper Columbia River basin.
- Using molecular genetics, population models, scale and otolith chemistry, and radio-telemetry to investigate hybridization between native westslope cutthroat trout and non-native rainbow trout in the upper Flathead River system, Montana.
- Seasonal movements and habitat use by native salmonids in the upper Flathead River system, Montana.
- Instream Flow Investigations: 3-D IFIM model development to quantify available habitat for bull trout and cutthroat trout habitat as related to changes in river discharge downriver of Hungry Horse and Libby Dams.
- Suppression of non-native rainbow and hybrid trout in the upper Flathead River system.
- Population dynamics of hybrid trout populations in the North Fork Flathead River (coordinated graduate student project through University of Montana, Missoula).
- Using bioenergetics modeling to investigate interactions between non-native northern pike and native salmonids in the lower Flathead River.

Professional Service/Awards

- Executive Committee, *Montana Chapter of the American Fisheries Society* (2003-2006; consecutive terms for president-elect, president, and past-president)
- Chair, Resident Fish Committee, Columbia River Basin**,** (2003-2005; consecutive terms for vice-chair and chair)
- Fisheries Division Team Award, *Montana Fish, Wildlife, and Parks* (2001)
- Outstanding Graduate Student of the Year Award**,** *College of Natural Resources, University of Idaho*, Moscow, Idaho (1999)
- Outstanding Graduate Student of the Year Award**,** *Department of Fish and Wildlife Resources, University of Idaho*, Moscow, Idaho (1999)
- Best Student Paper Award, *American Fisheries Society- Montana Chapter*, Big Sky, Montana (1999)
- Chapter President, *Palouse Unit of the American Fisheries Society*, University of Idaho, Moscow, Idaho (September, 1997- August, 1998)
- Referee Journal Reviewer**,** *North American Journal of Fisheries Management* (1997-present)
- Recipient of the Riley Creek Scholarship, *University of Idaho*, Moscow, Idaho (1998-1999)

Publications

- Muhlfeld, Clint C., Brian Marotz, and Simon Thorrold. In-review. Elemental analysis of westslope cutthroat trout scales to determine natal stream origin in the upper Flathead River drainage, Montana- a multi-spatial scale approach. *Transactions of the American Fisheries Society.*

- Muhlfeld, Clint C., and Brian Marotz. In-review. Seasonal movement and habitat use by sub-adult bull trout in the upper Flathead River system, Montana. *Transactions of the American Fisheries Society.*
- Muhlfeld, Clint C., and Rick Hunt. In-review. Movements by westslope cutthroat trout in response to rapid changes in temperature and flow downriver of a hydroelectric dam in Montana. *North American Journal of Fisheries.*
- Hitt, Nathaniel, Clint Muhlfeld, Chris Frissell, Fred Allendorf. 2003-In press. Hybridzation between native westslope cutthroat trout and non-native rainbow trout in western Montana streams. Canadian Journal of Fisheries and Aquatic Resources.
- Muhlfeld, Clint C., Steve Glutting, Rick Hunt, Durae Daniels, and Brian Marotz. 2003. Winter diel habitat use and movement by subadult bull trout in the upper Flathead River, Montana. *North American Journal of Fisheries Management*: Vol. 23, No. 1, pp. 163–171.
- Knudsen, Kathy L., Muhlfeld, Clint C., Sage, George K., Leary, Robb F. 2002. Genetic structure of Columbia River redband trout populations in the Kootenai River drainage, Montana, revealed by microsatellite and allozyme Loci. *Transactions of the American Fisheries Society*: Vol. 131, No. 6, pp. 1093–1105.
- Muhlfeld, Clint C. 2002. Spawning characteristics of redband trout in a headwater stream in Montana. *North American Journal of Fisheries Management*: Vol. 22, No. 4, pp. 1314–1320.
- Muhlfeld, Clint C., David H. Bennett, and Brian Marotz. 2001. Summer habitat use by Columbia River redband trout in the Kootenai River drainage, Montana. *North American Journal of Fisheries Management*: Vol. 21, No. 1, pp. 223–235.
- Muhlfeld, Clint C., Bennett, David H., Marotz, Brian. 2001. Fall and winter habitat use and movement by Columbia River redband trout in a small stream in Montana. *North American Journal of Fisheries Management*: Vol. 21, No. 1, pp. 170–177.
- Muhlfeld, Clint. 1999. Seasonal habitat use by redband trout in the Kootenai River drainage, Montana. Master's Thesis. University of Idaho, Moscow.

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Fisheries Biologist

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Education

University of Idaho - Moscow, Idaho.
Master of Science – Fisheries Resource Management.

University of Idaho – Moscow, Idaho.
Bachelor of Science – Fisheries Resource Management
Bachelor of Science – Wildlife Resource Managment

Professional experience

2002-Present Fisheries Biologist, Montana Fish, Wildlife & Parks. :Libby, Montana.
Duties: Libby Mitigation Fisheries Project fisheries biologist that plan and supervises the study design, research and mitigation measures intended to assess and offset the losses attributable to the construction and operation of Libby Dam.

1997 – 2001 Fisheries Biologist, Yakama Nation. Toppenish, Washington.
Duties: I was the primary principal investigator for three research projects. These project included the Yakima River coho salmon re-introduction project, the Yakima River fall chinook supplementation project, and the Yakima River predation study. Responsibilities included all aspects of these three projects including development of experimental designs, supervision of support personnel, data analysis, interpretation and report preparation.

1996-1997 Fisheries Biologist, U.S. Forest Service, Coeur d' Alene, Idaho.
Duties: Implemented several stream restoration projects on national forest land. Prepared biological assessments for 5 watershed and fisheries habitat enhancement projects. Collected fisheries abundance data via snorkeling and electrofishing to monitor fish population trends. Analyzed time series fisheries habitat and fisheries abundance data to determine environmental and fish populations trends which were the basis for yearly fisheries monitoring reports.

1994-1996 Graduate Research Assistant, University of Idaho (Moscow)
Duties: As a research assistant for the University of Idaho was responsible for the study design, data collection, data analysis, and completion report for a fisheries research project in partial fulfillment for the requirements of a Master of Science degree to determine the spatial distribution of westslope cutthroat trout in the Coeur d' Alene River basin.

Publications

Dunnigan, J.L. 1997. The spatial distribution of cutthroat trout in the Coeur d' Alene River system, Idaho. M.S. Thesis. University of Idaho, Moscow.

Dunnigan, J.L., Bennett, D.H., and Rieman, B.E. 1998. Effects of forest management on westslope cutthroat trout distribution and abundance in the Coeur d' Alene River system, Idaho, USA. Pages 471-476 *in* M.K. Brewin and D.M.A. Monita, technical coordinators Forest-fish conference: land management practices affecting aquatic ecosystems. Procedings Forest-Fish Conference, May 1-4, 1996, Calgary Alberta. Natural resources Canada, Canadian Forest Service. North Forest Centre, Edmonton, Alberta. Information report NOR-X-356.

Dunnigan, J.L. 2000. Yakima coho monitoring and evaluation. Project Annual Report, 1999. Bonneville Power Administration. Portland Oregon.

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Dunnigan, J.L. 1999. Feasibility and risks of coho reintroduction in mid-Columbia monitoring and evaluation. Project Annual Report. Bonneville Power Administration. Project 9604000. Portland Oregon.

End Part 2.