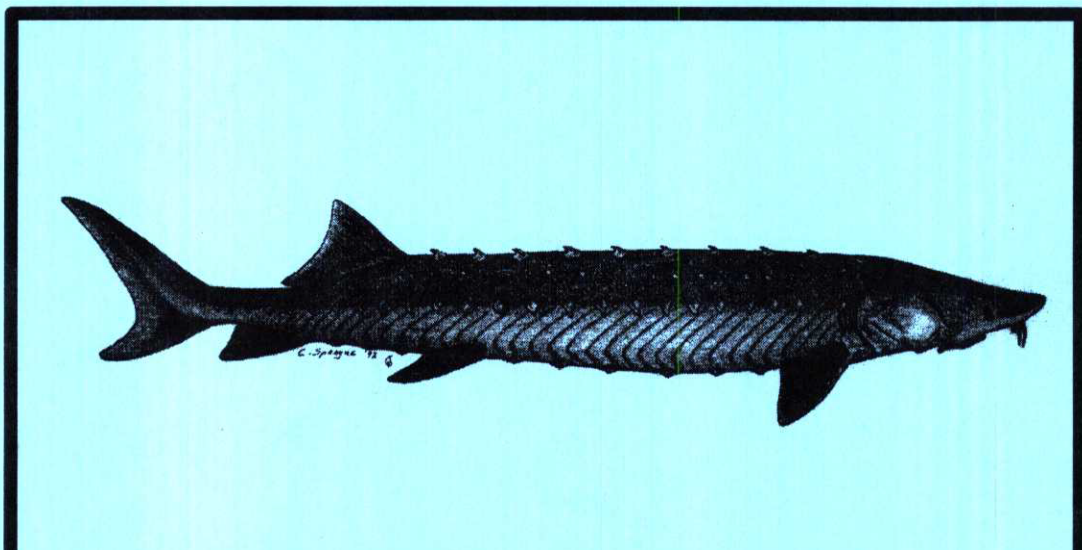
U.S. Fish & Wildlife Service

Recovery Plan for the Kootenai River Population of the White Sturgeon

(Acipenser transmontanus)



PART IV. APPENDICES

Appendix A. Current fish fauna of the Kootenai River basin.

Appendix B. Examination of the effects of two alternative flow augmentation strategies on the Kootenai Riverecosystem.

Appendix C. Kootenai basin integrated rule curves and tiered approach for white sturgeon flow release from Libby reservoir.

Appendix D. Breeding plan to preserve the genetic variability of the Kootenai River white sturgeon.

Appendix E. White sturgeon broodstock collection protocols.

Appendix F. Summary of the public, agency, and peer review comments on the draft Kootenai River white sturgeon recovery plan.

APPENDIX A. Current fish fauna of the Kootenai River basin. An asterisk (*) precedes the name of nonnative taxa.

Acipenseridae	
Acipenser transmontanus	white sturgeon
Salmonidae	
Coregonus clupeaformis	lake whitefish
Oncorhynchus clarki lewsii	westslope cutthroat
Oncorhynchus clarki clarkii	coastal cutthroat
Oncorhynchus nerka	sockeye salmon/kokanee
Oncorhynchus mykiss spp.	redband/rainbow trout
Prosopium williamsoni	mountain whitefish
Prosopium coulteri	pygmy whitefish
Salvelinus confluentus	bull trout
* *Salvelinus fontinalis*	brook trout
Cyprinidae	
Couesius plumbeus	lake chub
Mylocheilus caurinus	peamouth
Ptychocheilus oregonensis	Northern pike minnow
Richardsonius balteatus	redside shiner
Rhinichthys cataractae	longnose dace
Rhinichthys falcatus	leopard dace
Rhinichthys osculus	speckled dace
Catostomidae	
Catostomus catostomus	longnose sucker
Catostomus macrocheilus	largescale sucker
Ictaluradae	
* *Ameiurus melas*	black bullhead
Gadidae	
Lota lota	burbot
Centrarchidae	
* *Lepomis gibbosus*	pumpkinseed
* *Mircopterus salmoides*	largemouth bass

Percidae	
* *Perca flavescens*	yellow perch
Cottidae	
Cottus asper	prickly sculpin
Cottus cognatus	slimy sculpin
Cottus rhotheus	torrent sculpin

Appendix B:

EXAMINATION OF THE EFFECTS OF TWO ALTERNATIVE FLOW AUGMENTATION STRATEGIES ON THE KOOTENAI RIVER ECOSYSTEM

Prepared by the
Kootenai River White Sturgeon Recovery Team

June 1998

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

White Sturgeon Recovery Team
Examination of the Effects of Two Alternative Flow Augmentation Strategies on the Kootenai River Ecosystem

INTRODUCTION

The construction and operation of dams has negatively effected the physical and biological environments of many aquatic and riparian organisms throughout the Columbia River Basin. Effects have been documented from the headwater reservoirs downstream to the mouth of the Columbia and its estuary. Direct effects include altering natural stream hydrology, impeding or isolating fish spawning migrations, and direct mortality of fish. Operation has historically been dictated by potentially conflicting demands of power generation, flood control, navigation, irrigation and other human concerns. Environmental changes have contributed to major declines of fisheries resources throughout the Columbia system. Numerous fish populations have been listed as threatened or endangered under the Endangered Species Act (ESA), including Snake River chinook and sockeye salmon, several steelhead ESU's and Kootenai River white sturgeon. More recently however, dam operations at many main stem Columbia River dams have been altered in response to the needs of dwindling fish populations in the Columbia River Basin.

In 1995, two Federal agencies issued Biological Opinions for Columbia River dam operations including operating requirements for Libby Dam. Libby Dam impounds the Kootenai River system which originates in British Columbia, Canada (spelled Kootenay) and flows through the states of Montana and Idaho, before flowing north back into Canada. The U.S. Fish and Wildlife Service issued a Biological Opinion on these operations for the endangered Kootenai River white sturgeon (*Acipenser transmontanus*), five Snake River snails and bald eagles (USFWS 1994), while the National Marine Fisheries Service published their Biological Opinion for endangered salmon in the Snake River (NMFS 1995). Operations requested by these plans are similar, but they differ sufficiently relative to summer flow augmentation for the Kootenai River to warrant further examination.

PURPOSE

This paper analyses the relative effects of two Kootenai River flow augmentation strategies developed for listed Snake River salmon and Kootenai River white sturgeon: 1) KIRC/VARQ; and 2) the NMFS 1995 Biological Opinion operation for Snake River salmon (NMFS 95 BiOp). Results of this analysis were used to develop a preferred flow alternative to help recover endangered Kootenai River white sturgeon while improving system health for riverine species in the Kootenai River and the Columbia River drainage downstream.

BACKGROUND AND ACTIONS TO DATE

Prior to dam construction, the Kootenai River flowed freely with high spring flows averaging 61 kcfs (up to 114 kcfs). The natural annual flow hydrograph sustained the aquatic ecosystem, which included the Kootenai River white sturgeon and native westslope cutthroat (*Oncorhynchus clarki lewisi*), bull trout (*Salvelinus confluentus*), interior redband trout (*Oncorhynchus mykiss* subspecies), and burbot (*Lota lota*). The typical hydraulic cycle in the headwaters of the Columbia River included a high flow event during the spring melt (late May through early June) and a stabilized low flow period throughout the remainder of the year (Parrett and Hull 1985). Adult white sturgeon, cutthroat and redband, migrated upstream in the Kootenai River during the spring runoff to spawn. White sturgeon adults broadcast their eggs over clean cobble (McCabe and Tracy 1993; Parsley et al. 1993; Palmer et al. 1988). Trout constructed redds by burying their eggs in clean, unembedded gravels in the main stem Kootenai and tributary streams. Their progeny incubated and emerged after the spring melt when flows were naturally declining. In the Kootenai River, native riverine fauna adapted and persisted under natural annual water temperature and discharge regimes. Associated species assemblages in the Kootenai River Basin co-evolved in relative isolation since the Wisconsin ice age (about 10,000 years ago).

The white sturgeon population of the Kootenai River is now endangered (59 FR 45989, September 6, 1994). The fall spawning bull trout are included in the Columbia River population segment listed as threatened under ESA on June 10, 1998 (63 FR 31647). Westslope cutthroat, interior redband and burbot populations of the Kootenai River have also declined and are being closely monitored across their range (Partridge 1983, Anders 1993, Paragamian 1994, and Paragamian et al. 1996).

Natural riverine processes in the Kootenai River have been disrupted by the construction and operation of Libby Dam beginning in the mid-1960s. The dam was completed in 1972 and the pool filled for the first time in 1974. During the 1970s and 1980s, the annual schedule at Libby Dam captured the spring runoff until the reservoir approached full pool in July. The dam discharge was typically held to the minimum flow of 4,000 cubic feet per second (cfs) while the reservoir filled (mid April through mid July). Full pool is achieved at elevation 2459 feet above mean sea level. When the pool reaches the annual maximum refill, the dam discharge is controlled to approximate the inflow volume and the pool elevation remains stable. During late fall and winter, the reservoir is normally drafted for power generation and flood control. Reservoir storage released for these purposes causes flows to be above natural (pre-dam) levels during the historic low flow period. The reservoir reaches minimum capacity by mid-April, and the cycle is repeated annually. Dam operation has essentially reversed the natural hydrograph (Partridge 1983). Figure 1 shows the effect of Libby Dam operation on Kootenai River flows. Evidence suggests that river flow and water temperature influence the movements and reproduction of native species, including white sturgeon .

As dams were installed on many Columbia River tributaries, the overall storage capacity of the Columbia River system increased, and spring flows were diminished. Loss of the spring freshet is believed to be a primary factor in the decline of anadromous and resident fish populations in the Columbia River basin (ISG 1996, Apperson 1992, and Apperson and Anders 1991).

To partially address this problem, the USFWS in the 1995 Biological Opinion requested increased flows from Libby Dam during spring and early summer to aid the natural reproduction of the estimated 1,000-1,500 remaining adult Kootenai River white sturgeon.

Similarly, the NMFS Biological Opinion requested a more natural spring freshet to enhance the downstream movement of endangered Snake River salmon juveniles (smolts). Both plans attempt to reestablish a naturalized spring freshet, as limited by established flood control criteria, to create a more natural annual hydrograph in the Kootenai River. A portion of the water flowing into Libby Reservoir during spring is passed through Libby Dam to create a flow pattern as similar as possible to one which white sturgeon and other species in the Kootenai River adapted and co-evolved. The primary significant difference between the two Biological Opinions is that the NMFS plan calls for increased discharge during August to aid the downstream migration of salmon smolts.

The Kootenai River White Sturgeon Recovery Team (Team), established in 1995, recognized the importance of Libby Dam operations to the health and persistence of several fish populations listed under ESA in the Columbia River system (Table 1) as well as those species not currently listed. The Team adopted a new, adaptive management approach for Kootenai River flow management that was designed to balance power generation and flood control with concerns for white sturgeon, salmon and other resident fish populations. This approach, known as the Kootenai Integrated Rule Curve/Tiered Flow Approach (KIRC) incorporates flow releases from Libby Dam designed to promote natural reproduction of white sturgeon. According to this approach, Libby Dam discharge volume is determined as a function of the inflow volume to Libby Reservoir (Lake Koocanusa). The KIRCs are a mathematical tool to improve spring flow augmentation without compromising reservoir refill probability. The KIRCs provide for the needs of resident and anadromous fish species from a watershed

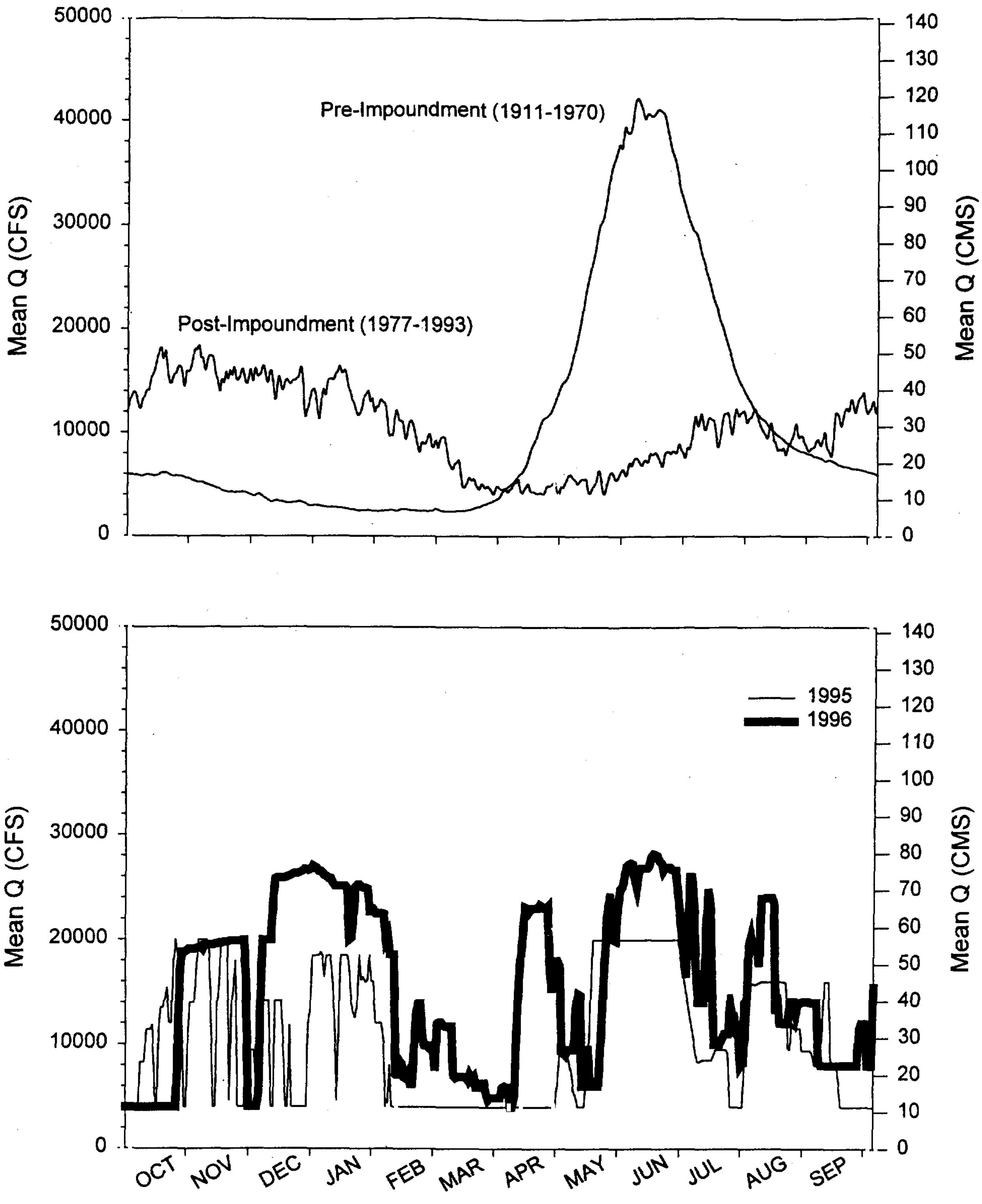


Figure 1. Effect of flow regulation on the annual hydrograph of the Kootenai River. Top chart compares the pre-dam condition to regulated flows prior to modifications for sturgeon. Bottom chart shows the effect of recent modifications for fisheries concerns.

perspective. Under this plan, system flood control is partially defined by a new strategy developed by the U.S. Army Corps of Engineers (ACOE) called VARQ (ACOE 1997). This "variable flow" flood control strategy allows greater flexibility for balancing upstream and downstream fisheries concerns. The KIRC and VARQ are identical during the period April 1 through July 30 when inflows are average (100 percent of normal) or greater. VARQ allows higher reservoir elevations than the KIRC during below average water years, which allows additional water storage (above the KIRCs) prior to spring runoff. During dry years (lowest 20 percent), stored water can be used to augment spring outflows without compromising reservoir refill probability. Henceforth in this document, the KIRCs with the VARQ flood control strategy will be referred to as KIRC/VARQ. This more natural discharge pattern for Libby Dam and the downstream river system was unanimously supported by the Team members as a key task in the draft and final draft Kootenai River White Sturgeon Recovery Plan.

Table 1. Current list of petitioned, proposed or listed aquatic species in the Columbia River basin.

- Steelhead trout, **listed** as threatened or endangered by ESU, August 2, 1997 (62 FR 43937)
- Bull trout, **listed as** threatened-Columbia River population segment June 10, 1998 (63 FR 31647).
- Snake River spring and fall chinook salmon, **listed** as threatened, April 22, 1992 (57 FR 14653)
- Snake River sockeye salmon, **listed** as endangered, November 20, 1991 (56 FR 58619)
- Westslope cutthroat trout, **petitioned** to be listed, June 1997, 90-day finding for an amended petition to **list** as threatened June 1, 1998 (63 FR 31691).
- Coho salmon, southern Oregon/Northern California Coast ESU, listed as threatened, May 6, 1997 (62 FR 24588)
- Kootenai River white sturgeon, **listed** as endangered, September 6, 1994 (59 FR 45989)
- Five Snake River snails, 4 **listed** as endangered and **listed** as threatened, December 14, 1992 (57 FR 59244)

In general, flow levels recommended by the Team (KIRC/VARQ flows) and by NMFS 95 BiOp are compatible throughout most of the operating year, but differ substantially during July and August. Fundamental differences in flow requests sparked heated debate which led to 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 (Wright 1996). The analysis compared the IRC concept (an earlier version of the KIRC) to the NMFS Biological Opinion, and two other alternatives. This analysis used a modified version of our Alternative 1 with existing ACOE flood constrains, not VARQ. In this scenario, lower reservoir elevation for flood control resulted in reduced storage for flow augmentation in dry years. Incremental tradeoffs between anadromous and resident fish species were not addressed. Instead, Wright and others (1996) focused the debate by identifying similarities and differences in dam operations described by the alternatives. Wright (1996) determined that the primary differences between the IRCs and NMFS Biological Opinion are: (1) the volume of reservoir water released during spring in years of low reservoir recharge; (2) the amount of flow augmentation and reservoir drawdown during late summer; and (3) resulting reservoir refill probability and summer elevations. The VARQ modification improves spring flows during dry years and increases reservoir refill probability (1 and 3 above).

During dry years in the Kootenai sub-basin, the KIRC/VARQ tiered flow approach would provide only a minimal spring freshet for white sturgeon, additional flow augmentation is possible using the VARQ strategy. Conversely, the NMFS Biological Opinion would draft the reservoir to attempt to meet flow targets in the lower Columbia in all years. Whereas the KIRC/VARQ attempts to fill Libby Reservoir in July and maintain the pool elevation near full, the NMFS Biological Opinion, in attempting to meet a minimum flow target of 200 kcfs at McNary Dam, drafts the reservoir 20 feet below full pool by the end of August. As a result, the reservoir refill probability is significantly reduced (by as much as 35 percent) as flows are increased downstream.

This paper examines relative effects of these operational strategies on the physical and biological condition of the Kootenai River system in the context of the entire Columbia Basin in the U.S. and Canada. The physical environment, flood plain function and biological responses were assessed relative to natural, pre-dam conditions. The analysis focuses on Libby Reservoir and the Kootenai River downstream to Kootenay Lake. Empirical evidence and previous analyses were used when available. Impacts to Kootenai white sturgeon are described based upon knowledge pertaining to the species in the Kootenai River and across its range.

DESCRIPTION OF ALTERNATIVE FLOW AUGMENTATION STRATEGIES

Alternative 1: The Kootenai Integrated Rule Curve/Variable Discharge Flood Control VARQ - No Summer Flow Augmentation

The Kootenai Integrated Rule Curves are a mathematical tool designed for Libby Dam water management to balance the requirements of power generation and flood control with resident and anadromous fish (Marotz et al. 1996). The curves are a family of operational rules for dam operation that incorporate incremental adjustments to allow for uncertainties in water availability. Libby Dam operation is determined based on inflow forecasts and constrained by the physical character of the dam and drainage basin. The first inflow forecast of the year becomes available in early January. Upon receipt of the forecast, the dam operator follows a drawdown schedule as dictated by the KIRC/VARQ corresponding with that forecasted inflow volume. Upon receipt of forecasts (February through June), the operator would adjust the elevational target to the new curve corresponding with the updated subsequent monthly inflow volume. This causes the actual operation to be flexible and variable over the operating season, yet predictable based on reservoir inflow forecasts. Actual operations will vary somewhat from the target elevations due to inflow forecasting error and unpredictable precipitation events. The curves were designed to limit the duration and frequencies of deep reservoir drawdowns, increase the frequency of reservoir refill, and produce a more natural discharge hydrograph in the Kootenai River downstream from Libby Dam.

The KIRCs delay the date of refill during high water years to reduce the potential for emergency use of the spillway. Forced spill caused by high pool elevations and/or excessive reservoir inflows, and gas supersaturation associated with spill in the Kootenai River, are thus avoided. Once full, Libby Reservoir remains at the maximum elevation through September 15. Inflowing water is passed through the dam, creating a gradual decline in discharge which mimics the natural flow regime.

The VARQ hydrology and strategy for system flood control was developed and critically examined by the ACOE Hydraulics Branch (ACOE 1997). Hydraulic modeling indicates that the operations defined by VARQ are nearly identical to the KIRCs during average to medium high water years. VARQ requires slightly deeper (5 to 10 feet) drawdown for flood control in the highest 10 percent of water years. For modeling purposes, the KIRCs were modified in high water years to be consistent with VARQ, resulting in the hybrid KIRC/VARQ. During below normal water conditions, VARQ allows higher reservoir elevations than described by the KIRCs which integrate power operations (and thus result in lower elevations). VARQ allows additional water to be stored prior to spring runoff in drier years (less than 100 percent normal inflow to Libby Reservoir), enabling greater discharges during spring while maintaining reservoir refill probability.

The KIRC alternative was designed to gradually ramp down from the spring peak to reduce flow fluctuations. During dry years, the maximum drawdown of the reservoir was reduced consistent with the NMFS 95 BiOp and VARQ to increase the volume of pass-through flows during spring runoff. The reservoir refill trajectory was reshaped to normalize the discharge. In wetter years, the discharge was smoothed to further extend the descending limb of the hydrograph. The alternative was designed to gradually ramp down from the spring peak to reduce flow fluctuations.

Alternative 2: NMFS 1995 Biological Opinion - 20 foot Reservoir Draft during August to Augment Summer Flows Downstream

The NMFS Biological Opinion specifies meeting the April 20 upper flood control rule curve (75 percent of the time) at Libby Dam to increase reservoir storage just prior to spring runoff (similar to VARQ). The intent is to provide higher spring flows as less water is required for reservoir refill. Reservoir refill may be sacrificed to meet downstream flow targets at McNary Dam in lower water years (less than 100 percent "normal" Columbia River flows defined as an annual flow volume less than 105.9 MAF at the Dalles).

The August releases called for by the NMFS Biological Opinion are designed to aid the migration of juvenile Snake River salmon as they pass through dams in the lower Columbia River. The NMFS Biological Opinion calls for maximum Libby Dam discharge (of up to 27 kcfs) during August until Libby Reservoir is drafted to 20 feet from full pool. Water from two headwater storage projects, Libby and Hungry Horse, is released to augment the natural flows in the Columbia River to meet a summer flow target of 200,000 cfs at McNary Dam. The goal is to increase water velocities in the pools upstream from dams in the lower Columbia to reduce particle travel times, a surrogate for fish movement, and ultimately to aid the migration of juvenile salmon toward the ocean.

This alternative produces an unnatural flow fluctuation in the Kootenai River during the productive summer months. Extreme reductions in flow between the discharge peaks cause large expanses of productive riffle habitat to become dewatered, reducing biological productivity in the affected river reach and subsequently downstream as well. These discharge fluctuations could be moderated by delaying the date of reservoir refill or by extending the period of flow augmentation. This strategy increased the risk of reservoir refill failure, which reduces biological productivity in the reservoir and causes the reservoir to begin the following year at a deficit, thus affecting the sustainability of the operation.

METHODS

Hydrologic Modeling

Operations specified by the NMFS Biological Opinion were provided by Bonneville Power Administration's Dittmar Control Center, Study 98C_01.OPERB (Roger Schiewe BPA and Michael Newsom NMFS, personal communication). Libby Reservoir elevation data were received electronically in a 50-year matrix (August 1929 through July 1978). Annual data represented 14 end of period elevations (monthly data with April and August split into half-month periods). Consecutive years were appended, then adjusted to perform simulations on a water year basis (October 1 through September 30).

To simplify visual comparisons of the three alternatives, we overlayed plots of resulting operations from low, average and high water years. Corresponding annual volumes of inflow to Libby Reservoir are: low inflow (6.068 Million Acre Feet [MAF], 75 percent normal), average (8.088 MAF, 100 percent normal) and high inflow (>10.110 MAF, 125 percent normal). A representative NMFS 95 BiOp operation for low, average, and high water years was constructed by selecting five or more years with inflows approximately equal to the specified annual inflow volumes ($\pm$ 0.5 SD), then calculating the mean elevation for each of the 14 periods. It was necessary to create these composite operations to mask the effect of differences in water availability in the main stem Columbia relative to the Kootenai sub-basin (i.e. water availability in the Kootenai system varies somewhat independently from water availability in the lower Columbia River). Years included in the composite operations are as follows:

Water Availability	Water Year	Annual Inflow (MAF)
High	1956	10.863
	1934	10.658
	1959	10.496
	1969	10.068
	1976	9.785
Medium	1963	8.101
	1953	8.088
	1935	8.046
	1932	8.017
Low	1929	6.259
	1970	6.179
	1940	6.014
	1936	5.974
	1945	5.904

Study 98C assumed that storage reservoirs would only be drafted to 20 feet below full pool in August if the seasonal target (July 1 through August 31) of 200 thousand cubic feet per second (kcfs) at McNary Dam was not met. This assumption resulted in varying degrees of reservoir drafting (0 to 20 feet from full pool during August) throughout the 50-year record, and caused the composite data to underestimate the effect of summer flow augmentation (a reservoir draft to 20 feet from full pool) as specified by the NMFS 95 BiOp. The NMFS 95 BiOp, p. 102, also states: "The TMT [Technical Management Team] may recommend lower summer reservoir elevations if necessary to meet [salmon] flow objectives depending on the circumstances of the runoff and the salmon migration (e.g., [sic] a low water year that is one in a series of low water years and an outmigrating population of fish that represents a strong year class)." This decision process could not be modeled in this analysis.

The KIRC/VARQ operations used for comparison were generated using the quantitative reservoir model LRMOD (Marotz et al. 1996). The KIRC targets were adjusted in average and higher water years to be consistent with VARQ (LMATRIX, ver. 97-06). Curve selection was set to interpolate elevational targets based on the reservoir inflow volume. The critical year function was disabled so that all years were considered critical year 1. The KIRC operation reflects a "smoothed" discharge, modified to reflect inseason management resulting in a more natural discharge shape. The reservoir elevation schedule was then slightly modified to accommodate the new hydrologic balance with the smoothed discharge schedule. Smoothing and reshaping the KIRC was accomplished using Microsoft Excel and multiple iterations using LRMOD.

Biological Modeling

Trophic responses from the two reservoir operations were estimated using the empirically calibrated biological reservoir model LRMOD. Model simulations were set for annual (as opposed to continuous) runs. Thermal effects downstream of Libby Dam were standardized across the alternatives using the automated withdrawal depth specification in the selective withdrawal (thermal control) component. This resulted in identical discharge temperature under both alternatives. Withdrawal depths were based on the existing reservoir surface elevation and thermal profile as calculated by the thermodynamics model component.

For both operation alternatives, we qualitatively assessed fish entrainment through Libby Dam. Entrainment of reservoir fish through Libby Dam turbines can be estimated using the empirically calibrated entrainment model developed for Libby Dam by Skaar et al. (1996) given the necessary field data. Multiple regression analysis explained that most of the raw variance (r^2=0.776) was explained by dam discharge, forebay fish density at 0-10 m above the withdrawal depth and areal fish density for all hydroacoustic transects. Entrainment was correlated with discharge (r^2=0.758). Skaar et al. (1996) found that kokanee constituted over 98 percent of fish entrained at Libby Dam. Since the two operational alternatives presented herein are hypothetical, field data were unavailable. Nonetheless, trends in fish density and vertical distribution can be extrapolated from sampling conducted from December 1990 through June 1993. 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). Discharges during spring and summer can be accurately estimated through computer modeling. If we assume that the selective withdrawal structure (depth of withdrawal) is consistent in all alternatives, and that seasonal trends in vertical fish distributions are held constant, we can qualitatively assess entrainment under the two alternatives. Differences in discharge volume during the spring and summer period are well correlated with fish entrainment at Libby Dam (Skaar et al. 1996).

RESULTS AND DISCUSSION

Reservoir Conditions

Alternative 1: KIRC/VARQ

Reduced summer drawdown resulting from the KIRC/VARQ operation (Figures 2, 3, and 4) protects aquatic and benthic food production in the reservoirs. Benthic insect life consists almost exclusively of *Dipterans*. Typical lifecycles extend from five weeks to nearly three years. Drawdowns dewater and kill larvae in the reservoir sediments (Marotz et al. 1996). Increased refill frequency improves biological production during the warm months, late May through early September. At full pool, the reservoir contains the maximum volume of optimal temperature water for fish growth and a large surface area for aquatic food production and deposition of terrestrial insects from the surrounding landscape. Refill timing also ensures that species of special concern, including westslope cutthroat trout and bull trout can pass into tributary habitat to spawn and survive. Overall, this operation would allow for roughly 70 percent of the optimum reservoir productivity (Table 2).

Entrainment of fish through Libby Dam is proportional to discharge volume. 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 (Skaar et al. 1996). Fish densities in the dam forebay are higher during spring than in any other season. Entrainment would be highest in June when releases are scheduled to mimic the natural spring runoff schedule. As a result of the tiered flow approach, highest entrainment rates would occur in above average water years when spring discharges are high. Lowest entrainment rates would occur in below average water years, proportional to low discharge volumes. Fish entrainment during spring under this alternative would be similar to the NMFS 95 BiOp Alternative 2 in above average water years. Entrainment would be less under this alternative than the NMFS 95 BiOp during average or drier water years. During summer, areal fish densities are lower than in May and June, although densities are typically higher in August than in late fall and winter. Entrainment during August resulting from the KIRC/VARQ alternative would be the less as compared to the NMFS 95 BiOp (Figures 5, 6, and 7).

Alternative 2: NMFS Biological Opinion

Computer simulations performed at BPA Dittmar Control Center show that the NMFS Biological Opinion, in attempting to meet an August flow target of 200 kcfs at McNary Dam, reduces reservoir refill probability (Wright 1996). In some years, the reservoir fails to refill by 20 feet or more. Refill failure reduces biological production in the reservoirs during the productive warm months (Table 2).

Under the NMFS 90 BiOp, a 20 foot draft of Koocanusa will essentially drain the reservoir on the Canadian side of the border so that all that remains in BC is a river flowing through mud flats. The Canadian anglers will not have access to the reservoir and those individuals who have invested in businesses associated with recreation will be greatly impacted. Furthermore, under the NMFS 95 BiOp alternative, fish entrainment through Libby Dam, which is proportional to discharge, would be higher during spring in average and dry water years, and higher during August, compared to the KIRC/VARQ alternative. This draft will entrain kokanee, burbot and the (newly listed) threatened bull trout, out of the reservoir; due to the absence of fish passage facilities these fish cannot get back to the reservoir. In addition to entrainment the draft will affect survival of all fish species since the productive capacity of the Koocanusa Reservoir will de greatly diminished.

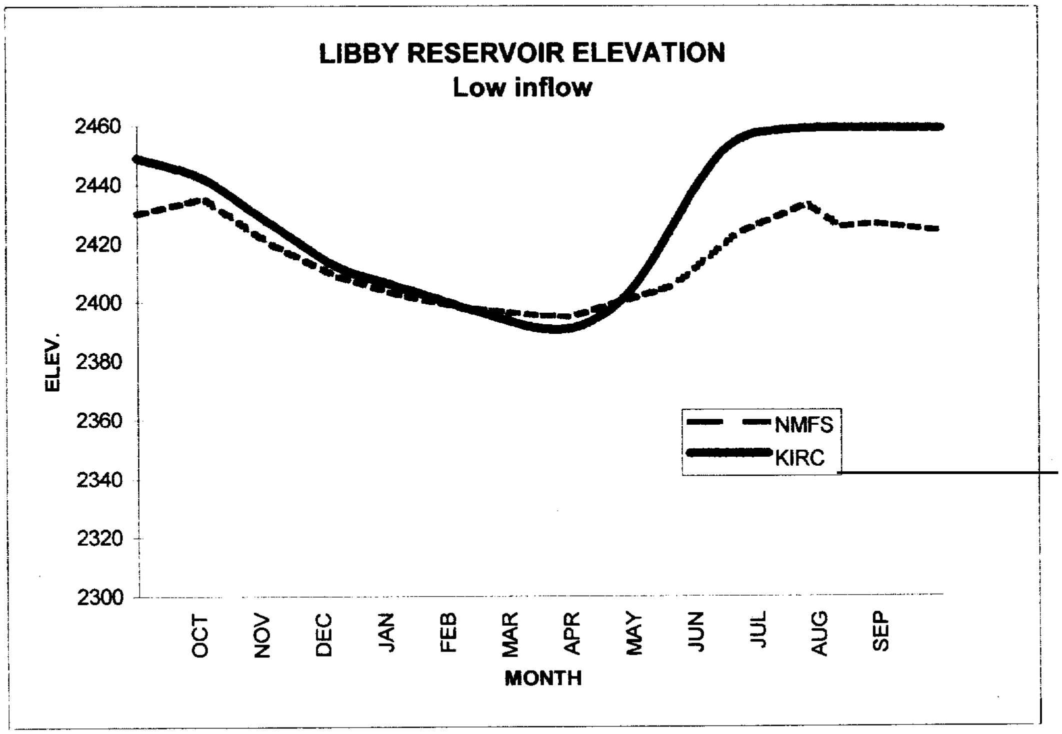


Figure 2. A comparison of Libby Reservoir elevations resulting from the two alternatives under low water conditions.

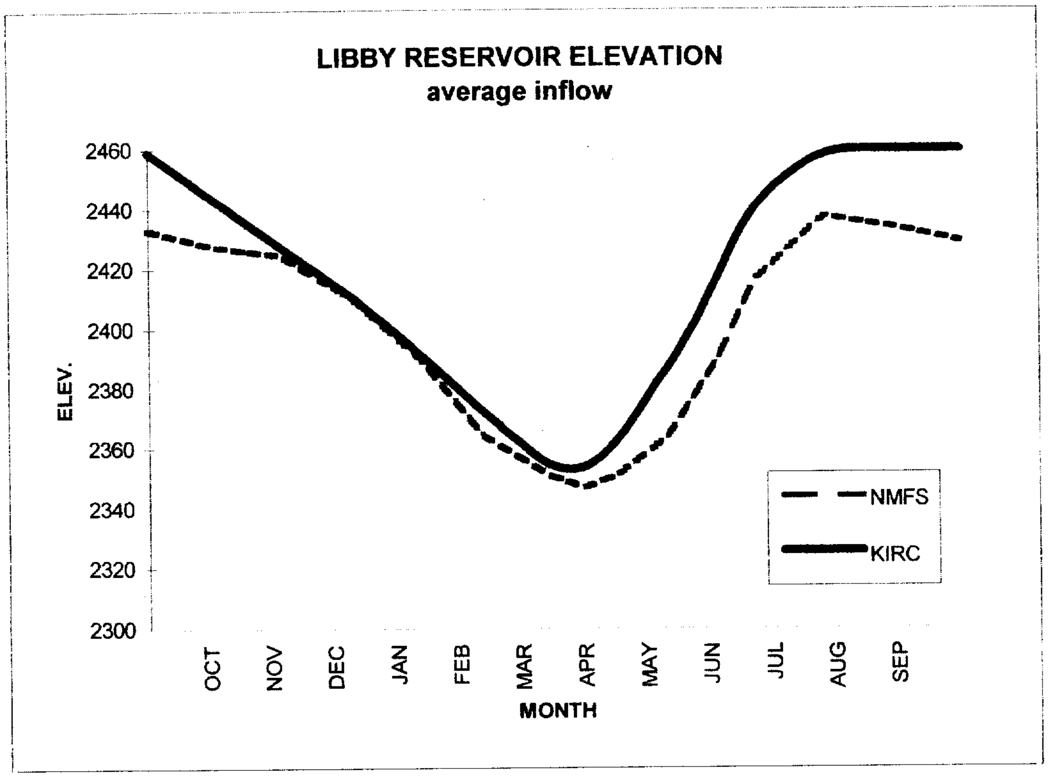


Figure 3. A comparison of Libby Reservoir elevations resulting from the two alternatives under average inflow conditions.

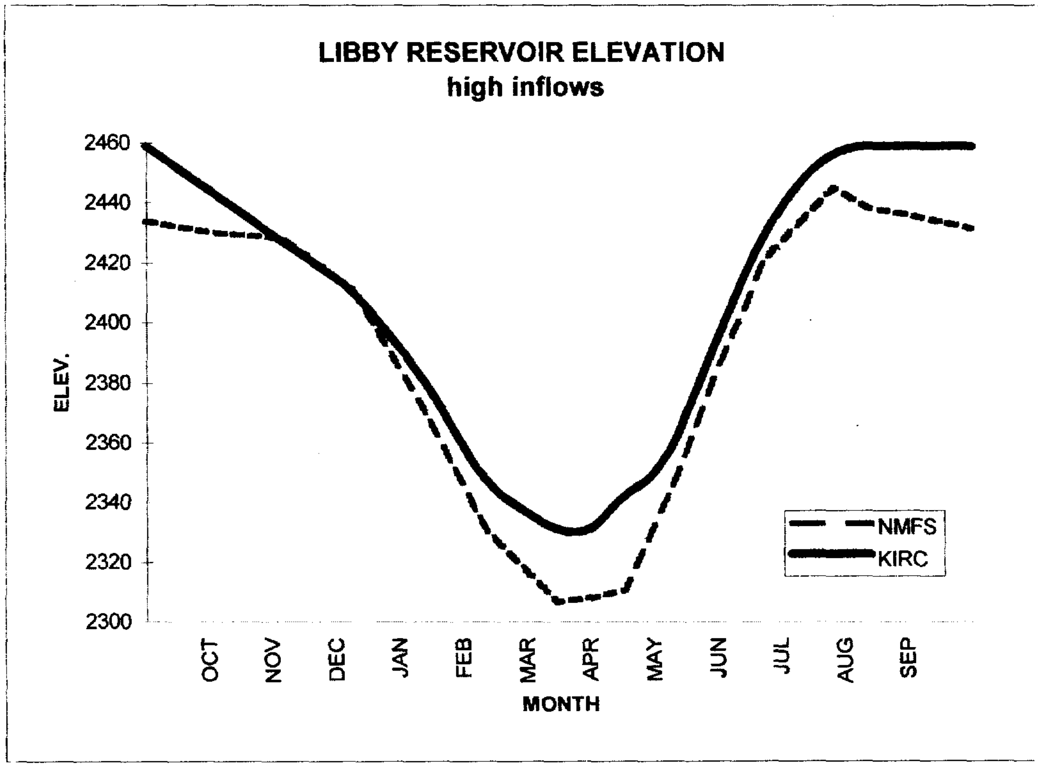


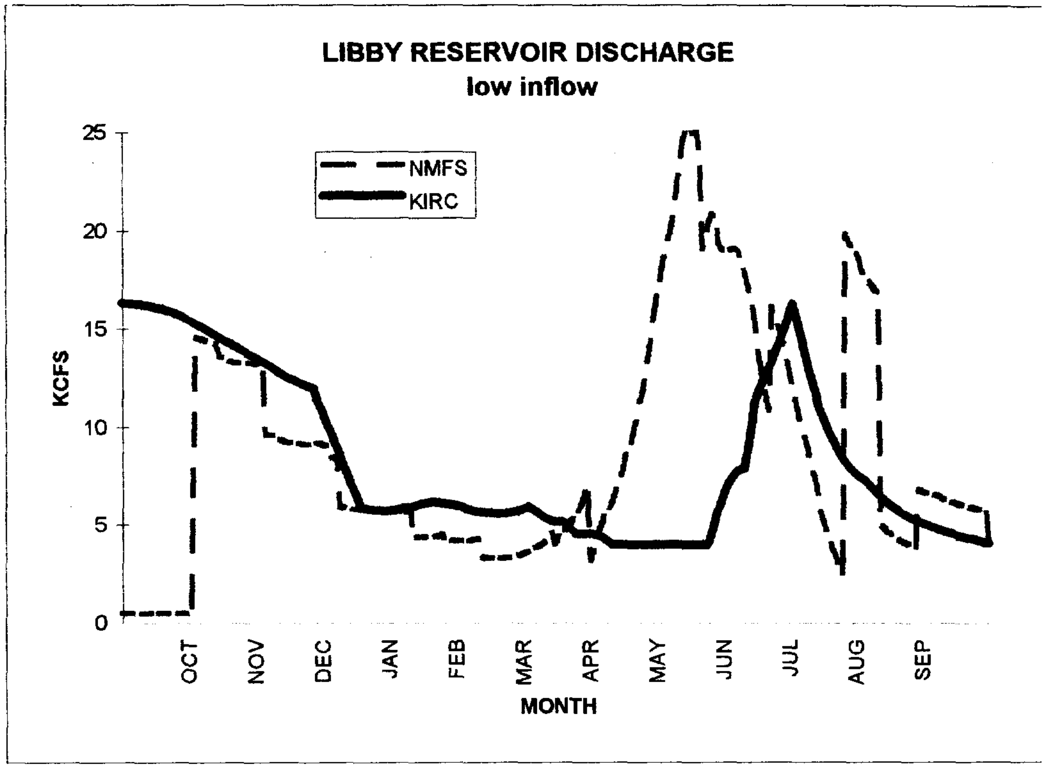
Figure 4. A comparison of Libby Reservoir elevations resulting from the two alternatives under high water conditions.

Table 2. Trophic responses in Libby Reservoir calculated using the reservoir model LRMOD (Marotz et al. 1996).

Alternative		*Primary Production (metric tons)*		*Secondary Production (metric tons)*		*Terrestrial Insect Deposition by Insect Order (% maximum)*				*Fish Growth kokanee*			
										TL (mm)		*Weight (g)*	
Water Avail.	*Name*	*Carbon Fixed*	*Wash out*	*Zoop Prod*	*Bent*[b]	*Col*	*Hem*	*Hom*	*Hym*	*Age I+*	*Age II+*	*Age I+*	*Age II+*
Low	NMFS	11836	37	1354	382.1	74.1	83.3	85.0	85.7	285	386	219	576
	KIRC	13003	30	1489	367.5	79.0	94.7	97.5	99.9	298	412	252	706
Avg.	NMFS	11063	39	1265	337.3	62.0	80.1	83.8	88.7	279	374	205	521
	KIRC	12178	35	1393	303.2	68.8	90.6	94.8	99.9	291	397	233	630
High	NMFS	10820	46	1236	229.7	56.6	80.3	85.0	90.2	278	372	202	510
	KIRC	11680	45	1335	301.5	62.7	87.9	92.9	99.9	287	389	223	589

[a] Results represent phytoplankton production (metric tons of carbon fixed) calibrated by C^{14} liquid scintillation. Phytoplankton washout through the dam (metric tons) calibrated by chlor ∝ vertical distribution and entrainment sampling. Total zooplankton production (metric tons) calibrated on phytoplankton production and seasonal measures of carbon transfer efficiencies. Benthic production (metric tons of emergent insects) calibrated on depth distribution of insect larvae and emergence captures. Terrestrial insect deposition (percent of maximum) by insect order Col= coleoptera, Hem= hemiptera , Hom= homoptera, and Hym= hymenoptera, calibrated on near shore (<100 m) and offshore surface insect tows. Fish growth (end of year kokanee size) in total length (TL) and weight (grams) calculated through multi variate analysis on water temperature structure and food availability.

[b] Benthic insect production is artificially enhanced by reservoir refill failure. This single year event is caused when the warm epilimnetic water settles over substrate containing high larval densities (in the infrequently dewatered zone), thus enhancing larval production and emergence. A single deep drawdown event or reservoir refill failure can impact benthic insect production for two years or longer.



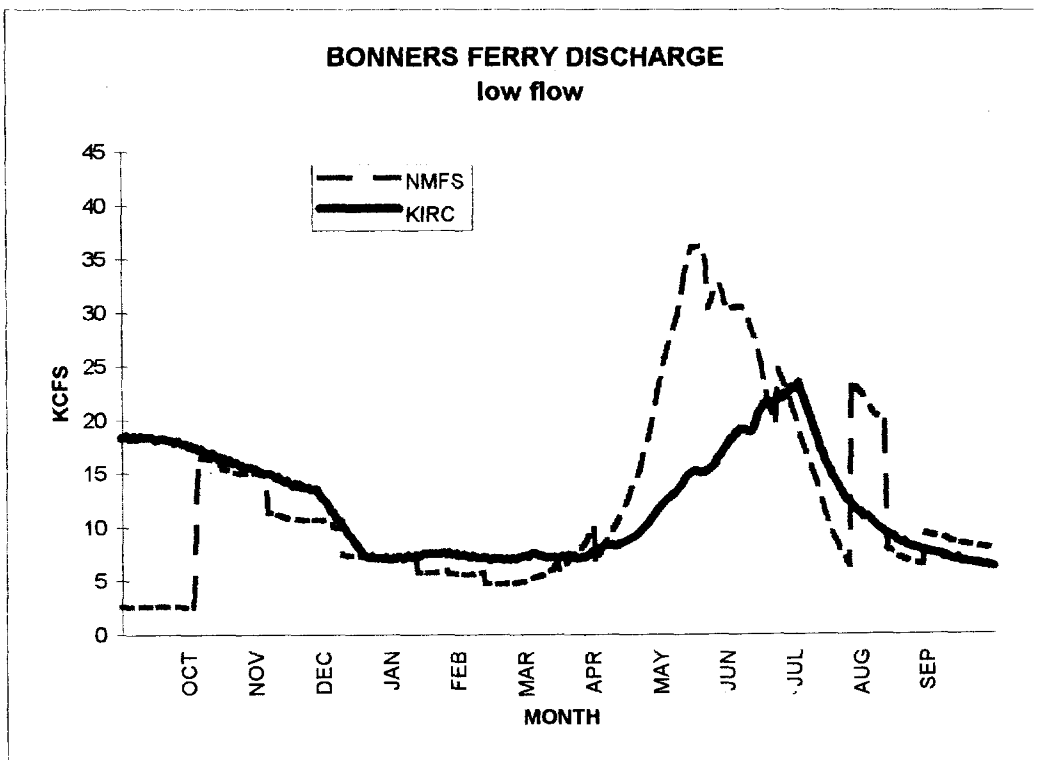
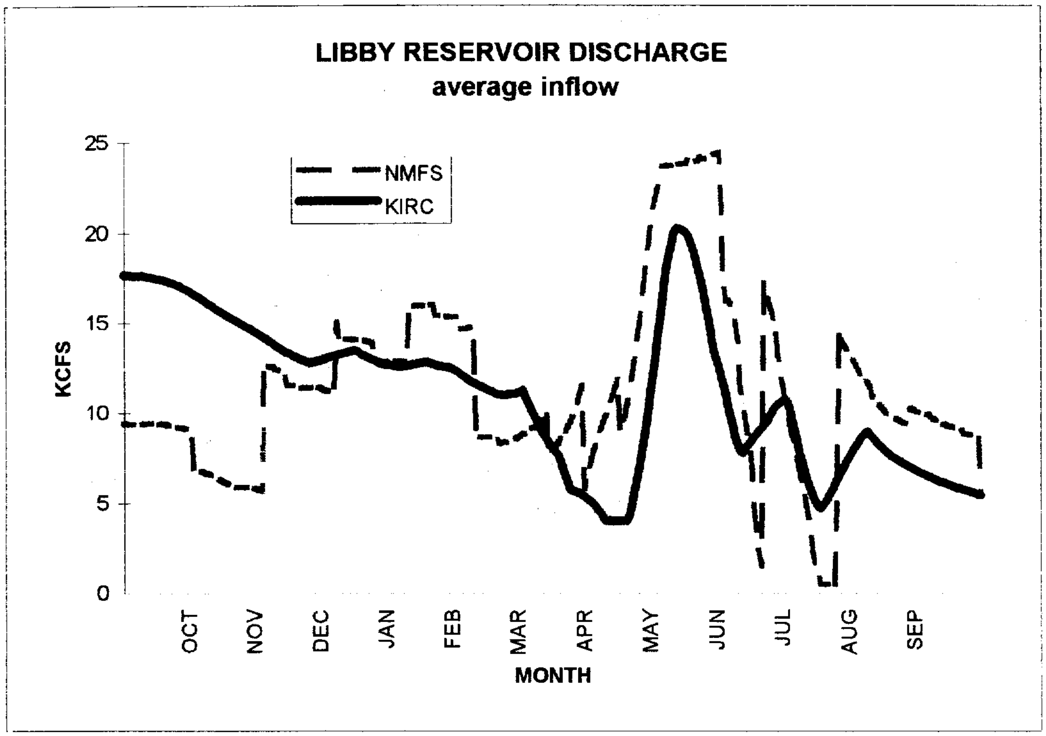


Figure 5. A comparison of Kootenai River discharge resulting from the two alternatives under low water conditions.



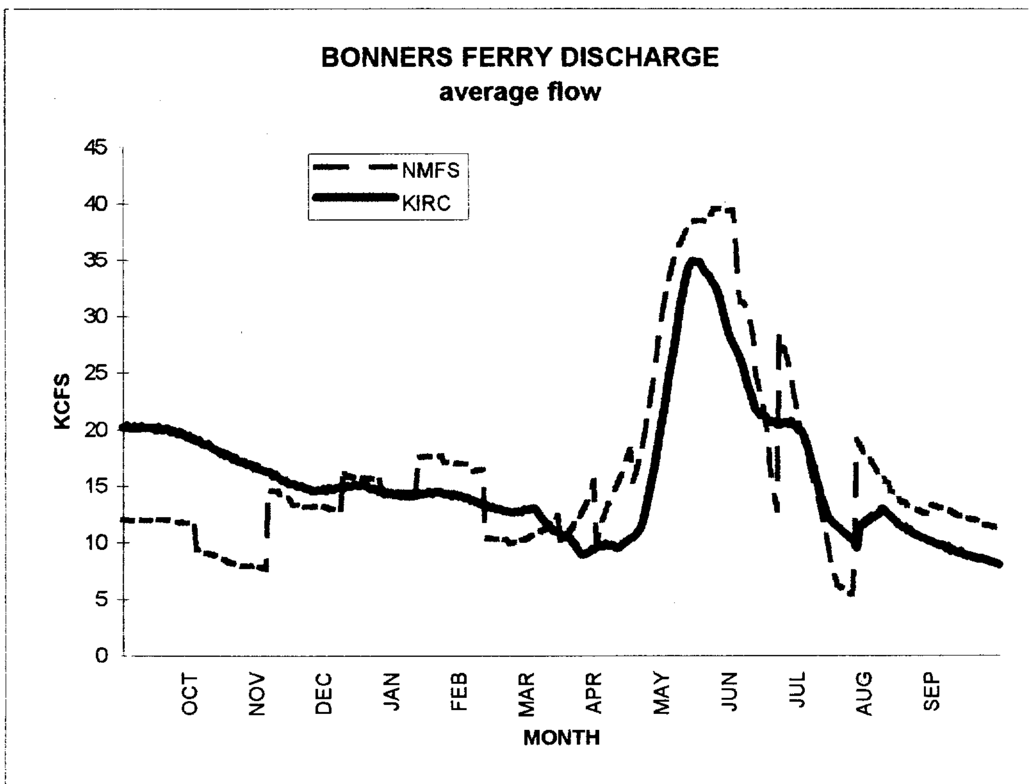
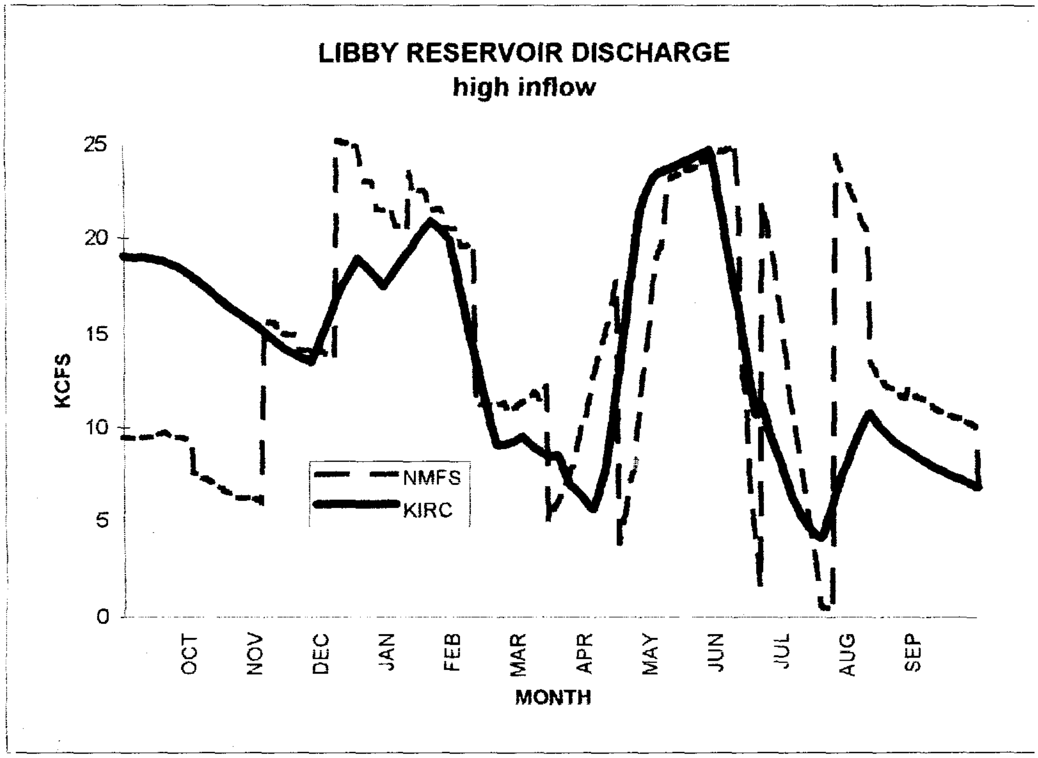


Figure 6. A comparison of Kootenai River discharge resulting from the two alternatives under average water conditions.



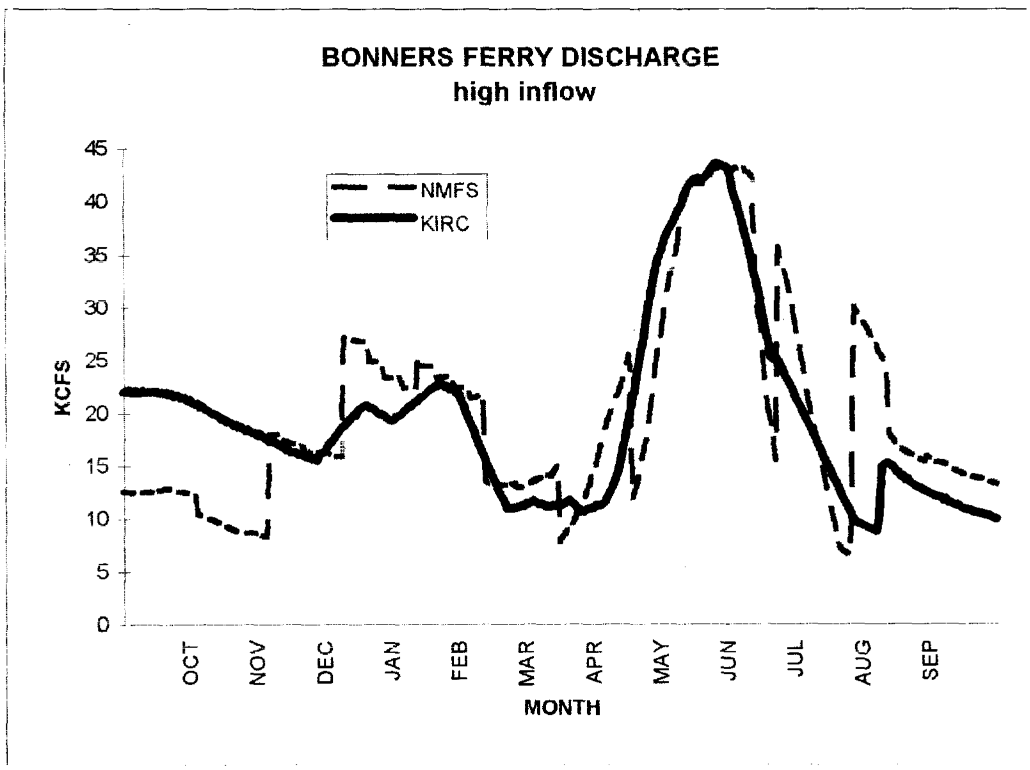


Figure 7. A comparison of Kootenai River discharge resulting from the two alternatives under high water conditions.

Kootenai River Conditions Downstream from Libby Dam

Alternative 1: KIRC/VARQ

An independent comparison of Columbia River flows during spring performed by Wright (1996) revealed that flows resulting from the IRCs (as modeled at Hungry Horse and Libby Dams) were nearly the same as the NMFS Biological Opinion (Table 3). Similarly in this analysis, spring discharges in the Kootenai River, resulting from the KIRC/VARQ operation are nearly consistent with the NMFS Biological Opinion during average to high water years, but less in low water years (Figures 5, 6, and 7). During low water years, the tiered flow approach incorporated into the KIRC/VARQs releases less water than called for by the NMFS Biological Opinion. This is because the tiered flows were designed to balance the effect of flow augmentation on reservoir refill and protect the needs of other fisheries resources in the Kootenai River system, whereas the NMFS 95 BiOp only attempts to meet flow targets in the lower Columbia (NMFS Biological Opinion, reasonable and prudent alternative #1).

The maximum allowable discharge volume at Libby Dam is dictated by the physical capacity of the turbines and acceptable spill levels. Libby Dam presently contains five turbines that can release a maximum of 27 kcfs, collectively. The spillway entrains atmospheric gas during operation, so only a small percentage of the total flow can be spilled before Montana water quality laws pertaining to dissolved gas are violated (e.g. not to exceed 110 percent gas saturation). Thus, the maximum flow in the river downstream of Libby Dam is limited by turbine capacity plus additional flows from unregulated tributaries that enter the Kootenai River downstream from the dam. Flood control criteria at Bonners Ferry, Idaho and Kootenay Lake B.C. (IJC 1938), further limit the maximum allowable flow. The unofficial flood control limit for zero damage at Bonners Ferry is river elevation 1764 feet (Merkle, 1996). Kootenai River surface elevation at Bonners Ferry is affected by river discharge and Kootenay Lake elevation.

The structure of the lotic community is defined by streamflow characteristics (Radar and Ward 1988; Poff and Ward 1989). The naturalized spring freshet resorts and cleans river sediments and restores nutrient cycles and floodplain function. The freshet re-suspends fine streambed sediments and coarser gravels, redefining the stream channel and redistributing bottom materials along the main channel, backwaters and banks (Wesche and Rechard 1980). Coarse cobbles are deposited in areas of high water velocity whereas fine silts and clays settle in calm margins and sheltered areas behind obstructions. Clean, unburied cobble provides interstitial spaces between the stones and ample surface area offering suitable habitat for benthic algae, aquatic insects, and young fish (Perry 1984, 1986; Hauer et al. 1997).

Table 3. Modeling results comparing Columbia River flows at McNary Dam (from Wright 1996).

	Flow in Kcfs April 15-30		
Water Availability	NMFS 95 BiOp	IRC	Difference
Lowest 8 water years	197	177	-20
12 low to medium years	230	221	-7
20 medium to high years	265	268	+3
10 high water years	312	312	0
Average of 50 years	255	251	-4
NMFS 95 BiOp flow target for period 220-260 Kcfs			

	Flow in Kcfs May 1 - June 30		
Water Availability	NMFS 95 BiOp	IRC	Difference
12 low to medium years	186	168	-18
20 medium to high years	238	232	-6
20 medium to high years	305	303	-2
10 high water years	386	383	-3
Average of 50 years	286	280	-6
NMFS 95 BiOp target flow for period 220-260 Kcfs			

*In this study the VARQ flood control strategy was not modeled. The IRC targets were superseded by existing "status quo" flood control curves if the flood control elevation was lower than the IRC. This resulted in lower spring flows during medium to dry years than would occur following KIRC/VARQ.

Gravels are deposited along the main channel where water velocity is reduced. Clean gravels with subsurface water seepage and groundwater inflow are sought by nest-building salmonids and broadcast spawners (Weaver and Fraley 1993; Peters 1962). Salmonid redds, constructed in gravels consisting of less than 30 percent fines (<0.65 cm) provide suitable oxygenation for incubating salmonid eggs and sack fry, enhancing survival through hatch and emergence (Weaver and Fraley 1993). Gravelly riffles are important for insect production and provide security habitat for fry and fingerlings. Preferred spawning substrate for white sturgeon, which are broadcast spawners, consists of gravel, cobbles and boulders (Hildebrand and McKenzie 1994; Parsley et al. 1993). Monitoring in the Kootenai River since 1991 indicates that most sturgeon egg deposition occurs over gravel and sand. This may be a result of inadequate river flows or Kootenay Lake elevations to attract sturgeon to areas with larger substrate materials (e.g. upstream of Bonners Ferry). In 1997, Kootenay Lake surface elevation and inflows remained high and several mature radio tagged sturgeon were documented upstream from Bonners Ferry, ID (Vaughan Paragamian, personal communication).

Fine clays, silts, sands, and organic materials deposited in low velocity areas (e.g. high on the streambanks) become dry as spring flows gradually recede. If stream flows stabilize at basal conditions, this rich soil becomes tightly bound by the roots of terrestrial vegetation. As plants recolonize the dewatered substrate, erosion and subsequent siltation of the streambed are reduced. Fine materials remaining in the stream support emergent vegetation and vascular aquatic plants. Established vegetation provides habitat for aquatic and terrestrial organisms. The KIRCs gradually ramp down from the spring runoff peak and moderate flow fluctuations, thus restoring these favorable biological conditions.

Under the more natural annual flow pattern provided by the KIRCs, the nutrient cycle more closely resembles pre-dam conditions compared to the NMFS 95 BiOp. Nutrients are carried with clay particles and organic materials during the freshet, similar to an unregulated system. Free nutrients released into the water fertilize primary producers at the base of the aquatic food web. Biological production increases with rising water temperatures as the summer progresses and flows decline to basal low flow conditions. Secondary production (e.g. zooplankton, insects, and mollusks) determines the amount of food available for tertiary consumers (including white sturgeon, other listed salmonids, and their prey).

Alternative 2: NMFS Biological Opinion

The NMFS Biological Opinion creates an augmented spring freshet followed by a trough, then a second flow peak in August (Figures 5, 6 and 7). The second peak in August is a departure from the natural hydrograph which would decline from a June peak to basal low flows by late July. A rapid flow reduction between the peaks would dewater a large portion of the river margins, stranding insects, zooplankton, fish and fish eggs (Hauer 1987; Armitage 1984; Hauer and Stanford 1982). The unnatural pulse of water during the biologically productive summer months is not consistent with the normative river concept described by the Independent Scientific Group (ISG 1996).

Prior to dam construction, summer flows in the Kootenai River gradually fell from approximately 11,000 cfs to 8,000 cfs during the month of August (Libby Dam Water Control Manual Plates 9-2, 3 & 4). However, the twenty foot August draft, called for by the NMFS 95 BiOp, would augment the flow with an additional 14,450 cfs from reservoir storage (resulting in a sudden increase in the hydrograph that would taper from 25,450 cfs to 22,450 cfs during the month of August) increasing the flow as much as 600 percent of the natural basal flow condition. The following effects would result.

A large expanse of the riverbed is flooded, then dewatered twice during the crucial larval sturgeon development period. This zone of fluctuation or "varial zone" is enlarged by unnatural flow fluctuation (Hauer et al. 1997). Aquatic organisms that colonize the varial zone may be unable to return to the river as the water recedes, becoming stranded on the dry banks (Perry 1984, Hauer et al. 1997.). Aquatic insect production that requires nearshore habitat stability is reduced or lost. The varial zone becomes biologically unproductive, diminishing overall system health. Fluctuating or abnormally high discharges also disrupt the natural revegetation, insect, and larval fish recolonization process. Aquatic and terrestrial vegetation that would normally provide secure habitat along the river margins and stabilize soils can not fully reestablish and fine materials are more easily eroded and swept back into the channel.

Hyporheic interactions, or groundwater interchange with the surface flow, can also be altered by intermittent, abnormally high flows. Augmented summer flows may increase the river stage by up to 4 feet. This amount of head differential can effect the direction of water flow into or out of groundwater storage in shallow unconfined aquifers which could also have negative effects on biological production. Fluctuating flows and resulting river stage changes alternately saturate and dewater the streambanks. Sediments carried with return flows can undercut and weaken the river banks, causing bank failure and increased sedimentation. Groundwater inflow can fertilize the river channel (Stanford and Hauer 1992) affecting eutrophication with positive or negative consequences. Thermal refuge for aquatic biota created by groundwater recharge can be influenced by hyporheic flow. Intermittent, frequent flow fluctuations also compromise the success of sturgeon experimental flows and higher velocities and river stage reduce the effectiveness of certain types of sampling gear when mature eggs and larval sturgeon are expected to be present in the Kootenai River.

Kootenay Lake Conditions (British Columbia)

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

Alternative 1: KIRC/VARQ

Dam releases under this alternative were designed to create a gradual ramp down from the spring runoff toward basal flows. Water retention time in the epilimnion of Kootenay Lake would therefore be greater than Alternative 2 during the warm summer months because Libby Dam discharge is least.

Alternative 2: NMFS Biological Opinion

The late summer water releases from Libby Dam called for by the NMFS Biological Opinion would cause the highest rate of water exchange in Kootenay Lake's epilimnion. Downstream loss of the most productive surface layer of Kootenay Lake would reduce food availability for lake-dwelling species. The Province of British Columbia has been fertilizing the North Arm of Kootenay Lake for the past seven years. The kokanee that the Ministry of Environment is attempting to recover spend a considerable portion of their lives in the South Arm. The large block of water that will have to pass through the South Arm in August will result in a net export of fish and their food, primarily cladocerans. This will likely affect survival of these kokanee and may jeopardize the overall success of the fertilization program which costs in the order of $400 to 500K per year.

Downstream from Kootenay Lake, the Kootenay River passes through numerous small (and old) hydro dams. This water must be passed relatively quickly and will likely result in increased levels of dissolved gas supersaturation as these projects are not capable of dealing with large volumes of water. In addition, BC Hydro may lose considerable power benefits by passing this water at a low-demand time of year.

Burbot, white sturgeon, and kokanee are in jeopardy in the Kootenay River downstream from the Canada-USA border. A large block of water in August, an unnatural event, will affect the survival of these fish by reducing productivity, eliminating certain habitats, moving fish downstream and possibly killing certain fish either directly, e.g., juvenile sturgeon, or indirectly, e.g. relocating some species such as burbot to habitats where they would be exposed to predators.

The Columbia River downstream from the Kootenay River confluence contains threatened stocks of sturgeon and burbot that would be further impacted by high levels of gas supersaturation as well as high flows at an unusual time of year. BC Hydro, Department of Fisheries and Oceans (DFO) and the Ministry are expending substantial resources trying to maintain this ecosystem for the aforenamed species as well as other sport fish, e.g., rainbow trout, mountain whitefish. Furthermore, other threatened and endangered species in this stretch of river, as well as various cottids and cyprinids would be affected by a high summer flow.

Effects on White Sturgeon

Although mature white sturgeon eggs have been captured in monitoring studies in recent years since Libby Dam began operating, only one larval and three pre-hatch sturgeon have been collected to date (Paragamian et al. *In Press*). Yearling sturgeon released experimentally from a conservation aquaculture program have survived to be recaptured in subsequent years. Sub-yearling survival is critical to natural recruitment and recovery of the endangered Kootenai River white sturgeon population. Although river discharge is but one of several environmental mechanisms suspected to influence early life survival, flow regulation effects all riverine trophic levels (Richards 1997, Poff and Ward 1989).

Reestablishment of a more substantial spring freshet (as constrained by flood control criteria) will re-sort some of the river substrate, creating more suitable spawning substrates, which benefits invertebrate production and food availability for tertiary
consumers (fish). A bank full flow should occur on a frequency of once every 2.5 years to maintain channel integrity (Wesche and Rechard 1980). Predation on the eggs of broadcast spawning fish species (e.g. white sturgeon) is reduced when eggs settle into interstitial space provided by cobble and coarse gravel substrates (Parsley et al. 1993), likely enhancing early life survival.

Alternative 1: KIRC/VARQ

Spring flows necessary for river channel maintenance and to re-sort and clean river substrate are presently limited by the physical structure of Libby Dam and flood control requirements. Libby Dam discharge is presently limited to maximum turbine capacity in five units (approximately 27,000 cfs). Flows from unregulated tributaries between Libby Dam and Kootenay Lake supplement dam discharge downstream. Maximum flows are regulated by maximum allowable flood stage (approximately 60,000 cfs) at Bonners Ferry which eliminates the extremely high flows necessary to completely resort the river substrate. Flow regulation has resulted in substrate imbeddedness and the buildup of deltaic materials at the mouths of tributary streams.

The tiered flow approach in the KIRC/VARQ alternative reestablishes a more natural spring runoff period. Model simulations estimate that combined flows in excess of 50,000 cfs can be achieved at Bonners Ferry in approximately four out of every ten years (Marotz et al. 1996). Approximating the bankfull flow on this frequency is expected to reduce imbeddedness and clean interstitial spaces in riffle areas. Flows during dry years are less under the tiered flow approach than those specified by the NMFS 95 BiOp.
The timing of spring flow augmentation would mimic pre-dam conditions, as dictated by the tiered flow approach. The frequency and volume of bankfull flows are controlled by turbine capacity and flood constraints as in the other alternatives. The gradual ramp down from the spring peak mimics the descending limb of the pre-dam hydrograph that was typical. Historically, white sturgeon incubation, hatching and early fry stage coincided with gradually declining flows, immediately after the spring runoff.

Flows resulting from the gradual ramp down from the spring peak may reduce predation mortality in larval sturgeon by increasing the area of submerged riverbed, thus increasing security habitat. This potential was supported by a risk-ratio calculation of instantaneous mortality (Carl Walters, University British Columbia, personal communication, Kootenai River Modeling Workshop February 18, 1997). A sudden decrease in white sturgeon recruitment occurred in 1973 and 1974 when Libby Dam began impounding the Kootenai River. Flows reduced by approximately a factor of 10 during the period when sturgeon eggs are incubating and fry are emerging (late May through early July). The decreased volume of water would accordingly concentrate predators and prey in a smaller area, increasing the risk of predation mortality. Thus, a gradual ramp down from the spring peak should reduce predation on white sturgeon fry. More stable flows during the biologically productive spring and summer months would benefit biological production in the affected river reach.

Alternative 2: NMFS Biological Opinion

The spring release called for by the NMFS 1995 Biological Opinion is similar to Alternatives 1 in that it would mimic the natural spring runoff. Maximum flows are regulated by maximum turbine capacity and allowable flood stage. Bankfull flows could be achieved on the same frequency as the KIRC/VARQ.

However, the August release is inconsistent with the restorative flows recommended in KIRCs in the Kootenai River. White sturgeon can be directly affected (through stranding of juveniles) or indirectly affected (through food web dynamics) by summertime flow augmentation (Stanford et al. 1996, Hauer et al. 1997). A large expanse of the riverbed is flooded, then dewatered twice during the period crucial to sub-yearling sturgeon development and survival. Summer releases dictated by the NMFS Biological Opinion, therefore, likely impact post-larval survival and may hamper recovery of the endangered Kootenai River white sturgeon population.

Although information on early life habitat requirements of sub-yearling Kootenai white sturgeon is incomplete, the Team is concerned that rapid flow reduction following the sturgeon release could strand larvae or juveniles if they utilize the river margins or backwater areas. Unseasonably high water velocities during August could displace juvenile sturgeon that evolved under a natural hydrograph that provided more stable low flows during the critical life cycle stage from fry to yearling.

Flow fluctuation during the most productive warm months could also negatively affect sub-yearling sturgeon feeding and food resources. White sturgeon food habits during their first year include insects and other invertebrates known to be impacted by flow fluctuation (Hauer et al. 1997). Scott and Crossman (1973) reported that age 0 white sturgeon diets consisted predominantly of Chironomid larvae. The amphipod Corophium accounted for 98 percent of diet items from 149 age 0 white sturgeon (20-267 mm TL) collected from Bonneville and The Dalles pools in the Columbia River from (Sprague et al. 1993). Wydowski and Whitney (1979) reported that the stomachs of small white sturgeon in California contained primarily *Mysis* shrimp and amphipods. Age 0 lake sturgeon (*Acipenser fulvescens*) were observed in close contact with the substrate, oriented upstream, apparently feeding on drifting benthic organisms (Kempinger, 1996). Kempinger (1996) also reported that species of Baetidae nymphs and Dipteran larvae were the two principle organisms consumed by lake sturgeons during their first summer of life. Paragamian et al. (1997) found that chironomid larvae make up over 90 percent of the stomach contents of 23 juvenile white sturgeon recaptures of hatchery fish stocked 2-3 months earlier in the Kootenai River. Obviously, any flow operation that reduces invertebrate production and abundance could have a negative effect on sub-yearling white sturgeon growth and survival.

Other Effects

A new strategy for system flood control (VARQ) is required to balance the needs of reservoir and anadromous in the Columbia system. VARQ was critically examined by technical modelers of the Army Corps of Engineers (ACOE) Hydraulics and Hydrology Branch. ACOE modelers established that the KIRCs were nearly identical to a new system flood control strategy being developed by the ACOE in average to high water years. Earlier problems identified by ACOE modelers (e.g. April releases and insufficient drawdown in the highest ten percent of water years) have been corrected so that the KIRCs are now consistent with VARQ in high water years. Differences between VARQ and KIRCs during lower water years are a result of integrating power constraints. This variable flow strategy (VARQ) is crucial to increasing and shaping spring runoff (within flood constraints) while maximizing reservoir refill probability. A preliminary flood control analysis on VARQ and KIRCs was completed by ACOE in February of 1997. A combination of KIRCs and VARQ is being explored for Libby operation based on that information, which indicates that flood control requirements can be met for Bonners Ferry providing that adequate drafting occurs in high-runoff years.

Wright (1996) reported that the enhanced reservoir operation (IRC concept) was the least expensive of the alternatives analyzed, saving the power system an annual incremental average of $27 million as compared to the NMFS Biological Opinion. Furthermore, the mathematical decision process for establishing reservoir elevations and flow targets, based on updated inflow forecasts, is amenable to power and flood control planning.

In the past, BC Hydro has tried to accommodate the NMFS demand for a 20 foot draft of Koocanusa by implementing what is termed the Arrow-Libby swap. The problem with this operational practice is that the kokanee populations in the Arrow Reservoir have collapsed, primarily due to a lack of productivity. Just as with Kootenay Lake, a drawdown of the Arrow to provide water for the NMFS flow target at McNary will affect kokanee survival in the Arrow by flushing some of the remaining kokanee and their food out of the reservoir.

CONCLUSIONS

Water released for salmon during dry years as called for in the NMFS 95 BiOp would disrupt the desired balance between Kootenai River white sturgeon recovery needs, resident fish needs, and Libby Reservoir refill probability which effects biological productivity in the reservoir and river. Reservoir refill failures during dry years are expected under the KIRC/VARQ operation, but less frequently than would occur by implementing the NMFS Biological Opinion. Extreme reservoir refill failure (more than 20 feet) negatively affects biological production in the reservoir, entrains more fish through Libby Dam, and negatively affects fishing, recreation, and tourism. Reservoir refill failure in the U.S. and Canadian portion of the Kootenai system compromises the system's ability to store water for release during the following spring. The best conditions for white sturgeon and the Kootenai River ecosystem can be achieved by implementing operations similar to the KIRC/VARQ at Libby Reservoir and other Columbia Basin storage projects (e.g. Mica, Arrow, Dworshak). In doing so, sub-basins experiencing wet conditions can supply the bulk of salmon flow augmentation, while dry sub-basins would provide less flow, protecting important reservoir and riverine stocks. Combined flows from the headwater sub-basins could then be shaped to achieve the greatest benefit for salmon and other anadromous stocks while protecting fish populations in the dry sub-basins. A gradual ramp down from the spring runoff in the sub-basins can be used to normalize the river hydrograph below headwater projects.

We agree with NMFS that ESA recovery actions throughout the entire Columbia River Basin should be balanced and coordinated to accomplish simultaneous recovery of multiple species throughout the Columbia Basin. Given the available information, the Team believes the KIRC/tiered flow operation best meets this objective (Table 4). The KIRC tiered flow approach uses available water to mimic natural hydraulic conditions, provides an experimental design to assess environmental conditions need for natural recruitment of juvenile white sturgeon to the Kootenai River population, and balances recovery actions while providing adequate habitat conditions for the threatened bull trout and other non-listed fish stocks consistent with ESA. Pass through flows can be shaped to achieve the greatest benefit for sturgeon, salmon, bull trout, and non-listed stocks. Finally, implementation of the KIRC tiered flow approach will require that research and monitoring efforts focus on the benefits and impacts of summer flow augmentation so that areas of conflict can be resolved based on empirical scientific evidence.

Table 4. A descriptive comparison of the two operational alternatives. Symbols denote biological responses to the various operational strategies (see footnote[2]).

Physical or Biological Effect	Alternative 1 KIRC/VARQ	Alternative 2 NMFS 95 BiOp
Reservoir Refill Probability	✫	☆
Maximum Reservoir Drawdown	★	✮
Primary Productivity	✫	✮
Zooplankton Production	✫	✮
Benthic Insect Production	★	✫
Terrestrial Insect Deposition	✫	☆
Fish Growth	★	☆
Fish Entrainment Loss via Turbines	★	☆
Flow Fluctuation (size of varial zone)	★	☆
Riverine Biological Productivity	✫	☆
Impacts to White Sturgeon	✫	☆
Kootenay Lake Water Exchange Rate - Epilimnion	✫	☆
Salmon Spring Flow Augmentation Low Inflow	✮	★

[2] Symbols are ordered from biologically optimized ★, productive ✫, low productivity ✮, and poor condition ☆.

Physical or Biological Effect	Alternative 1 KIRC/VARQ	Alternative 2 NMFS 95 BiOp
Salmon Spring Flow Augmentation Average Inflow	✫	★
Salmon Spring Flow Augmentation High Inflow	★	★
Salmon Summer Flow Augmentation Low Inflow	☆	✬
Salmon Summer Flow Augmentation Average Inflow	✬	✫
Salmon Summer Flow Augmentation High Inflow	✫	★

[1] Symbols are ordered from biologically optimized ★, productive ✫, low productivity ✬, and poor condition ☆.

LITERATURE CITED

ACOE. 1997. Columbia River Basin system flood control review preliminary analysis report. U.S. Army Corps of Engineers, North Pacific Division. 98 pp. (plus appendices).

Anders, P.J. 1993. Kootenai River fisheries studies: Kootenai River tributary kokanee spawning ground survey. Annual Report of Research FY 1993, Report C. Kootenai Tribe of Idaho and Bonneville Power Administration. Contract No. DE-B179-88BP93743. Project No. 88-64. Portland, Oregon. 10 pp.

Anders, P.J. and R.E. Westerhof. 1996. Natural spawning of white sturgeon (*Acipenser transmontanus*) in the Kootenai River, Idaho, 1995. Preliminary Report of Research FY 95. Kootenai Tribe of Idaho and Bonneville Power Administration. Portland, Oregon. 14 pp.

Apperson, K.A. 1992. Kootenai River white sturgeon investigations and experimental culture. Annual Progress Report FY 1991. Idaho Department of Fish and Game and Bonneville Power Administration. Contract No. DE-AI79-88BP93497. Project No. 88-65. Portland, Oregon.

Apperson, K.A. and P.J. Anders. 1991. Kootenai River white sturgeon investigations and experimental culture. Annual Progress Report FY 1990. Idaho Department of Fish and Game and Bonneville Power Administration. Contract No. DE-AI79-88BP93497. Project No. 88-65. Portland, Oregon. 67 pp.

Armitage, P.D. 1984. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities. Pages 139-165 in A. Lillehammer and S.J. Saltveit, editors. Regulated Rivers. University Press. Oslo, Norway.

Ashley, K. and L. Thompson. 1996. Kootenay Lake Fertilization experiment - Year 3 (1994/1995) report. Fisheries Project Report No. RD 49. Fisheries Branch, Ministry of Environment, Lands and Parks, University of British Columbia.

Council. 1994. Northwest Power Planning Council Fish and Wildlife Program. Document 94-55.

Daley, R.J., E.C. Carmack, C.B.J. Gray, C.H. Pharo, S. Jasper, and R.C. Weigand. 1981. The effects of upstream impoundments on the limnology of Kootenay Lake, B.C. Scientific Series No. 117, National Water Research Institute, British Columbia.

Fraley, J.J., B. Marotz, J. Decker-Hess, W. Beattie, and R. Zubik. 1989. Mitigation, compensation, and future protection for fish populations affected by hydropower development in the Upper Columbia System, Montana, U.S.A. Regulated Rivers: Research and Management (3):3-18.

Hauer, F.R., J.B. Biby, J.T. Gangemi and J.A. Stanford. 1997. Long-term influence of Libby Dam operation on the ecology of macrozoobenthos of the Kootenai River. Report to Montana Fish, Wildlife & Parks. University of Montana, Yellow Bay Biological Station, Polson, Montana.

Hauer, F.R. and J.A. Stanford. 1982. Ecological responses of hydropsychid caddisflies to stream regulation. Canadian Journal of Fisheries Aquatic Science 39(9):1235-1242.

Hildebrand, L, and S. McKenzie. 1994. Status of white sturgeon in the Columbia River, B.C. Final Report for B.C. Hydro. R.L.&L. Environmental Services, Limited.

Independent Scientific Group. 1996. Prepublication Copy. Return to the River: Restoration of salmonid fishes in the Columbia River ecosystem. Development of an alternative conceptual foundation and review and synthesis of science underlying the Columbia River Basin Fish and Wildlife Program of the Northwest Power Planning Council Document 96-6.

International Joint Commission. 1938. Application to construct and operate Corra Linn Dam on Kootenay Lake, B.C. West Kootenay Power and Light Company. Order of Approval.

Kempinger, J.J. 1996. Habitat, growth, and food of young lake sturgeons in the Lake Winnebago System, Wisconsin. North American Journal of Fisheries Management. 16(1):102-114.

Marotz, B., D. Gustafson, C. Althen, and B. Lonon. 1996. Model development to establish Integrated Operation Rule Curves for Hungry Horse and Libby reservoirs, Montana. Montana Fish, Wildlife & Parks report to Bonneville Power Administration. DOE/BP-92452-1. Portland, Oregon. 114 p.

May, B., S. Perry, J. Huston, and J. DosSantos. 1981. Kootenai River fisheries investigations. Montana Fish, Wildlife & Parks, Fisheries Division, Annual Progress Report. Kalispell, Montana.

McCabe, G.T., and C.A. Tracy. 1993. Spawning characteristics and early life history of white sturgeon *Acipenser transmontanus* in the lower Columbia River. Report A. In: Status and habitat requirements of the white sturgeon populations in the Columbia River downstream of McNary Dam. Vol. 1. Final Report to Bonneville Power Administration. Project No. 86-50. Portland, Oregon.

Merkle, L.O. 1996. New zero damage stage for Kootenai River at Bonners Ferry. US Army Corps of Engineers, Seattle District, Hydraulics and Hydrology Branch. Memorandum dated 4 June 1996.

NMFS. 1995. Endangered Species Act - Section 7 Consultation, Biological Opinion: Reinitiation of consultation on 1994-1998 operation of the Federal Columbia River Power System and juvenile transportation program in 1995 and future years. Consultation by National Marine Fisheries Service, Northwest Region. U.S. Army Corps of Engineers, Bonneville Power Administration, Bureau of Reclamation, National Marine Fisheries Service.

Palmer, D.E., M.J. Parsley, and L.G. Beckman. 1988. Report C. In: Status and habitat requirements of the white sturgeon populations in the Columbia River downstream of McNary Dam. Vol. 1. Final Report to Bonneville Power Administration. Project No. 86-50. Portland, Oregon.

Paragamian, V.L. 1994. Kootenai River Fisheries Investigations: Stock status of Burbot and rainbow trout and fisheries inventory. Annual Report 1993. Idaho Department of Fish and Game and Bonneville Power Administration. Contract No. DE-B179-88BP93497. Portland, Oregon. 28 pp.

Paragamian, V.L., G. Kruse, and W. Wakkinen. 1996. Kootenai River Fisheries Investigations: Stock status of Burbot and rainbow trout and fisheries inventory. Annual Report 1995. Idaho Department of Fish and Game and Bonneville Power Administration. Contract No. DE-B179-88BP93497. Portland, Oregon.

Parret, C. and J.A. Hull. 1985. Streamflow characteristics of mountain streams in western Montana. U.S. Geological Survey. Water-supply paper 2260.

Parsley, M.J., L.g. Beckman, and G.T. McCabe, Jr. 1993. Habitat use by spawning and rearing white sturgeon in the Columbia River downstream from McNary Dam. In: Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam. Final Report by Oregon Dept. of Fish and Wildlife, National Marine Fisheries Service, US Fish and Wildlife Service, and Washington Department of Fisheries to Bonneville Power Administration. Portland, Oregon.

Partridge, F. 1983. Kootenai River fisheries investigations in Idaho. Idaho Department of Fish and Game, Boise, Idaho.

Perry, S.A. 1984. Comparative ecology of benthic communities in natural and regulated areas of the Flathead and Kootenai Rivers, Montana. North Texas State University. Denton, Texas.

Perry, S.A., W.B. Perry and J.A. Stanford. 1986. Effects of stream regulation on density, growth, and emergence of two mayflies (Ephemeroptera: Ephemerellidae) and a caddisfly (Trichoptera: Hydropsychidae) in two Rocky Mountain rivers (U.S.A.). Canadian Journal of Zoology 64:656-666.

Peters, J.C. 1962. The effects of stream sedimentation on trout embryo survival. In Biological Problems in Water Pollution, Third Seminar, 1962, pp. 275-279. Public Health Service Publication 999-WP-25.

Poff, N.L. and J.V. Ward. 1989. Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Can. J. Fish. Aquat. Sci. 46(10):1805-1818.

Radar, R.R. and Ward, J.V. 1988. Influence of regulation and environmental conditions and the macroinvertebrate community in the upper Colorado River. Regulated Rivers. 2:597-618.

Richards, D. 1997. Kootenai River biological baseline status report. Kootenai Tribe of Idaho and Bonneville Power Administration. Contract No. 95BI40364. Project No. 94-49. Portland, Oregon. 62 pp.

Scott, W.B., and E.J. Crossman. 1973. Freshwater fishes of Canada. Research Board of Canada. Bulletin 184. 966 pp.

Skaar, D., J. DeShazer, L. Garrow, T. Ostrowski, and B. Thornberg. 1996. Quantification of Libby Reservoir levels needed to maintain or enhance reservoir fisheries: Investigations of fish entrainment through Libby Dam, 1990-1994. Montana Fish, Wildlife & Parks and Bonneville Power Administration. Contract No. DE-AI79-83BP12660. Project No. 83-467. Portland, Oregon. 110 pp.

Sprague, C.R., L.G. Beckman, and S.D. Duke. 1993. Prey selection by juvenile white sturgeon in reservoirs of the Columbia River. Final Report to Bonneville Power Administration. Project 86-50. 2:232-239.

Stanford, A. J. and F. R. Hauer. 1992. Mitigating the impacts of stream and lake regulation in the Flathead River catchment, Montana, USA: An Ecosystem Perspective, Aquatic Conservation: Marine and Freshwater Ecosystems 2: 35-63.

Stanford, J.A., J.V. Ward, W.J. Liss, C.A. Frissell, R.N. Williams, J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research & Management, 12:391-413.

US Fish and Wildlife Service. 1994. Endangered and threatened wildlife and plants; determination of endangered status for the Kootenai River population of white sturgeon—final rule. Federal Register 59(171):45989-46002. (September 6, 1994).

Walters, Carl. 1997. Personal Communication and minutes from the February 18, 1997 Kootenai River Modeling Workshop. Dr. Carl Walters, University of British Columbia, Victoria, B.C.

Weaver, T.M., and J.J. Fraley. 1993. A method to measure emergence success of westslope cutthroat trout fry from varying substrate compositions in a natural stream channel. North American Journal of Fisheries Management 13:817-822.

Wesche, T.A. and P.A. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. Eisenower Consortium Bulletin 9.

Wright, A. 1996. Review of Columbia River operating criteria. Facilitators Report to National Marine Fisheries Service and Bonneville Power Administration. Al Wright Consulting, Portland, OR. 15 pp.

Wydowski, R.S., and R.R. Whitney. 1979. Inland fishes of Washington. University of Washington Press. ISBN 0-295-95643-7.

APPENDIX C. Kootenai Basin Integrated Rule Curves and Tiered Approach for White Sturgeon Flow Release from Libby Reservoir.

The Model

A FORTRAN simulation model was developed by Montana Fish, Wildlife & Parks and Montana State University for Libby Reservoir (also known as Koocanusa Reservoir) located in northwestern Montana (Marotz et al. 1996). The model simulates the physical operation of the dam, including experimental flow augmentation for white sturgeon recovery and downstream flood concerns, and predicts the resulting thermal structure of the reservoir and tailwater temperature. Biological responses include: primary production in the reservoir and washout through the dam turbines, zooplankton production and washout, the deposition of terrestrial insects on the reservoir surface, benthic dipteran production and body growth of the major game fish, kokanee. Input to the model is restricted to annual inflow forecasts, the annual inflow hydrograph, minimum and maximum outflow limits, and a proposal of either the annual surface elevation schedule or the annual schedule of dam discharges. The model user has the option to specify the depth at which water is withdrawn from the reservoir throughout the simulation to control water temperature in the discharge, or the model will automate depth selection to meet a pre-programmed temperature regime downstream. All other parameters and coefficients were fixed based on a long-term source of empirical data (1983-1996). Additional data were used to refine the model during the ensuing years. The model was designed to generate accurate, short-term predictions specific to Libby Reservoir and is not directly applicable to other waters. The modeling strategy, however, is portable to other reservoir systems where sufficient data are available.

The model was empirically calibrated using field data from an extensive sampling program 1983 through 1990 (Chisholm et al. 1989; Fraley et al. 1989, and MFWP file data). Field data from 1991 through 1997 were used to expand the utility and correct uncertainties in the model. The physical model facilitates the assessment of power and flood control operations under varying water conditions, drought to flood. Biological components were designed to compare one operational strategy to another, and assess their relative effects on the aquatic environment. The model simulates the water balance in the Kootenai River, Kootenay Lake, Duncan Dam and Corra Linn Dam operations.

Reservoir operation guidelines were developed to balance fisheries concerns in the headwaters with anadromous species recovery actions in the lower Columbia River. Fisheries operations were integrated with power production and flood control to reduce the economic impact of fisheries recovery actions. An earlier version of the operating plan (called Integrated Rule Curves or IRCs) were critically reviewed in the Columbia Basin System Operation Review (SOR EIS 1995; Geist et al. 1996), a process funded by the National Marine Fisheries

Service and BPA to balance salmon recovery with resident fish concerns (Wright 1996), the Fisheries Research Institute (Dr. James Anderson and Dr. Gordon Swartzman), and were determined to be consistent with the Normative River concept (ISG 1996). The IRCs were adopted by the Northwest Power Planning Council during their phase IV amendment process (NPPC 1994) and could have been implemented beginning in 1995. The original IRCs were subsequently modified by the White Sturgeon Recovery Team to refine relationships specific to white sturgeon and to better balance the requirements of resident and anadromous species. A variable release schedule was programmed to assess experimental recovery actions for the endangered Kootenai River white sturgeon. The resulting operational plan was named the Kootenai Basin Integrated Rule Curves (KIRCs).

The KIRCs are a family of operational rules for dam operation that incorporate incremental adjustments to allow for uncertainties in water availability. Dam operation is scheduled based on inflow forecasts and the physical character of the drainage basin and dam design. The first inflow forecast of the year becomes available in early January. Upon receipt of the forecast, the dam operator would store or release water to achieve the correct elevation as described by the curve corresponding with that inflow forecast. Upon receipt of an updated forecast, the operator would adjust the elevation to the new curve corresponding with the updated inflow volume and so on. This causes the actual operation to be flexible and variable over time. Actual operations will vary somewhat from the target elevations due to inflow forecasting error. The curves were designed to limit the duration and frequencies of deep drawdowns and reservoir refill failure and produce a more natural 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 of optimal temperature water for fish growth and a large surface area for the deposition of terrestrial insects from the surrounding landscape. Refill timing also assures that passage into spawning and rearing habitats in tributaries is maintained for species of special concern in Montana, including westslope cutthroat trout and the bull trout. Biological production in the free flowing river reaches downstream 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. The volume and shape of the spring freshet is based on water availability. Flows released from Libby Dam then continue downstream to aid anadromous salmon smolt migration.

Results

Problems occur for resident fish in reservoirs when the pool fails to refill or is drawn down beginning in late summer or early fall. The reduced volume and surface area limits the fall food supply and volume of optimal water temperatures during the critical trout growth period. The food web supporting fish is most productive in the shallower and warmer littoral or nearshore zones of the reservoirs during the summer months. The contribution of terrestrial insects as a food source for fish is reduced as the surface area shrinks and water recedes from shoreline vegetation with a drawdown. These insects are most abundant near the shore from June through September and are the most important food supply for insectivorous fish species during summer and fall. Surface elevations continue to decline during winter, arriving at the lowest point in the annual cycle in April. Aquatic insects are killed as water recedes from the littoral zone. Benthic insects are an important spring food supply for westslope cutthroat trout, a species of special concern in Montana, and other important game and forage species. Frequent dewatering reduces the biomass of insects, especially because the shallow zone is the most productive for insects. At least two years are required for aquatic insect populations to rebound after a single deep drawdown event. Deep drawdowns also increase the probability that the reservoir will fail to refill during the following year. Zooplankton, an important food for kokanee, juvenile trout and adult trout during winter, are washed out of the reservoir through dam turbines as the reservoir shrinks. Thus excessive reservoir drawdown and refill failure impact fish food availability and, therefore, fish growth, and recreation (Chisholm et al. 1989; May et al. 1988; Marotz et al 1996). Modeling and field research indicate that reservoir productivity can, with time, rebound after infrequent deep drawdowns. However, even infrequent drawdowns have lasting biological effects.

KIRCs limit the duration and frequency of deep drawdowns and reservoir refill failure. Reduced drawdown protects aquatic insect larvae, assuring that a large percentage will survive to emerge as pupae and adults. Increased refill frequency improves biological productivity during the summer months, provides an ample volume of optimal temperature for fish growth, and a large surface area for deposition of terrestrial insects during the summer months. Refill also assures that passage into spawning tributaries is maintained for adfluvial trout, including westslope cutthroat and bull trout.

Outflows from the dams affect the river ecology. River flows are crucial to all life stages of aquatic organisms. Spring flushing flows sort river gravel and define the channels creating a healthy environment for fish and the food organism that they depend on. Flow fluctuations during the rest of the year, especially the productive summer months, are harmful to aquatic life. The resulting zone of fluctuation, or varial zone, becomes biologically unproductive habitat, diminishing system health. Aquatic insects, fish and fish eggs occupying the varial zone may be unable to return to the river as the water recedes, becoming stranded on the dry banks. Fluctuating or abnormally high discharges also disrupt the natural revegetation process. Aquatic and terrestrial vegetation that would normally provide secure habitat along the river margins and stabilize soils cannot fully reestablish, and fine sediment materials are more easily eroded and swept back into the channel. In a natural river environment, the nearshore habitat is productive and critical to fish. Riparian vegetation reestablishes seasonally, providing secure habitat along river margins and reducing erosion of silt into the river. If flow fluctuation is reduced by gradually ramping down discharges (as in the KIRCs), impacts to biological production can be reduced.

Local and System Flood Control

Kootenai River flood control measures extend downstream to Corra Linn Dam at the outlet from Kootenay Lake. The model calculates side flows to the Kootenai River (from inflowing water sources) between Libby Dam and Bonners Ferry, Idaho, and sources flowing into Kootenay Lake, British Columbia. Kootenai River flow targets are calculated at Bonners Ferry, and elevational targets at Kootenay Lake, to avoid flooding. Dynamic estimates of side flows can also be added to Libby Dam discharges to calculate the resultant flow at Bonners Ferry. Inflows to Kootenay Lake, flood storage at Duncan Reservoir and lake/discharge relationships for Corra Linn Dam were incorporated into the model to mimic coordinated flood control measures stated in the International Joint Commission Treaty.

The KIRC strategy for flood abatement is to route water through the system so that large peaks in runoff are eliminated, similar to the Variable Flow (VARQ) flood control strategy developed by the Army Corps of Engineers (ACOE). The ACOE Hydraulics Branch critically compared the original IRCs and VARQ and determined that the strategies were similar, with notable differences. In less than average water years, VARQ required less drafting for flood control than the currently used ACOE flood control rule curves, and reservoir elevations were higher than those described by the IRC's. We view this as an opportunity for more operational flexibility above the IRCs so that more water can be "saved" during dry years to augment spring flows and to create a naturalized spring freshet (within flood constraints) without compromising reservoir refill. In average to medium high water years, VARQ and IRCs were identical. This is an improvement over historic operations because reservoir elevations remain higher prior to the spring runoff, so that a larger percentage of the runoff volume can be shaped to create a normalized spring freshet while improving reservoir refill probability. The ACOE analysis revealed that during high water years at Libby Dam, the VARQ required slightly lower elevations for flood control than the IRCs. In response, during 1996 the FWP and the Confederated Salish and Kootenai Tribes (CSKT) adjusted the Libby KIRCs downward to be consistent with VARQ. In doing so, we reduced the risk of a forced spill due to reservoir overflow and associated gas supersaturation in the river downstream. This variable flow strategy (VARQ) is crucial to create a naturalized spring runoff (within flood constraints) while maintaining reservoir refill probability. Careful implementation of IRC/VARQ at Libby Dam will improve spring flows for Kootenai white sturgeon and anadromous stocks in the lower Columbia, while simultaneously improving conditions for westslope cutthroat and bull trout.

Tiered Approach for Kootenai White Sturgeon Spawning Flows

Based on currently available information, white sturgeon in the Kootenai River require a naturalized spring freshet and favorable water temperatures to promote recruitment of juveniles. Spawning has been documented at spring flows of only 20 kcfs, but survival from eggs to yearling stage appears to be related to flow and temperature. We have therefore developed an experimental flow augmentation plan that is based on water availability (reservoir inflow forecasts). The volume of the planned releases are larger in high water years and smaller in low water years.

This Tiered Flow Approach relies on the Army Corp's VARQ flood control strategy, which differs from the flood control operation currently being implemented by the Army Corps. The existing operation attempts to store as much of the spring runoff as possible. This requires a large reservoir drawdown to evacuate sufficient storage to contain the spring runoff, and dam discharge during the spring runoff is held to the minimum allowable flow. Conversely, the VARQ/Tiered flows embodied in the KIRCs plans to release a naturally shaped spring freshet during runoff and stores only the amount of water that would exceed flood capacity in the river downstream. By doing so, less reservoir drafting is required, which benefits reservoir biology. It also improves reservoir refill because less water is required to refill the smaller volume of vacated storage capacity. VARQ enables dam operators to store more water prior to runoff (even more than Integrated Rule Curves) in below average water years. This water can then be released to augment spring flows (for white sturgeon and ESA salmon and steelhead) without impacting reservoir refill. The VARQ/Tiered Flow Approach is the most critical tool at our disposal to simultaneously balance the needs of resident and anadromous fish recovery by providing greater operational flexibility in dry years to help salmon/steelhead without harming native resident fish species.

The flow targets and KIRCs provide flexibility to assure that the runoff event corresponds with optimal water temperatures. A vertical array of thermometers on the upstream face of Libby Dam reveals the reservoir's thermal structure. As optimal water temperatures become available at the appropriate outlet depth, sturgeon releases can be shaped to achieve the optimal mix of flow and temperature.

The volume of the experimental flows are selected based on the May 1 inflow forecast volume (reservoir inflow expected during the period April 1 through September 30 in MAF). These targets represent minimum flows at Bonners Ferry (Libby Dam discharge plus unregulated inflows between Libby Dam and Bonners Ferry). When the forecast underestimates the actual inflow volume, minimum sturgeon flow targets are exceeded as excess water is released to slow the rate of reservoir refill (as dictated by the KIRCs). Overestimation results in the release of stored water to achieve the minimum flow target. In both cases, flows can be shaped through inseason management to achieve the most desirable balance between discharge shape and reservoir refill trajectory. For planning purposes, earlier inflow forecasts may be used to estimate the volume of the sturgeon release. Estimates should be updated as new forecasts become available.

The Libby Reservoir model was configured to automate the selection of flow targets and shape unexpected flow events resulting from forecasting error to within flood constraints. Analysis of the 50-year period of record (1929-1978) revealed that sturgeon targets can be met without impacting reservoir productivity. Sturgeon releases are not scheduled during low water years (lowest 20 percent) unless increased discharges are needed for emergency flood control.

Two of the fifty years of record (1948 and 1979) would require in-season management (increased sturgeon flows) for flood control. Water year 1974 was classified as a low water year (critical year 3), so under the tiered flow approach no flow augmentation would have occurred. Inflows were sufficiently high, however, that by late May it became obvious that the inflow forecasts were too low and that water must be released to maintain flood storage capacity behind Libby Dam. The model run was reprogrammed to simulate in-season management by releasing the appropriate sturgeon target (>8.5 MAF) to control the flood and avoid a forced spill. In reality, the 1974 flood was managed in nearly the same manner, providing adequate conditions for sturgeon as evidenced by successful recruitment from the 1974 year class (Apperson and Anders 1991).

Similarly, in 1948 the inflow forecast grossly underestimated the actual runoff volume. If Libby Dam had existed in 1948, the faulty inflow forecasts would not have warned dam operators to evacuate sufficient storage volume to control the flood. The corresponding sturgeon flow target based on the underestimated May 1 forecast would likewise not have maintained sufficient flood storage to reregulate the runoff. However, experienced dam operators would have been aware that the reservoir was refilling too rapidly and that a forced spill was imminent. To simulate this ability to respond to real time situations, we modified the 1948 simulation to release the maximum allowable sturgeon flow in response to the flood emergency.

Model evaluations revealed that impacts to the reservoir fishery can be reduced by implementing the VARQ flood control strategy. By explicitly storing water that would historically be released during winter, flows can be enhanced during June to create a more natural runoff event without impacting reservoir refill probability. VARQ creates greater flexibility for dam operation during less than average water years. Water released to provide more favorable conditions for sturgeon, continue downstream to aid juvenile anadromous smolt migrations to the Pacific Ocean. Westslope cutthroat and rainbow trout also respond favorably to a normalized spring discharge which corresponds with their life cycle requirements.

References

Council. 1994. Northwest Power Planning Council Fish and Wildlife Program. Document 94-55.

Fraley, J.J., B. Marotz, J. Decker-Hess, W. Beattie, and R. Zubik. 1989. Mitigation, compensation, and future protection for fish populations affected by hydropower development in the Upper Columbia System, Montana, U.S.A. Regulated Rivers: Research and Management (3):3-18.

Geist, D.R., L.W. Vail and D.J. Epstein. 1996. Analysis of potential impacts to resident fish from Columbia River system operation alternatives. Environmental Management 20(2):275-288.

Independent Scientific Group. Prepublication Copy 1996. Return to the River: Restoration of salmonid fishes in the Columbia River ecosystem. Development of an alternative conceptual foundation and review and synthesis of science underlying the Columbia River Basin Fish and Wildlife Program of the Northwest Power Planning Council Document 96-6.

Marotz, B., D. Gustafson, C. Althen, and B. Lonon. 1996. Model development to establish Integrated Operation Rule Curves for Hungry Horse and Libby reservoirs, Montana. Montana Fish, Wildlife & Parks report to Bonneville Power Administration, Portland, OR DOE/BP-92452-1. 114 p.

SOR EIS. 1995. Columbia River System Operation Review. Environmental Impact Statement. Main report and Appendix K, resident fish. Bonneville Power Administration, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation. DOE/EIS-0170.

Wright, A. 1996. Review of Columbia River operating criteria. Report to National Marine Fisheries Service and Bonneville Power Administration by Al Wright Consulting, Portland, OR.

Appendix D: Breeding Plan to Preserve the Genetic Variability of the Kootenai River White Sturgeon

Prepared By:

Harold L. Kincaid
U.S. Fish and Wildlife Service
National Fishery Research and Development Laboratory
Wellsboro, Pennsylvania

Prepared For:

U. S. Department of Energy
Bonneville Power Administration
Division of Fish and Wildlife
P. O. Box 3621
Portland, Oregon 97208

Project No. 93-27
Contract No. DE-AI79-93BP02886

November 10, 1993

ACKNOWLEDGEMENTS

I thank Kimberly Apperson, Ned Horner, Paul Anders, and Gary Aitken for providing sturgeon culture and life history information and for consultation on development of the breeding plan. I thank Bernie May, Charles Krueger, Martin Dilauro, and James Meade for critical review of the final document. Rick Westerhof served as Project manager for Bonneville Power Administration on this project and was very helpful in providing hard-to-get published and unpublished reports on previous sturgeon research.

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

Natural reproduction in the Kootenai River white sturgeon population has not produced a successful year class since 1974, resulting in a declining broodstock and 20 consecutive year classes missing from the age-class structure. This report describes a captive breeding plan designed to preserve the remaining genetic variability and to begin rebuilding the natural age class structure.

The captive breeding program will use 3-9 females and an equal number of males captured from the Kootenai River each spring. Fish will be spawned in pairs or in diallel mating designs to produce individual families that will be reared separately to maintain family identity. Fish will be marked to identify family and year class before return to the river. Fish should be returned to the river as fall fingerlings to minimize potential adaptation to the hatchery environment. Initially, while tagging methods are tested to ensure positive identification after return to the river, it may be necessary to plant fish as spring yearlings. Number of fish planted will be equalized at 5,000 per family if fall fingerlings or 1,000 per family if spring yearlings. Assuming annual survival rates of 20% during the first winter for fall fingerling plants and 50% for years 1-3, and 85% for years 4-20 of all fish planted, the target numbers would yield 7.9 progeny per family or about 4 breeding pairs at age 20. Natural survival in the river environment during the 19+ years from planting to maturity would result in variability in genetic contribution of families to the next broodstock generation. Fish planted per family would be adjusted in future years when actual survival rate information is known. Broodfish will be tagged when captured to minimize multiple spawning of the same fish.

Implementation of this breeding plan each year for the 20-year generation interval, using 5 different mating pairs each year, will yield an effective population size of 200, or 22.5% of the estimated 1990 population. Because this captive breeding program is designed to produce approximately 8 breeding adults per family and to approximate a "normal expanding" natural population, it should not exaggerate the contribution of a small fraction of the parent population, as occurs in typical supplementation programs. This captive breeding plan should be discontinued once habitat is re-established to permit successful natural spawning and recruitment in the Kootenai River.

Breeding Plan to Preserve the Genetic Variability of the Kootenai River White Sturgeon

INTRODUCTION

The Kootenai River white sturgeon (*Acipenser transmontanus*) is a closed population residing in the Kootenai River between Kootenai Falls (50 km below Libby Dam) and Bonnington Falls (Corra Linn Dam). This population has been isolated from other Columbia River white sturgeon stocks for approximately 10,000 years (Northcote 1973). Estimates by Partridge (1983) and Apperson and Anders (1990) show the number of fish in the population declined from 1,148 in 1982 to 880 in 1990, a reduction of 27% in only 8 years. Fish numbers declined because reproduction and recruitment have been unsuccessful since 1974 (Apperson and Anders 1990, 1991). The threat of further decline in fish number and loss of genetic variability led local conservation groups to petition the U.S. Fish and Wildlife Service in June 1992 to list the Kootenai River white sturgeon as an endangered population under the Endangered Species Act of 1973 (Duke 1993).

Several steps have been taken to protect the Kootenai River white sturgeon. Fishing restrictions were imposed in Montana (fishery closed in 1979), Idaho (fishing limited to catch and release in 1984), and British Columbia (fishing limited to catch and release in 1984) to limit further losses. The Kootenai River White Sturgeon Committee, with representation from federal and state agencies, the Kootenai Tribe, and public interest groups, was formed in 1992 to undertake efforts to increase flow rate and restore natural river habitat. Efforts by management agencies to restore the habitat needed for sturgeon spawning and recruitment have yielded little progress to date. Until the habitat is restored, a systematic program to preserve the genetic diversity of this population should be implemented because natural aging processes (mortality and senility) and poaching will continue to reduce the population each year until it approaches extinction.

Natural reproduction has failed in this population for the past 19 years or the equivalent of one full generation. As a result, the natural age structure has been seriously disrupted and the effective population size reduced. Management agencies currently think that reproductive failure occurs because (1) adults fail to spawn due to lack of sufficient water flow to allow successful natural spawning (Apperson and Anders 1990, 1991), and (2) progeny fail to survive to the yearling stage due to lack of food supply, toxic contamination, or dewatering of nursery areas (Apperson and Anders 1990; Don Scaar, Montana Department of Fish, Wildlife, and Parks, personal communication). Flows in the Kootenai River from June to October have been much lower than historic flows since completion of Libby Dam in 1972. Spawning success would be affected if May-June flows are inadequate to attract mature fish to spawning areas or to support successful spawning. Low flows from July to September would also contribute to reduced larval survival by dewatering significant parts of the shallow larval feeding areas.

In the absence of natural reproduction and restoration of natural spawning conditions, a genetic preservation program must be initiated that includes limited culture. The wild adults remaining in the population must be spawned for an entire generation of year classes before these fish are irretrievably lost, if the existing genetic variability is to be preserved and a natural age structure re-established. The proposed program would capture wild fish, collect gametes, and produce the essential new generation. Progeny would be reared through the vulnerable juvenile stages (incubation, sac-fry, initial feeding fry, and fingerling stages) as separate families using procedures described by Conte (1988). Fish would be returned to the Kootenai River at the earliest life stage at which they could be recruited successfully and survive to maturity. The potential hazards of using captive culture (inbreeding, genetic drift, domestication, selection, behavioral conditioning, and exposure to disease) and the negative interactions of hatchery and wild fishes that effect the hatchery generation have been well documented (Hynes et al. 1981, Krueger et al. 1981, Kincaid 1983, Allendorf and Ryman 1987, Kapuscinski and Jacobson 1987, Waples 1991). However, waiting for restoration of natural reproduction is a more dangerous risk because the entire population is threatened. The continued decline in population size risks additional loss of genetic variability and possible extinction of the population.

Many of the potentially detrimental effects associated with captive culture can be reduced significantly by incorporating simple precautions into the breeding plan (Hynes et al. 1981, Krueger et al. 1981, Kincaid 1983, Allendorf and Ryman 1987, Kapuscinski and Jacobson 1987). These precautions include (1) plant fish at the earliest possible life stage, (2) maintain fish at low rearing densities during culture, (3) maintain high numbers of brood fish (effective population numbers), (4) equalize the genetic contribution of all parental fish to the next generation, (5) capture brood fish from throughout the fishery and spawning season, (6) spawn all mature adults available, and (7) avoid selection of brood fish and progeny based on physical appearance and captive performance.

This breeding plan provides a systematic approach to preserve the Kootenai River white sturgeon gene pool, while management agencies work to restore river habitat conducive to natural spawning and larval survival. Until a breeding plan is initiated, however, the number of fish in this population will continue to decline. This plan guides management in the systematic collection and spawning of wild adults before they are lost from the breeding population. This approach attempts to preserve a greater portion of the available genetic variability than "doing nothing while we wait" for restoration of natural spawning conditions.

NOTE: **The captive breeding program outlined here should be discontinued when natural reproduction is re-established. If natural reproduction is not restored, however, the program must be continued every year for a minimum of one generation (a 20-year period) to restore the natural age structure. If the breeding plan is followed faithfully for the 20-year generation interval, it will yield a broodstock with an effective population size of approximately 200, or 22.7% of the current population.**

OBJECTIVES

The objectives of the proposed breeding plan are as follows:

1. Describe a long-term breeding approach to preserve genetic variability.
2. Provide a multi-year breeding system to re-establish age structure.
3. Provide a breeding structure to create and maintain a "high" effective population size.
4. Describe "preservation stocking" methods to minimize potential detrimental effects of conventional supplemental stocking programs.
5. Describe small-lot cultural procedures to reduce the risk of detrimental genetic effects commonly associated with intensive hatchery production.
6. Describe a marking system to maintain family identity throughout the life cycle.

EFFECTIVE BREEDING POPULATION

The effective breeding number (N_e) for a population is the number of individuals in a random breeding population with an equal sex ratio, which would yield the same rate of inbreeding or genetic drift as the population being studied (Falconer 1981).

$$N_e = \frac{4 \times N_m \times N_F}{(N_m + N_F)}$$

This formula calculates the N_e (effective population size) for populations produced from random mating N_m male parents and N_f female parents. Ideally, N_e is calculated from counts of the actual number of parents that contribute progeny to the next broodstock generation. Because the actual number of individuals contributing progeny to the next generation and the number of progeny each contributes is unknown in most populations, the number of individuals that spawn and produce progeny is used in the calculation, i.e., the total number of fish spawned of each sex. For animal species with multi-year generation intervals, N_e is calculated using the sum of all males (N_m) and females (N_f) spawning each year for the number of years in the generation interval adjusted by any difference in sex ratio and the number of individuals that spawn more than once per generation. The generation interval is defined as the average age of females at first maturity, or about 20 years for the Kootenai River white sturgeon. The N_e will be the total of all spawners (different fish spawned) over the 20-year generation interval.

The situation assumed for the Kootenai River white sturgeon population produced under the proposed captive culture program is that (1) each fish spawns only once per generation, (2) each individual contributes progeny to a single generation (i.e., generations do not overlap), and (3) each parent contributes an equal number of progeny to the next generation. While white sturgeon can (and do) spawn multiple times during their reproductive life, the above conservative assumptions are reasonable because (1) the actual spawning frequency of white sturgeon in the Kootenai River is unknown, (2) little successful reproduction has been documented in this population since 1974 (about one generation) to contribute a progeny generation, and (3) the proposed breeding plan limits, but does not eliminate, multi-year spawning of individual fish.

Ideally, all sexually mature individuals should be spawned to contribute progeny to the next generation, to ensure the total parental gene pool is transmitted to the progeny generation. In the situation where a natural population is perpetuated by randomly sampling the parental generation, the minimum recommended number of founder stock to ensure the genetic integrity of the gene pool is 100 to 200 fish (Allendorf and Phelps 1980, Hynes et al. 1981, Krueger et al. 1981, Kincaid 1983). In light of the threatened status of Kootenai River white sturgeon, a random sample of 200 fish (100 males and 100 females) should be spawned to contribute progeny to the next generation over the next 20 years. This works out to an average of 10 brood fish (total of males and females) per year, i.e., 10 different fish each year for 20 years. While the actual number in any given year may be more or less, the average of 10 needs to be achieved to minimize the risk of losing genetic variability. The annual N_e values, for different numbers of males and females available for mating, are shown in Table 1. The practice of stocking equal numbers of progeny from each family will maximize N_e by reducing variability of family size and will also minimize any effects of domestication (Ryman and Laikre 1990, Allendorf 1993).

The Kootenai River white sturgeon restoration program will undertake concurrent thrusts: (1) to obtain higher water flows in the river to re-establish natural spawning habitat, and (2) to initiate a captive culture program to preserve the existing genetic variation until natural spawning is restored. As a result, a constraint is placed on the captive culture program to ensure that at least 50% of mature females in any given year are retained in the fishery and allowed to spawn "naturally," if river conditions permit. Reports by Apperson and Anders (1990, 1991) indicate 19-55 females are mature each year. Using the lower value, up to 9 females could be captured and spawned to produce fish for the culture program. To ensure that mature fish are available to spawn (naturally) in the river when adequate spawning conditions are present, any fish (male or female) not required for the cultural program must be returned to the river before the start of the spawning season.

ANNUAL BREEDING AND CAPTIVE CULTURE PLAN

This breeding plan requires the systematic capture of sexually mature wild fish from staging areas in the Kootenai River. Captured fish will be held for 1 to 2 months until ready to spawn. At maturity, each female will be spawned and the eggs fertilized with milt from one male (see mating design options that follow) to form a family. The resulting families will be incubated separately. After recovery from the spawning operation, wild brood fish will be returned to the river at the point of capture. When a family is hatched and before the fry begin to feed, it will be divided randomly into two or more separate tanks for rearing to the target stocking age. Throughout the cultural operation, special care must be taken to ensure that positive family identity is maintained. When tanks become overcrowded, fish will be divided randomly (i.e., no selection of fish except for gross abnormalities) into two tanks. When fish reach the target stocking age, equal numbers of fish from each family will be stocked into the river. Repeating the basic breeding plan each year over the entire generation interval will produce successive year classes to re-establish the natural age structure of the wild population. All fish that are surplus to stocking needs will be destroyed using approved euthanasia procedures.

NOTE: Surplus fish should not be retained in the program to avoid the temptation to plant (supplemental stocking) them, which is not desirable in programs designed to preserve the genetic variation of unique gene pools.

MATING DESIGN OPTIONS

The number of mature males and females captured from the fishery will vary from year to year, leading to the need for both single pair and half-sib family mating designs. Ideally, single pair matings (one male to one female) are preferred, with each fish used as a parent only once. However, in view of the difficulty in capturing sexually mature fish, the expectation that more males than females will be recovered, and the frequency of multiple recaptures of the same fish in successive years, the following rules for mating and handling fish will be followed.

1. When the number of spawning fish is 4 or more mating pairs (4 males and 4 females), mate one male to one female (using each fish as a parent in only one mating) to create totally unrelated families. Fish in excess of 8 pairs will be returned to the river and allowed to spawn naturally.
2. When there are 3 mature females in the captured broodstock, eggs from each female should be divided into 3 aliquots and mated to different males to form half-sib families for each female. Because males must not be used in more the one mating, a total of 9 males will be required. Males will be randomly assigned to the individual females. This will create a set of three half-sib families for each female, with no relationship between female half-sib family sets. Males in excess of 9 will be released and allowed to spawn naturally.
3. When there are 2 mature females in the captured broodstock, eggs from each female should be divided into 4 aliquots and mated to different males to form half-sib families for each female. Because males must not be used in more the one mating, a total of 8 males will be required. Males will be randomly assigned to the individual females. This will create a set of four half-sib families for each female, with no relationship between female half-sib family sets. Males in excess of eight will be released and allowed to spawn naturally.
4. When only one mature female is available, no lots will be spawned. All fish will be returned to the river and allowed to spawn naturally.
5. After a fish, male or female, has produced one (1) progeny family, it should not be spawned again for at least 5 years. If the fish is recaptured during the 5-year period, it should be released and allowed to spawn naturally. After 5 years, a fish could be used to produce a second family if no other unused fish are available for spawning. No fish should be used more that twice in the culture program, except females mated to multiple males in items 2 and 3 above. This rule serves to limit and equalize the genetic contribution of individual parents to the progeny generation under the captive culture program. Its primary effect will be to limit repeated use of males captured each year because the reported spawning frequency is 2-4 years for males and 3-10 years for females (Conte 1988). Fish that mature multiple years during the next 20 years will have the opportunity to contribute to the fishery through the captive culture program and natural spawning.
6. All fish not already tagged will be PIT (passive integrated transponder) tagged as they are captured and a permanent record established. Data recorded will include the capture location and the length, weight, and breeding history of each fish.

RECORD SYSTEM

Breeding history, recapture frequency, and progeny production information from each brood fish is essential for management to know the genetic contribution to the succeeding generation and the ultimate success of the long-term genetic variability maintenance program. The record system must contain at least the following information: (1) identity of individual brood fish, (2) progeny family identification, (3) progeny year-class identification, (4) number of progeny stocked per family, (5) survival of each family to maturity, and (6) contribution of each family to the next captive broodstock generation.

A tagging system (PIT tags) to provide positive identification of parental fish will be essential for development of breeding history information to allow biologists to limit the genetic contribution of individuals captured year after year. A marking system will also be essential to identify families and year classes for determination of post-stocking survival and subsequent genetic contribution to the next generation. Because PIT tags are expensive and too large for subyearling fish, they are not suitable for use on fall fingerlings. A multiple mark system, using a combination of coded-wire tags and scute removal (Rein et al. 1993), would provide positive identification of families, year-classes, and hatchery origin needed to accommodate a subyearling planting program. The coded-wire tag would identify that a fish was produced by a captive broodstock mating and would provide family and year-class information. Scute removal in specific locations would also provide a visual mark to identify the family and the year-class of all fish planted. When fish are recovered from the fishery at a later age, they would be identified by reading the scute record then PIT tagged to initiate the individual and family record. As fish are recaptured in the future, tag number, distinguishing mark, length, weight, recovery location, and recovery date will be recorded in the permanent record. Information gained from this program will allow managers to evaluate survival, growth, and reproduction on a family basis.

TARGET STOCKING NUMBER

The recruitment goal for each family in this program is "enough fish to produce 4 to 10 adults at 20 years of age." This number will allow the broodstock population to expand slowly with a "natural" variability in family contribution to the succeeding generation. The genetic contribution of each family will be limited by the number of fish planted, and each brood fish will be limited by the number of times its gametes are used in captive matings. Variation in the number of progeny contributed to the next broodstock generation will occur naturally because of differential survival resulting from natural selection and random chance after the fish are returned to the river. The primary difficulty in determining the number of fish to stock from each family is a lack of information on post-stocking survival of juvenile white sturgeon from age 0 to age 20. This lack of information prevents calculation of optimal stocking rates based on age at stocking. In addition, normal year-to-year environmental variation in precipitation, flooding, flow rates, temperature, predator populations, and food supply can create wide variation in annual and long-term survival.

A range of survival rates at successive life stages can be modeled, leading to very different optimum planting rates (Table 2). If fish are planted at age 1+ and have annual survival rates of 50% the first year, 60% the second, 70% the third, and 80% thereafter through the 18th year (age 20), a 1,000 fish plant will yield 7 brood fish at age 20 (Case 5, Table 2). Based on these assumptions, stocking 1,000 fish per family would produce the 4-10 breeding adults desired in the next broodstock generation. Until better information is developed, a target of 1,000 yearling or 5,000 fall fingerlings (age, 3-6 months) should be planted per family. These numbers would be adjusted when recovery data from the initial plantings become available.

PRESERVATION STOCKING

The standard concept of supplemental stocking is that large numbers of fish are reared to the fingerling or yearling stage, then planted on top of a "natural" population to expand the production of that fishery. The goal of a supplemental stocking program is typically to expand the population or increase production of a fishery; little attention is given to preservation of the existing gene pool. The term "preservation stocking" is used here to indicate that preservation of genetic variability is the primary objective of the program; "slow" expansion of the population is a secondary goal. Undesirable effects commonly associated with supplemental stocking occur when the hatchery product (1) competes with wild fish for food and rearing space, resulting in reduced survival of the wild fish; (2) competes with wild fish for spawning habitat, resulting in reduced reproduction of the wild fish; and (3) interbreeds with wild fish, resulting in the introduction of hatchery-adapted genes, which dilute the genetic attributes and gene complexes that enhance "wild" survival, growth, and reproductive performance. This plan differs from "conventional" supplemental stocking in several ways. First, because the current broodstock has not reproduced successfully since 1974, there is no reproducing population of white sturgeon in the Kootenai River to compete and interbreed with fish planted under this plan. Second, the number of fish planted will be small compared with conventional supplemental stocking programs. The number of fish planted per family will be equalized at a level designed to produce only 2-5 times broodstock replacement numbers.

The objective of this plan is to preserve the existing gene pool; therefore, the number of fish planted will represent equal numbers from all available families and will be only enough to produce 4-10 adults per family at maturity. As individual fish will be used as parents only once every 5 years, the likelihood of inbreeding in future generations will be reduced. Effects of preservation stocking, as outlined under this plan, do not pose a threat to the genetic composition of the existing gene pool. Conversely, this plan offers an approach for preserving the genetic variability remaining in this seriously threatened, declining white sturgeon population.

RECOMMENDATIONS FOR OTHER STEPS TO AID RESTORATION

During the initial stages of this program major efforts should be made to collect additional genetic information on the Kootenai River white sturgeon, to develop cultural technology to rear multiple small lots, and to develop nonsurgical spawning techniques.

1. Limited genetic baseline information (Setter and Brannon, 1992) and no breeding history are available on the Kootenai River White sturgeon. Because there is a high probability that actual effective population size is much less than indicated by the 1990 estimate of population size (880 individuals), a refined estimate of N_e would be valuable. The linkage disequilibrium method (Bartley et al. 1992) for N_e estimation would be appropriate and should be applied over the next 2 years. Non-lethal tissue samples (blood, muscle, and scute) could be taken from fish captured during routine netting operations for population assessment and broodstock capture. Tissue samples from each fish captured over a 2-year period (about 25-40 fish) would provide the information necessary to estimate N_e. This information would help determine the urgency of implementing restoration efforts and provide guidance for adjustments to the proposed breeding plan.
2. The goal for the cultural operation will be an annual production of 8-12 separate lots (families), each consisting of 5,000 fingerlings or 1,000 yearlings for stocking in the Kootenai River. This is new technology for many culturists and fishery biologists. Hatchery facilities will need to be re-designed and modified to accommodate these small groups effectively. Cultural practices and procedures will also need revision to provide reduced rearing densities, introduce special precautions to ensure absolute separation of family groups during culture, and implement tagging systems to give positive identification of individuals throughout the life cycle.
3. Techniques are needed for reliable, nonsurgical spawning of white sturgeon. Currently, most females are spawned by surgical removal of the eggs. The fish must then be held in the hatchery until the incision is healed. This means that while the female produced several hundred thousand eggs, only those retained for culture are available to the fishery; the remaining eggs are lost. Methods are needed to allow fish to be released after the initial spawning to complete spawning naturally in the river. If this is not possible, an alternative would be development of methodology to release fertilized eggs in "appropriate" spawning sites. A means

is needed to ensure that gametes produced "in the river" can be used for both captive and natural spawning to provide maximum likelihood that the genetic variability of the Kootenai River white sturgeon will be preserved.

COMPARISON OF RESTORATION APPROACHES

Two approaches are proposed to restore white sturgeon in the Kootenai River. The first approach is to restore water flows in the Kootenai River, during the spawning season and developing fry period, to levels approaching those recorded in the early 1970's and known to support successful reproduction of white sturgeon. There is high expectation that increased water flow will support natural spawning, which will increase population number and begin to restore a natural age class structure. The advantage of this approach is that it is natural, and fish would not be subjected to hatchery culture, thereby avoiding potential domestication and exposure to disease organisms. The disadvantage is that population size would continue to decrease, with the associated loss of genetic variability, until the natural spawning habitat is restored. Despite high expectation, however, the possibility exists that increasing water flows alone may not restore natural spawning. If this were the case, and in light of the time needed for verification of successful spawning and recruitment, it could be several years before the true situation became known. During the period of verification, population size would continue to decline, and more of the older fish would become senile. The result would be continued disruption of age class structure, with additional missing year classes. If water flows to support natural spawning are not provided every year, the problem of verification of the true situation will be exacerbated because fewer juveniles would be available for capture.

The second approach, use of the captive breeding program described here, has the following advantages: (1) rebuilding the age structure would begin immediately, with a random portion of the mature broodfish each year contributing progeny to the next generation. All of these fish are currently lost to the fishery because of inadequate natural spawning habitat; (2) increased numbers of broodfish would contribute to the next generation before they were lost to senility or death; and (3) higher numbers of fish would survive to ages that could be successfully recruited into the population. Disadvantages include (1) increased exposure of broodfish and progeny to the cultural environment, i.e., artificial feed, tanks, handling, and diseases; (2) unavailability of captive fish to spawn naturally if suitable spawning conditions were present in the river; and (3) increased costs to produce and tag fish over several years.

The idea that these two approaches are incompatible is a misconception. There is no biological reason to prevent simultaneous implementation of both approaches. Indeed, when the advantages and disadvantages of both approaches are considered in light of the current "threatened" status of the Kootenai River white sturgeon, simultaneous implementation of both approaches seems to offer the highest probability to protect and preserve the genetic variability of the Kootenai River white sturgeon.

The captive breeding plan allows management to begin the long-term process of re-establishing the natural age structure, using progeny from a random sample of the mature broodfish each year, before the population is reduced further. Captive breeding should be continued until evidence is available to show that natural reproduction is yielding adequate recruits to sustain the genetic variability of the population. Likewise, work to re-establish flow rates capable of supporting "quality" spawning and rearing habitat for all life stages should move forward as quickly as possible. Once natural habitat for sturgeon has been re-established, the captive breeding program should be discontinued. The two approaches are supportive of each other and not incompatible when applied properly.

REFERENCES

Allendorf, F. W. 1993. Delay of adaptation to captive breeding by equalizing family size. Conservation Biology 7(2):416-419.

Allendorf, F. W. and S. R. Phelps. 1980. Loss of genetic variation in a hatchery stock of cutthroat trout. Transactions of the American Fisheries Society 109:532-543.

Allendorf, F. W. and N. Ryman. 1987. Genetic management of hatchery stock: past, present, and future. Pages 141-159 in N. Ryman and F. Utter, editors. Population Genetics and Fisheries Management, Washington Sea Grant Publications/University of Washington Press. Seattle, Washington and London, England.

Apperson, K. A. and P. J. Anders. 1990. Kootenai River white sturgeon investigations and experimental culture. Annual Progress Report FY 1989. Bonneville Power Administration. 60 pp.

Apperson, K. A. and P. J. Anders. 1991. Kootenai River white sturgeon investigations and experimental culture. Annual Progress Report FY 1990. Bonneville Power Administration. 75 pp.

Bartley, D., M. Bagley, G. Gall, and B. Bentley. 1992. Use of linkage disequilibrium data to estimate effective size of hatchery and natural fish populations. Conservation Biology 6(3):365-375.

Conte, F. S., S. I. Doroshov, P. B. Lutes, and E. M. Strange. 1988. Hatchery manual for the white sturgeon Acipenser transmontanus Richardson with application to other North American Acipenseridae. Cooperative Extension, University of California, Division of Aquaculture and Natural Resources, Publication 3322.

Duke, S. D. 1993. Endangered and threatened wildlife and plants; Proposed endangered status for the Kootenai River population of the white sturgeon. Federal Register 58(128):36379-36386.

Falconer, D. S. 1981. Introduction to quantitative genetics, 2nd Edition. Longman Inc., London. 352 pp.

Hynes, J. D., E. H. Brown Jr., J. H. Helle, N. Ryman, and D. A. Webster. 1981. Guidelines for the culture of fish stocks for resource management. Canadian Journal of Fisheries and Aquatic Sciences 38:1867-1876.

Kapuscinski, A. and L. Jacobson. 1987. Genetic guidelines for fisheries management. Minnesota Sea Grant Program, Sea Grant Research Report Number 17. 66 pp.

Kincaid, H. L. 1983. Inbreeding in fish populations used in aquaculture. Aquaculture 3:215-227.

Krueger, C., A. Garrett, T. Dehring, and F. Allendorf. 1981. Genetic aspects of fisheries rehabilitation programs. Canadian Journal of Fisheries and Aquatic Sciences. 38:1877-1881.

Northcote, T. C. 1973. Some impacts of man on Kootenay Lake and it's salmonids. Great Lakes Fisheries Commission, Technical Report 2.

Partridge, F. 1983. River and stream investigations. Idaho Department of Fish and Game, Federal Aid to Fish and Wildlife Restoration, Project F-73-R-5, Subproject IV, Study VI: Kootenai River Fisheries Investigations. 94 pp.

Rein, T., R. Beamesderfer, and C. Foster. 1993. Retention, recognition, and effects on survival of several tags and marks on white sturgeon. Pages 35-45 in R. C. Beamesderfer and A. A. Nigro, editors. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary dam. Volume 2, Bonneville Power Administration.

Ryman, N. and L. Laikre. 1990. Effects of supportive breeding on the genetically effective population size. Conservation Biology 5:325-329.

Setter, A. and E. Brannon. 1992. A summary of stock identification research on white sturgeon on the Columbia River (1985-1990). Bonneville Power Administration. 99 pp.

Waples, R. 1991. Genetic interactions between hatchery and wild salmonids: Lessons from the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 48(supplement 1):124-133.

Table 1. Effective population number based on the actual number of males and females used to produce the progeny generation. Identify the number of females in columns and the number of males in rows; the calculated effective breeding number for this combination can be read at the column and row intersection.

Number male parents	Number female parents											
	1	2	3	4	5	6	7	8	9	10	11	12
1	2.0	2.7	3.0	3.2	3.3	3.4	3.5	3.6	3.6	3.6	3.7	3.7
2	2.7	4.0	4.8	5.3	5.7	6.0	6.2	6.4	6.5	6.7	6.8	6.9
3	3.0	4.8	6.0	6.9	7.5	8.0	8.4	8.7	9.0	9.2	9.4	9.6
4	3.2	5.3	6.9	8.0	8.9	9.6	10.2	10.7	11.1	11.4	11.7	12.0
5	3.3	5.7	7.5	8.9	10.0	10.9	11.7	12.3	12.9	13.3	13.8	14.1
6	3.4	6.0	8.0	9.6	10.9	12.0	12.9	13.7	14.4	15.0	15.5	16.0
7	3.5	6.2	8.4	10.2	11.7	12.9	14.0	14.9	15.7	16.5	17.1	17.7
8	3.6	6.4	8.7	10.7	12.3	13.7	14.9	16.0	16.9	17.8	18.5	19.1
9	3.6	6.5	9.0	11.1	12.9	14.4	15.7	16.9	18.0	19.0	19.8	20.6
10	3.6	6.7	9.2	11.4	13.3	15.0	16.5	17.8	19.0	20.0	21.0	21.8
11	3.7	6.8	9.4	11.7	13.8	15.5	17.1	18.5	19.8	20.6	22.0	23.0
12	3.7	6.9	9.6	12.0	14.1	16.0	17.7	19.1	20.6	21.8	23.0	24.0

Table 2. Expected survival of white sturgeon for an 18-year period after planting, under different scenarios of annual survival rates. All examples are calculated on an initial stocking of 1,000 fish.

Years in river	Case 1 % surv.	Case 1 No. fish	Case 2 % surv.	Case 2 No. fish	Case 3 % surv.	Case 3 No. fish	Case 4 % surv.	Case 4 No. fish	Case 5 % surv.	Case 5 No. fish	Case 6 % surv.	Case 6 No. fish
1	0.5	500	0.5	500	0.5	500	0.50	500	0.5	500	0.50	500
2	0.5	250	0.6	300	0.6	300	0.60	300	0.6	300	0.60	300
3	0.5	125	0.6	180	0.7	210	0.70	210	0.7	210	0.70	210
4	0.5	63	0.6	108	0.7	147	0.75	158	0.8	168	0.80	168
5	0.5	31	0.6	65	0.7	103	0.75	118	0.8	134	0.85	143
6	0.5	16	0.6	39	0.7	72	0.75	89	0.8	108	0.85	121
7	0.5	8	0.6	23	0.7	50	0.75	66	0.8	86	0.85	103
8	0.5	4	0.6	14	0.7	35	0.75	50	0.8	69	0.85	88
9	0.5	2	0.6	8	0.7	25	0.75	37	0.8	55	0.85	75
10	0.5	1	0.6	5	0.7	17	0.75	28	0.8	44	0.85	63
11	0.5	0	0.6	3	0.7	12	0.75	21	0.8	35	0.85	54
12	0.5	0	0.6	2	0.7	9	0.75	16	0.8	28	0.85	46
13	0.5	0	0.6	1	0.7	6	0.75	12	0.8	23	0.85	39
14	0.5	0	0.6	1	0.7	4	0.75	9	0.8	18	0.85	33
15	0.5	0	0.6	0	0.7	3	0.75	7	0.8	14	0.85	28
16	0.5	0	0.6	0	0.7	2	0.75	5	0.8	12	0.85	24
17	0.5	0	0.6	0	0.7	1	0.75	4	0.8	9	0.85	20
18	0.5	0	0.6	0	0.7	1	0.75	3	0.8	7	0.85	17

Years in river	Case 7 % surv.	Case 7 No. fish	Case 8 % surv.	Case 8 No. fish	Case 9 % surv.	Case 9 No. fish	Case 10 % surv.	Case 10 No. fish	Case 11 % surv.	Case 11 No. fish	Case 12 % surv.	Case 12 No. fish
1	0.6	600	0.3	300	0.3	300	0.40	400	0.2	200	0.20	200
2	0.8	480	0.4	120	0.4	120	0.60	240	0.4	80	0.50	100
3	0.9	432	0.8	96	0.9	108	0.75	180	0.6	48	0.60	60
4	0.9	389	0.8	77	0.9	97	0.75	135	0.8	38	0.70	42
5	0.9	350	0.8	61	0.9	88	0.75	101	0.9	35	0.80	34
6	0.9	315	0.8	49	0.9	79	0.75	76	0.9	31	0.80	27
7	0.9	283	0.8	39	0.9	71	0.75	57	0.9	28	0.85	23
8	0.9	255	0.8	32	0.9	64	0.75	43	0.9	25	0.85	19
9	0.9	230	0.8	25	0.9	57	0.75	32	0.9	23	0.90	18
10	0.9	207	0.8	20	0.9	52	0.75	24	0.9	20	0.90	16
11	0.9	186	0.8	16	0.9	47	0.75	18	0.9	18	0.95	15
12	0.9	167	0.8	13	0.9	42	0.75	14	0.9	17	0.95	14
13	0.9	151	0.8	10	0.9	38	0.75	10	0.9	15	0.95	14

Table 2. Continued.

Years in river	Case 7 % surv.	Case 7 No. fish	Case 8 % surv.	Case 8 No. fish	Case 9 % surv.	Case 9 No. fish	Case 10 % surv.	Case 10 No. fish	Case 11 % surv.	Case 11 No. fish	Case 12 % surv.	Case 12 No. fish
14	0.9	136	0.8	8	0.9	34	0.75	8	0.9	13	0.95	13
15	0.9	122	0.8	7	0.9	31	0.75	6	0.9	12	0.95	12
16	0.9	110	0.8	5	0.9	28	0.75	4	0.9	11	0.95	12
17	0.9	99	0.8	4	0.9	25	0.75	3	0.9	10	0.95	11
18	0.9	89	0.8	3	0.9	22	0.75	2	0.9	9	0.95	10

Table 3. Continued.

Count of years	Years	Survival calculation (3.26%)	Annual rate of loss from the population (%)									
			1	2	3	4	5	6	7	8	9	10
135	2125	10	227	58	14	4						
140	2130	8	215	52	12	3						
145	2135	7	205	47	11	2						
150	2140	6	195	43	9							
155	2145	5	185	38	8							
160	2150	4	176	35	7							
165	2155	4	168	31	6							
170	2160	3	159	28	5							
175	2165	3	152	26	4							
180	2170	2	144	23	4							
185	2175		137	21	3							
190	2180		130	19	3							
195	2185		124	17	2							
200	2190		118	15	2							
205	2195		112	14								
210	2200		107	13								
215	2205		101	11								
220	2210		96	10								
225	2215		92	9								
230	2220		87	8								
235	2225		83	8								
240	2230		79	7								
245	2235		75	6								
250	2240		71	6								
Project years to extinction		191	643	324	209	155	123	102	87	76	67	60

Table 3. Expected population size at 5 year intervals during the 250 year period from 1982 to 2340 are calculated, assuming an initial population of 880 and constant annual mortality rates of 1 to 10%. A 3.26% annual mortality rate (calculated mortality rate from 1982 and 1990 population estimates) is projected to show the current rate of population decline. Time to extinction was calculated for each mortality rate.

Count of years	Years	Survival calculation (3.26%)	Annual rate of loss from the population (%)									
			1	2	3	4	5	6	7	8	9	10
5	1995	745	837	795	756	718	681	646	612	580	549	520
10	2000	631	796	719	649	585	527	474	426	382	343	307
15	2005	535	757	650	557	477	408	348	296	252	214	181
20	2010	483	720	587	479	389	315	225	206	166	133	107
25	2015	383	684	531	411	317	244	187	143	109	83	63
30	2020	325	651	480	353	259	189	138	100	72	52	37
35	2025	275	619	434	303	211	146	101	69	48	32	22
40	2030	233	589	392	260	172	113	74	48	31	20	13
45	2035	197	565	362	223	140	88	54	34	21	13	8
50	2040	167	532	320	192	114	68	40	23	14	8	5
55	2045	141	506	290	165	93	52	29	16	9	5	
60	2050	120	481	262	142	76	41	21	11	6		
65	2055	101	458	237	122	62	31	16	8	4		
70	2060	86	435	214	104	51	24	12	5			
75	2065	73	414	193	90	41	19	8	4			
80	2070	62	394	175	77	34	15	6				
85	2075	52	375	158	66	27	11	5				
90	2080	44	356	143	57	22	9	3				
95	2085	37	339	129	49	18	7	2				
100	2090	32	322	117	42	15	5					
105	2095	27	306	105	36	12	4					
110	2100	23	291	95	31	10	3					
115	2105	19	277	86	26	8	2					
120	2110	16	263	78	23	7						
125	2115	14	251	70	20	5						
130	2120	12	238	64	17	4						

Appendix E. White sturgeon broodstock collection protocols.

Purpose: Develop genetically sound guidelines for Kootenai River white sturgeon broodstock collection and mating design options.

- This protocol is designed to maximize white sturgeon broodstock collection efficiency, reproductive success and genetic variation of broodstock while maximizing negative effects of handling stress on the wild population. It is also designed to minimize negative effects of broodstock collection on natural spawning of white sturgeon in the Kootenai River.

- Broodstock should be collected from a wide geographic and temporal range to maximize genetic variability of individual white sturgeon broodstock for the Kootenai Hatchery.

- While genetic variation (heterozygosity) among individuals in the Kootenai River white sturgeon population is currently unknown, this approach is designed to maximize the diversity of genetic material passed on from the spawned adults to the F1 generation produced in the Kootenai Hatchery.

- Collect and spawn 3 to 6 ripe females and 6 to 9 ripe males annually for spawning in the Kootenai Hatchery for a 10 consecutive year period (1996 through 2005) in the following fashion, with a goal of approximating an annual spawning population number of 10:

Number of females	Max. # of males	Maximum Spawning Population	Max. # of Families
3	9	9.0	9
4	8	10.7	8
5	5	10.0	5
6	6	12.0	6

- Broodstock collection can occur anywhere in the Kootenai River before the first day of egg mat deployment.

- No egg mats will be placed in the Kootenai River downstream from Burton Creek (rkm 227.7).

- When augmented flows in the spring increase or ramp up at a rate $\geq$ 4,000 cfs/day, IDFG may remove egg sampling mats from the Kootenai river for a maximum of three days. The IDFG will notify KTOI at least 24 hours before egg mat removal and 24 hours before re-deployment. During this three day period, the KTOI can fish for white sturgeon broodfish anywhere downstream from Myrtle Creek (rkm 235.6) until mats are re-deployed.

- Fishing to collect hatchery broodstock can begin as early as April 1, and continue until July 1, 1996 downstream from rkm 227.5 and in other areas according to the following conditions:

- The Shorty's Island area (approx. rkm 230-231): This one kilometer reach is reserved exclusively for broodstock collection; no egg mats will be deployed in this reach. This reach will be identified in the field as the pumping station outlet (upstream end) to rkm 230 on the downstream end (marked with stake and flagging on each side of the river)

- No broodstock collection can occur upstream from Shorty's Island <u>with one exception</u>: If no gravid females are in the Kootenai Hatchery by May 15, 1996, then up to 2 gravid females may be taken from Ambush Rock (rkm 243.5 - 224.6, mill boat ramp). No egg mats will be placed in this river section under this condition.

- White sturgeon fitted with active radio or sonic transmitters captured during broodstock collection will <u>not</u> be brought to the Kootenai Hatchery to be spawned; they must be released unharmed as quickly as possible.

- As soon as white sturgeon broodstock collection is completed, all areas of the Kootenai River are available for egg larval sampling.

APPENDIX F: Summary of the Public, Agency, and Peer Review Comments on the Draft Kootenai River White Sturgeon Recovery Plan.

On July 2, 1996, the Fish and Wildlife Service released the Draft Recovery Plan for the Kootenai River population of white sturgeon for a 90-day comment period that ended September 30, 1996, for Federal agencies, State and local governments, members of the public and peer review (61 Federal Register 34441).

Eighteen letters were received, each containing varying numbers of comments. The Fish and Wildlife Service also sent letters to seven "experts" in the field of white sturgeon biology and conservation requesting comments on the Draft Recovery Plan. Responses were received from four of these experts, who provided comments and recommendations on the proposed conservation aquaculture program, the adequacy of ongoing monitoring and research activities, and on the downlisting and delisting criteria.

Number of letters received, by affiliation:

Federal agencies	4 letters
State and local governments	5 letters
Business and industry	1 letter
Canada	3 letters
Native American Tribes	1 letter
General public	2 letters
Academia and professionals	2 letters

Summary of Significant Comments and Fish and Wildlife Service Responses

The Fish and Wildlife Service reviewed all of the comments received during the comment period. Many specific comments reoccurred in the letters. Comments updating the information in the draft recovery plan have been incorporated into the appropriate section of this final recovery plan. The substantive comments and the Fish and Wildlife Service's response to each are summarized as follows:

Comment 1: Statements in the draft recovery plan appear to relegate white sturgeon recovery to a lesser status than Snake River salmon recovery.

Response 1: The Fish and Wildlife Service disagrees and attempts have been made to correct this misconception. Recovery plans describe reasonable actions that are believed necessary to recover and protect threatened or endangered species. Recovery actions cannot occur without full consideration of their effects on other resources, including other listed species. In this example, proposed changes in Libby Dam operations to benefit white sturgeon may need to be modified in future years under certain environmental conditions (i.e. drought or low water conditions) to benefit listed Snake River salmon. The National Marine Fisheries Service has yet to complete a final recovery plan for salmon. Therefore, we cannot discuss how the National Marine Fisheries Service recovery plan complements white sturgeon recovery in the Kootenai River.

Libby Dam is the only facility in the United States within the Columbia River basin that affects Kootenai River white sturgeon and other facilities in the United States could provide comparable water volumes for salmon recovery needs. The Fish and Wildlife Service and National Marine Fisheries Service have informally agreed that should recommendations for listed Snake River salmon pose unacceptable risks to white sturgeon survival and recovery, the National Marine Fisheries Service would defer and recommend water releases from other Columbia River facilities.

Comment 2: The recovery plan should clarify the statement "...In most years, the plan should complement conservation measures designed by the National Marine Fisheries Service to meet Snake River chinook and sockeye salmon recovery objectives downstream in the Columbia River."

Response 2: Language has been inserted to clarify that balance with salmon recovery is achievable in "...all but the most extreme low water years...."

Comment 3: Language added to the draft recovery plan "...or meeting section 7 requirements for Snake River salmon.." creates a situation in dry years where Libby Dam releases would impact reservoir refill and impact the system's ability to meet flow targets the following year.

Response 3: The Fish and Wildlife Service agrees that in low flow years, requests for Kootenai River flows to meet section 7 requirements for listed salmon downstream will impact Koocanusa Reservoir refill probability. Although there would be no additional spring flow requests for white sturgeon during low flow years (e.g., critical water years 3 or 4), additional demands for Kootenai River water may need to be addressed.

Comment 4: Will you ever be able to define what is needed and develop recovery criteria for habitat restoration or when the white sturgeon population can be down listed or delisted?

Response 4: Specific recovery criteria have been developed. They will be refined as new population status, life history, biological productivity, and flow augmentation monitoring information is collected. Recovery will require that natural reproduction occurs and a demonstration that Kootenai River environmental conditions that produce natural reproduction are repeatable.

Comment 5: State a time frame for developing delisting criteria.

Response 5: The following language has been added "...it will be approximately 25 years following approval of this recovery plan before delisting of the white sturgeon population can be considered. Twenty-five years is the approximate period for female white sturgeon added to the population during the next 10 years to reach maturity and reproduce to complete a new generation or spawning cycle."

Comment 6: The final recovery plan should provide more clarity regarding what version of Integrated Rule Curves will be used for white sturgeon recovery.

Response 6: The final recovery plan includes a thorough description and evaluation of effects of the proposed Kootenai Integrated Rule Curves (KIRCs) (see Appendix B).

Comment 7: The Army Corps of Engineers has determined that the Integrated Rule Curves do not provide adequate flood storage in the highest runoff years. The Army Corps of Engineers is investigating a variable release strategy for flood control (VARQ) that could allow the implementation of an Integrated-Rule-Curves-type operation in many years of low to moderate runoff, but will supersede Integrated Rule Curves in above average volume runoff years.

Response 7: The proposed Kootenai Integrated Rule Curves reconciles differences between Integrated Rule Curves and variable release strategy to address flood control concerns.

Comment 8: The National Marine Fisheries Service's 1995 Biological Opinion on the operation of the Federal Columbia River Power System is consistent with the operational requirements at Libby Dam for Kootenai River white sturgeon.

Response 8: This recovery plan attempts to restore more normative Kootenai River flows, and it is difficult to justify support of August or late summer flows that are three to five times greater than those of a natural, unregulated hydrograph, as outlined in the Biological Opinion. Summer flushing of epilimnetic water from Kootenay Lake adversely affects invertebrate and fish production. It is the Fish and Wildlife Service's hope that other United States facilities could provide the necessary volumes of water for salmon recovery while retaining as much of the natural hydrograph as possible on the Kootenai River.

Comment 9: Montana's Integrated Rule Curves conflict with the National Marine Fisheries Service's Biological Opinion and the National Marine Fisheries Service's proposed recovery plan for Snake River salmon. Moreover, the National Marine Fisheries Service "...cautioned that it could undermine the federal government's position to protect both endangered salmon and sturgeon if USFWS white sturgeon plan supported Libby Dam Integrated Rule Curves."

Response 9: As stated in response 8, it is difficult to justify support of August or late summer flows that are three to five times greater than those of a natural, unregulated hydrograph. However, this apparent conflict has been successfully mitigated by up to a 50 percent August flow reduction achieved through negotiations with BC Hydro. With National Marine Fisheries Service support we may find a way to firm up water exchanges or establish new strategies such as limited manipulation of Kootenay Lake for storage of salmon flow water. Future decisions pending on John Day Reservoir drawdown proposals for the lower Columbia River could greatly diminish the need for later summer Kootenai River water releases.

Comment 10: Nothing in the Draft Sturgeon Plan suggests that it is necessary to the recovery of Kootenai River sturgeon to use operational guidelines based upon Integrated Rule Curves. "The National Marine Fisheries Service 'strongly' suggests that the final Plan adopt the Opinion operation at Libby Dam...."

Response 10: See response 9.

Comment 11: The Idaho Department of Fish and Game has "...some serious reservations about the Conservation Culture Plan." These "...programs should be experimental and short-lived; no longer than ten years."

Response 11: The recovery team and the Fish and Wildlife Service believe the conservation aquaculture program, as described in the final recovery plan and based on available information, is a necessary component of recovery to prevent the near-term extinction of the white sturgeon population. The following language has also been inserted in Part II, Recovery Criteria to address the 10-year limit, "...the Fish and Wildlife Service may recommend that the conservation aquaculture program be extended beyond 10 years if adequate natural reproduction to support full protection of the existing Kootenai River white sturgeon gene pool is not clearly demonstrated."

Comment 12: The Idaho Department of Fish and Game recommends that the conservation culture program, if implemented, adhere to the "Kincaid Plan", and that "...Strict disease protocols must be identified and enforced."

Response 12: The Fish and Wildlife Service agrees. The proposed conservation aquaculture program is based primarily on the breeding plan developed by Harold Kincaid in 1993. Recovery task 242 describes the development of a fish health plan for hatchery-reared white sturgeon, including disease protocols.

Comment 13: Adult broodstock should possibly be reared in a hatchery as a genetic reserve to produce offspring in the event of a "...disastrous population collapse."

Response 13: We agree that such a conservation measure may become appropriate in the future, however, such an action at this time was deemed premature because of the current wild population size and proposed conservation culture program.

Comment 14: Why was the conservation plan submitted by the Kootenai Tribe of Idaho in 1994 not accepted at that time in lieu of listing?

Response 14: During the public comment period on the proposed rule, the Fish and Wildlife Service received recovery strategies from the Idaho Department of Fish and Game; Montana Department of Fish, Wildlife, and Parks; and the Kootenai Tribe of Idaho. The Fish and Wildlife Service evaluation of the strategies indicated that they did not sufficiently reduce the threats to sturgeon and improve their status to eliminate the need for protection under the Endangered Species Act. However, these strategies were reviewed by the Fish and Wildlife Service and were useful in describing the major issues, and developing tentative solutions and quantifiable goals for Kootenai River white sturgeon as described in the recovery plan.

In addition, the Fish and Wildlife Service was unable to develop a prelisting conservation agreement with the Federal action agencies.

Comment 15: How will proposed recovery actions affect Kootenay Lake elevations and consequently recreation and beach access in British Columbia?

Response 15: With the regulation of inflows by Libby Dam the interpretation of the International Joint Commission (IJC) Order has resulted in Kootenay Lake mean maximum levels being more than 2 meters (6.6 feet) lower since the construction and operation of Libby Dam in 1974. The lower maximum lake elevation may have contributed to the lack of successful white sturgeon reproduction in the Kootenai River by altering river stage, flow velocity, and substrate relationships in the vicinity of sturgeon spawning habitat near Bonners Ferry. Specific impacts to Kootenay Lake elevations and associated beaches are not known at this time since elevations necessary for successful white sturgeon recruitment are not yet known (see recovery task 32 for a more complete discussion of this issue).

Discussions to date have been confined to seasonal adjustments within the operating prescriptions of the 1938 International Joint Commission Order. Further, these adjustments have been limited to those elevations below which significant recreation facilities and other developments have encroached in the Kootenai River flood plain since 1974.

Comment 16: Some of the draft recovery plan's recommended actions are not evenly applied.

Response 16: The Fish and Wildlife Service evaluated all currently known threats to the population and developed a prioritized list of recommended actions and activities to "...reestablish natural recruitment, minimize additional loss of genetic variability to the white sturgeon population, and successfully mitigate biological and physical habitat changes caused by the construction and operation of Libby Dam...."

Comment 17: The Fish and Wildlife Service should amend the "...plan to reflect the need for a more natural hydrograph during the entire residency of spawning and rearing sturgeon in the Kootenai River."

Response 17: We believe this has been addressed adequately through recovery activities designed to identify and restore white sturgeon habitats necessary to sustain white sturgeon reproduction (spawning and early age recruitment) and rearing while minimizing effects on other uses of Kootenai River basin waters, e.g. recreational facilities and the resident fishery in Koocanusa Reservoir.

Comment 18: The effects of early 1900's diking along the Kootenai River have not been adequately addressed in the draft recovery plan as a significant factor in the white sturgeon population decline.

Response 18: The elimination of side-channel slough habitats in the Kootenai River is acknowledged as a contributing factor in the white sturgeon's decline. In a more normative condition, sloughs and the flood plain provide habitat for fish sites, for sediment deposition, and for nutrient exchange. These areas have been eliminated by diking and channelization. Recovery task 122 seeks to identify opportunities to restore flood plain functions along the Kootenai River using available State and Federal funds. The task recommends finding landowners in flood-prone areas that may be willing to sell, lease, or assign conservation easements on portions of their land suitable for restoring natural flood plain functions.

Comment 19: The final recovery plan should clarify statements regarding current level of pollution to the Kootenai River.

Response 19: Language has been added to the recovery plan to clarify that fertilizer processing, lead-zinc mine, and vermiculite pollutant discharges have been eliminated.

Comment 20: Do other spawning areas, besides the Kootenai River, exist for this population of white sturgeon.

Response 20: There is no evidence that white sturgeon spawn in areas outside the Kootenai River.

Comment 21: Inventories on all aquatic species should be routine if possible.

Response 21: Recovery tasks 51 through 56 deal with other native fish species in the Canadian and United States portions of the Kootenai River drainage.

Comment 22: The recovery plan should outline possible mechanisms of impact to Kootenai River white sturgeon from the collapse of the kokanee population in Kootenay Lake.

Response 22: The long-term decline in kokanee stocks has been attributed to a decrease in biological productivity in Kootenay Lake. Kokanee were once considered an important prey item for adult white sturgeon. Recovery tasks 331 and 332 have been added to partially address the productivity issue, including the role of Kootenay Lake kokanee in white sturgeon recovery.

Comment 23: The recovery plan "...is based on allocating a higher priority to the Kootenai white sturgeon than to other Canadian fish stocks."

Response 23: Recovery plans provide information and guidance the Fish and

Wildlife Service believes will lead to recovery of listed species, in this case the Kootenai River white sturgeon . This recovery plan places high priority on those actions that must be taken to prevent extinction or further decline in the near future. However, recovery objectives are designed to balance white sturgeon recovery measures with requirements for other aquatic species and recreational fisheries within the United States and Canada portions of the Kootenai River drainage.

Comment 24: The question of who is responsible for mitigation and/or compensation from these proposed operational changes that will impact Canadian fisheries and other water uses should be addressed.

Response 24: At this point, the Fish and Wildlife Service is unaware of specific Canadian fisheries impacts requiring mitigation as a result of white sturgeon operations. The issues of impacts to Canadian power generation and other water uses are still being considered by the governments of Canada and the United States.

Comment 25: Are there natural reasons why abundance has declined as well as the usual man-made changes?

Response 25: Like many river ecosystems, the Kootenai River corridor has been considerably altered by human influences. We lack sufficient early data to say whether natural causes are responsible for any of the declines.

Comment 26: Was there any evidence of missing year classes in the past (prior to the construction and operation of Libby Dam)?

Response 26: Study results presented by Partridge (1983) and Apperson and Anders (1991) demonstrate that white sturgeon recruitment has been intermittent prior to the construction of Libby Dam. This is demonstrated by the absence of year classes 1965 to 1969, 1971 to 1973, and 1975.

Comment 27: Sturgeon are not doing well in other areas. Are there similar reasons for decline similar to those demonstrated for the Kootenai River population?

Response 27: With few exceptions, most wild sturgeon populations throughout the world are declining due to the combined effects of dam construction, over fishing, and water pollution.