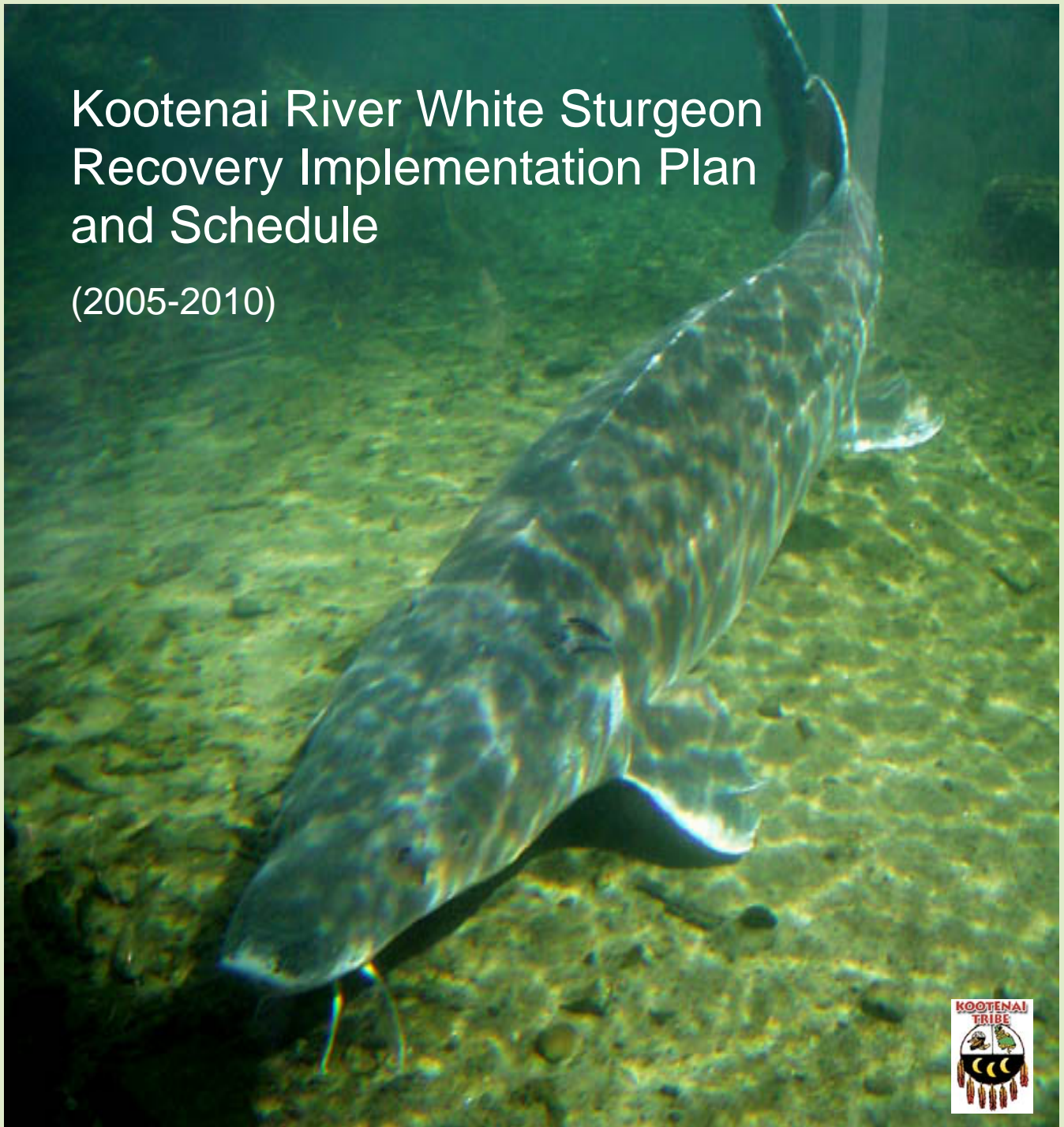


# Kootenai River White Sturgeon Recovery Implementation Plan and Schedule

(2005-2010)



Preparation of this Implementation Plan was administered by the Kootenai Tribe of Idaho through a contract from the Bonneville Power Administration (Project 198806400, Contract No. 00020490) as part of the Northwest Power and Conservation Council's Fish and Wildlife Program., with assistance from the Kootenai River White Sturgeon Recovery Team.



## Document Citation

Kootenai Tribe of Idaho (KTOI) 2005. Anders, P., R. Beamesderfer, M. Neufeld, and S. Ireland (eds). Kootenai River White Sturgeon Recovery Implementation Plan and Schedule (2005-2010). Prepared by S. P. Cramer and Associates for the Kootenai Tribe of Idaho, with assistance from the Kootenai River White Sturgeon Recovery Team (50 pp).

## About this Recovery Implementation Plan and Schedule

This Plan and Schedule delineate research, monitoring and evaluation actions believed necessary to protect, rehabilitate, and maintain Kootenai River white sturgeon in conjunction with activities highlighted in the population's Recovery Plan (USFWS 1999). Information in this Plan and Schedule is intended to complement current Recovery Plan activities and provide information valuable in its update.

This Plan and Schedule resulted from cooperative efforts of U.S. and Canadian Federal, Provincial, and State agencies, Native American Tribes, and does not necessarily represent the views or the official positions or approval of all individuals or agencies involved with its formulation. This Plan is intended to be adaptive in nature, and therefore is subject to future modification as dictated by new findings, changes in species status, the completion of research, monitoring, and evaluation tasks contained herein, and in the Recovery Plan for Kootenai River white sturgeon (USFWS 1999).

## Collaborators

BC Hydro  
Bonneville Power Administration (BPA)  
British Columbia Ministry of Environment (BC MoE)  
Fisheries and Oceans Canada (DFO)  
Freshwater Fisheries Society of British Columbia (FFSBC)  
Idaho Department of Fish and Game (IDFG)  
Kootenai Tribe of Idaho (KTOI)  
Montana Fish Wildlife and Parks (MFWP)  
Northwest Power and Conservation Council (NWPCC)  
S. P. Cramer and Associates (SPC&A)  
U.S. Army Corps of Engineers (USACE)  
U.S. Fish and Wildlife Service (USFWS)  
U.S. Geological Survey (USGS)



# Kootenai River White Sturgeon Recovery Implementation Plan and Schedule (2005 - 2010)

<b>INTRODUCTION .....</b>	<b>3</b>
<b>IMPLEMENTATION PLAN .....</b>	<b>5</b>
<b>STRATEGY 1. RESTORE NATURAL RECRUITMENT OF KOOTENAI STURGEON.....</b>	<b>5</b>
1A. Flow Augmentation .....	6
1B. Sturgeon Spawning, Incubation, and Early Rearing Habitat Restoration.....	7
1C. Ecosystem Restoration .....	22
<b>STRATEGY 2. USE CONSERVATION AQUACULTURE TO PREVENT EXTINCTION. ....</b>	<b>28</b>
2A. Production .....	28
2B. Facilities.....	30
2C. Practices.....	31
2C. Hatchery Monitoring and Evaluation .....	31
<b>STRATEGY 3. STURGEON RECOVERY AND ECOSYSTEM RESTORATION MONITORING.....</b>	<b>34</b>
3A. Natural Spawning Assessments .....	34
3B. Adult Assessments.....	34
3C. Juvenile Assessments.....	35
3D. Telemetry .....	36
3E. Habitat Assessment & Monitoring .....	36
3F. Data Management & Reporting.....	36
<b>STRATEGY 4. UPDATE AND REVISE RECOVERY PLAN CRITERIA AND OBJECTIVES.....</b>	<b>37</b>
<b>SCHEDULE .....</b>	<b>39</b>
<b>STRATEGY 1. NATURAL RECRUITMENT .....</b>	<b>39</b>
<b>STRATEGY 2. AQUACULTURE.....</b>	<b>43</b>
<b>STRATEGY 3. RECOVERY MONITORING .....</b>	<b>45</b>
<b>STRATEGY 4. RECOVERY IMPLEMENTATION.....</b>	<b>39</b>
<b>REFERENCES .....</b>	<b>47</b>

## Introduction

**Background** - Kootenai River white sturgeon have been declining for at least 50 years and extinction of the wild population is now imminent (Paragamian et al. 2005). Only 630 adults were estimated to remain in 2002 from a population ten times that size just 20 years ago. Significant recruitment of young sturgeon has not been observed since the early 1970s and consistent annual recruitment has not been seen since the 1950s. The remaining wild population consists of a cohort of large, old fish that is declining by about 9% per year as fish die naturally and are not replaced. At this rate, the wild population will disappear around the year 2040 (Paragamian et al. 2005). Numbers have already reached critical low levels where genetic and demographic risks are acute.

The Kootenai River White Sturgeon Recovery Team was convened in 1994, provided a draft Recovery Plan in 1996 and the first complete Recovery Plan for Kootenai River white sturgeon in 1999 (USFWS 1996, 1999). The Plan outlined a four part strategy for recovery, including: 1) measures to restore natural recruitment, 2) use of conservation aquaculture to prevent extinction, 3) monitoring survival and recovery, and 4) updating and revising recovery plan criteria and objectives as new information becomes available. Sturgeon recovery efforts are occurring against a backdrop of a broader ecosystem protection and restoration program for the Kootenai River ecosystem (Walters et al. 2005). With abundance halving time of approximately 8 years, the Kootenai River white sturgeon population is rapidly dwindling (Paragamian et al. 2005), leaving managers little time to act.

**Recruitment failure** - Decades of study consistently indicate that recruitment failure occurs between embryo and larval stages. This assertion is based on four key observations. First, almost no recruitment has occurred during the last 30 years. Second, thousands of naturally produced white sturgeon embryos, most viable, have been collected over the past decade, resulting from an estimated 9 to 20 spawning events each year (Paragamian and Wakkinen 2002). Third, Kootenai River white sturgeon spawning has been documented during most years from 1990 through 2005. Finally, no larvae and very few wild juveniles have been collected during recent decades despite years of intensive sampling. Concurrently, post-release hatchery reared juveniles (as young as 9 months of age at release) consistently exhibit successful growth and survival (Ireland et al. 2002). Recruitment has failed, in part because fish are currently spawning at sites where or when conditions appear unsuitable for successful incubation and early rearing. Research to date suggests that recruitment failure is caused by egg or larval suffocation, predation and/or other mortality factors associated with these early life stages (Anders 1991; Anders and Richards 1996; Duke et al. 1999; USFWS 1999; Paragamian et al 2001; Anders et al. 2002).

A variety of interrelated factors have clearly contributed to the decline of Kootenai white sturgeon; various hypotheses for recruitment failure are not mutually exclusive (Anders 1991; Anders and Richards 1996; Duke et al. 1999; USFWS 1994; 1996; 1999; Anders et al. 2002). Anders et al. (2002) suggested that Kootenai River white sturgeon recruitment failure is likely the result of additive mortality from: 1) increased predation efficiencies due to low turbidity, velocity, and an relative increase in predatory fishes, 2) a reduced number of eggs produced by a dwindling spawning population, and 3) spawning in habitat lacking interstitial space (embryo suffocation). Quite simply, the combined egg and embryo mortality from all biotic and abiotic factors kills more eggs and embryos than the dwindling wild population is currently capable of

producing. Thus, natural recruitment failure appears to be caused by some combination of habitat and stock limitation, by the mechanisms mentioned above.

Although past research has helped narrow the range of possible causes of natural recruitment failure, the relative significance of each potential impact remains uncertain because multiple ecological, biological, and physical habitat changes occurred simultaneously. This makes it difficult to choose among competing hypotheses and difficult to know where exactly to focus recovery efforts for maximum benefit. In an ideal world, specific recovery measures would be identified and implemented based on a series of complementary research investigations to definitively identify the proximate causes and specific mechanisms of recruitment failure.

The acute status of Kootenai sturgeon and current inability to compartmentalize the complex ecosystem do not afford the luxury of time for exhaustive research studies on every potential mechanism of recruitment failure. Mechanistic studies cannot replace the need for experimental evaluations of implemented adaptive management experiments.

During the five years covered by this Plan (2005-2010), the “kitchen sink” adaptive management approach, described by Walters et al. (2005) from the summer 2004 IKERT discussion, will be applied to Kootenai River sturgeon habitat and recovery needs. This approach involves simultaneous implementation of multiple remedial actions to achieve the desired outcome in the shortest amount of time possible. In this case the desired outcome is reestablishment of natural recruitment, or on smaller experimental scales, in-river production of viable larvae. If desired outcomes occur, individual measures may be terminated to determine their specific effects on in-river larval production and recruitment).

This approach differs from a common approach of sequentially implementing and evaluating single recovery treatments and adding new treatments if initial treatments fail to provide in-river larval production or restore recruitment.

Additional investigations might be helpful in reducing critical uncertainties and identifying other potential avenues for recruitment restoration. Current recruitment failure hypotheses may evolve and new hypotheses may emerge during the period covered by this Plan. Emerging hypotheses will be evaluated and considered for inclusion in the Plan as part of an adaptive management platform.

# Implementation Plan

This implementation plan and schedule provides detailed measures, tasks, and activities planned from 2005 through 2010 based on strategies identified in the Recovery Plan and new information that has been developed since 1999 when the plan was adopted. This 5-Year Plan has four main components corresponding to the four primary strategies in the 1999 Recovery Plan: 1) Recruitment restoration, 2) Conservation aquaculture, 3) Monitoring and evaluation, and 4) Recovery Plan adaptation and revision (Figure 1). The accompanying implementation schedule identifies annually implemented core program elements and the timing and progression of additional measures designed to recover Kootenai River white sturgeon.

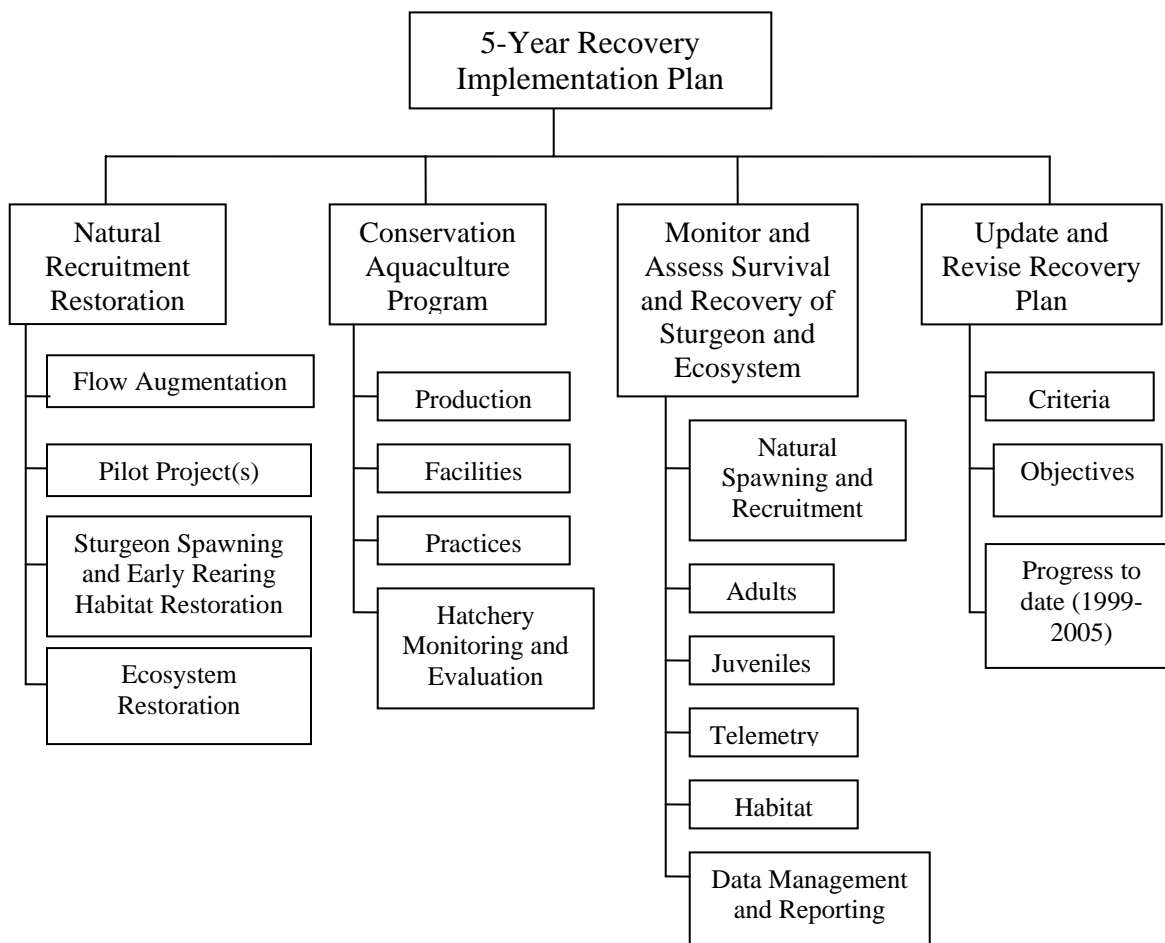


Figure 1. Organization of 5-Year Recovery Implementation Plan and Schedule.

## ***Strategy 1. Restore natural recruitment of Kootenai River white sturgeon.***

Efforts to re-establish natural recruitment of Kootenai River white sturgeon initially focused on flows and experimental alteration of Libby Dam operations (USFWS 1996; Duke et al 1999; USFWS 1999). Since 1994, Libby Dam discharges during spring have been augmented and shaped in an ongoing but unsuccessful attempt to stimulate natural recruitment of Kootenai sturgeon.

Recruitment has been positively correlated with flow in other white sturgeon populations (Miller and Beckman 1993). Paragamian and Wakkinen (2002) suggested that augmented spring flows have successfully cued spawning migration and spawning, but have not been sufficient to move fish into better spawning habitat or to create the appropriate conditions in the current spawning habitat. Natural spawning has been confirmed during 14 of the past 15 years (V. Paragamian, IDFG, personal communication), yet significant natural recruitment has not occurred during any of these years, with or without augmented discharge. Lack of controlled studies currently prohibits clear understanding of the effects of augmented discharge tests. However, the range of tested conditions has not succeeded in moving fish upstream to spawn in habitat thought capable of contributing to survival and recruitment. It remains unclear if augmented discharge tests were simply of insufficient magnitude to provide recruitment, or did not coincide with the correct Kootenay Lake level to produce conditions for natural recruitment. It is possible that significant recruitment cannot be achieved without significant spring flows that at least partially emulate the conditions under which historical recruitment was significant. Thus, additional research is needed to determine the necessary combinations of flow and other factors necessary to prevent sturgeon extinction through restoration of natural recruitment.

Golder Associates (2005) reported that analyses of all currently available data were unable to demonstrate definitive effects of temperature and discharge on the timing of white sturgeon spawning in the Waneta area of the Upper Columbia River.

However, if Kootenai River white sturgeon recruitment is co-limited by physical/hydraulic and biological/ecological/demographic factors, then increasing discharge alone cannot be expected to re-establish natural recruitment. This co-limitation and/or unmet flow volume and duration thresholds may explain failure of flow augmentation to restore white sturgeon recruitment in the Kootenai River since the early 1990s, and during post-dam years since 1974.

### **1A. Flow Augmentation**

***Measure 1A.1. Configure Libby Dam discharges to emulate an annual normative hydrograph pattern as much as possible given other demands and constraints, while minimizing risks to levees and adjacent lands and balancing tradeoffs with impacts to other species.***

Critical components of a flow augmentation plan include: 1) experimental restoration of hard-bottom features in the river reach where sturgeon now spawn without recruiting, and 2) development and testing of an “aquatic ecosystem management” hydrograph for Libby Dam releases. A restorative hydrograph could involve lower winter flows to provide a more natural ecosystem low-flow “reset” feature, and higher spring-summer peak flows to improve conditions for sturgeon spawning and to beneficially contribute to sediment and nutrient transport functions.

***Measure 1A.2. Implement specific annual operational guidelines for Libby Dam to benefit natural spawning and recruitment conditions during March through September.***

*Ecosystem restoration (normative) mainstem flows* – (All agencies) Libby Dam operation for flood control and power production has reversed the natural (pre-dam) Kootenai River hydrograph and has significantly altered downstream thermographs and water quality parameter values. All collaborators in the lower Kootenai River Subbasin have a vested interest in providing a more natural or normative river downstream from Libby Dam for a variety of ecological, social, cultural, recreational, and economic reasons, while sharing a vested interest in maximizing positive and minimizing negative effects on flood control and power production (Walters et al. 2005).

***Measure 1A.3. Capitalize on annual variation in runoff conditions and pursue additional opportunities for increased sturgeon flows during late spring and early summer to evaluate potential sturgeon recruitment benefits.***

Continue annual flow planning for sturgeon spawning and recruitment based on tiered volumes.

***Measure 1A.4. Adapt operational guidelines based on new information as available.***

Address flows to individual measures, such as set-and-jet and associated monitoring, and sturgeon response to new habitat placement, and modify test flow conditions based on new information.

## **1B. Sturgeon Spawning, Incubation, and Early Rearing Habitat Restoration**

Although attention has largely focused on the potential roles of Libby Dam in recruitment failure, the onset of natural recruitment failure pre-dated the completion of Libby Dam (1974) by 25 years (Figure 4 in: Paragamian et al. 2005). The most rigorous analysis of recruitment failure to date reported that recruitment declined during the 1950s, but was further impacted by construction and operation of Libby Dam in 1972 (Paragamian et al. 2005).

Thus, restoration measures in addition to and in combination with flow will likely be required to restore recruitment and prerequisite suitable habitat conditions. Without immediate implementation of substantive habitat restoration measures, there will soon be too few wild adults to benefit from habitat improvements. Even with continued natural recruitment by remnant adults, future natural production must rely upon reproduction of hatchery produced Kootenai River fish after significant numbers reach sexual maturity (Paragamian et al. 2005).

Significant habitat improvements in a river the size of the Kootenai will be costly and the likelihood of river- or population-scale benefits of specific actions remain uncertain. However, declining wild adult sturgeon numbers and limited resources for large-scale habitat restoration programs do not afford the luxury of implementing large-scale experiments without incorporating the best available science and information to guide design. Thus, two distinct physical habitat restoration strategies have been identified to provide suitable spawning, incubation and larval rearing habitat conditions for Kootenai River white sturgeon: 1) provide



suitable habitat conditions where fish currently spawn, and 2) bring or attract spawning fish to suitable habitat.

***Measure 1B.1. Rock Fill: Add rock to substrate in current spawning areas to evaluate its role in providing suitable spawning and incubation conditions.***

The lack of suitable spawning and incubation substrate in current spawning areas is thought to be a primary factor limiting sturgeon recruitment. Sturgeon eggs and embryos have been consistently collected from deep high-velocity parts of the river channel near Shorty's Island. However, it is assumed that shifting sand dunes in that reach may cover and smother eggs, or they may be consumed by omnivorous fishes (Anders et al. 2002). Rocks and their interstitial spaces may provide the necessary attachment surfaces and clean interstitial spaces needed for embryo (fertilized egg) incubation and early larval rearing based on conditions observed for other white sturgeon populations, and may also provide microhabitat conditions required for egg and embryo survival (Parsley et al 1994; Anders et al. 2002; Parsley et al. 2002). Generally, submerged rock along the east bank at the toe of the levee near Shorty's Island is thought to have potential for successful egg incubation. A small number of eggs were sampled with substrate mats on this rock bench during 2005. Unsorted rock with some degree of interstitial space has existed at the toes of levees in this and other locations since levees were constructed during the early to mid 1900s. However, even if this rock serves as embryo incubation habitat, it has contributed little to natural recruitment.

Task 1B.1.1. Evaluate feasibility of small rock introduction project as habitat alteration in current spawning area to re-establish in-river larval production or recruitment (Pilot Study).

Before a large-scale substrate introduction project can be considered, more information is needed to determine whether rock placement will produce the desired conditions. Desired conditions must also be defined. Critical questions include whether rock can be placed so that at least some protrudes above the soft river bottom substrate and whether interstitial spaces will remain free of sand.

*Activity 1B.1.1.a. Use computer hydraulic modeling to investigate possible alternatives for the size and shape of a large-scale substrate structure.*

Numerical modeling of substrate alternatives could identify velocity changes and increased flood heights associated with various structure configurations based on USGS hydraulic models and bathymetry data.

*Activity 1B.1.1.b. Use physical hydraulic simulation modeling to test alternatives for the size and shape of a large-scale substrate structure.*

A physical model can be used to evaluate each design by measuring flow velocities and turbulence (3-D velocity variation) in and around the structure and to monitor scour and deposition tendencies.

*Activity 1B.1.1.c. Conduct exploratory geotechnical sampling and analysis to evaluate subsurface substrate characteristics at the proposed study site(s).*

Additional sampling and analysis of substrate composition and characteristics may be required to design an approach that will remain functional for a significant period of time.

*Activity 1B.1.1.d. Obtain appropriate permits for a pilot rock placement experiment.*

Permitting for this pilot project will involve internal coordination, coordination w/ permitting agencies, and coordination with other resource entities (notable example: KRWSRT). Evaluations other than for permits will also be needed (e.g. CWA Sec. 404, which is otherwise regulated by the USACE and the USEPA). Depending on staging and other land use requirements, there may be National Historic Preservation Act (NHPA) or other considerations.

*Activity 1B.1.1.e. Conduct a limited-scale rock placement experiment in the spawning reach near Shorty's Island to test whether rock placement provides desired flow and substrate conditions and how placement is affected by settling or sedimentation.*

The pilot project includes an experimental test of rock placement in the current spawning area. Since current spawning does not lead to recruitment, this test site poses no further risk to sturgeon production but does provide an in-river opportunity to empirically test the concept under current conditions.

*Activity 1B.1.1.f. Measure physical conditions associated with experimental rock placement.*

Physical measurements will include rock pile length, width, and height above the surrounding substrate, local velocity changes and flow field characterizations around the rock placement site, degree of settling into existing substrate, local scouring and sedimentation of interstitial spaces. Evaluations may involve direct measurements, acoustic surveys, and remote camera surveys.

*Activity 1B.1.1.g. Measure biological response to experimental rock placement.*

This measure has two components: 1) attraction to or use of added rocks for spawning, and 2) embryo incubation assessment.

Assessing use of substrate for spawning may involve fix station positioning systems.

The embryo incubation assessment may involve seeding rocks with captively fertilized embryos. Monitor egg retention and hatching using appropriate methodologies such as substrate retrieval, drift sampling, and/ or underwater photographic and acoustic cameras.

*Activity 1B.1.1.h. Use results of pilot study, physical/hydraulic computer modeling and biological monitoring results to develop alternatives and associated cost estimates.*

The pilot study and associated modeling are designed to provide the information needed to assess the feasibility of a large-scale rock addition project.

Task 1B.1.2. Design, implement and evaluate a large-scale rock introduction project where feasible as guided by pilot project results (Task 1B.1.1).

Results of the pilot project will determine whether a larger-scale project is appropriate and feasible, and will provide information regarding appropriate dimensions, orientation, and rock placement. Pilot project results will also

provide much of the project design information needed to pursue development and funding of large scale project(s).

*Activity 1B.1.2.a. Seek and obtain funding for rock placement implementation and evaluation through the USACE 1135 and other funding avenues.*

Under the authority provided by Section 1135 of the Water Resources Development Act of 1986, the USACE may plan, design and build modifications to existing Corps projects, or areas degraded by Corps projects, to restore aquatic habitats for fish and wildlife. Projects must be in the public interest and cost effective and are limited to \$5 million in Federal cost. A non-Federal sponsor must contribute 25% of the cost of planning, design, and construction, and 100% of the cost of operation and maintenance. The process for Section 1135 projects begins after a non-federal sponsor requests USACE assistance under the program. When funding is available, the USACE prepares a *Preliminary Restoration Plan* (PRP) paid for by the federal government. The PRP is used to determine whether federal involvement is appropriate. It describes the project benefits and contains an initial schedule and budget. The Final PRP contains a letter from the non-federal sponsor indicating that they understand their obligations for cost sharing and obtaining any necessary real estate. A portion of the non-federal sponsor's share may be work in-kind. BPA funds, since they are not congressionally appropriated, may contribute to the non-federal sponsor's share.

*Activity 1B.1.2.b. Complete project design, design evaluation, permitting, and contracting.*

If the total estimated federal cost is over \$1 million, the USACE prepares a feasibility study, then plans and specifications. This includes appropriate NEPA documentation (EA with FONSI, or EA leading to EIS). If the federal cost is under \$1 million, the USACE conducts a Preliminary Design Analysis (PDA), which is an abbreviated procedure involving the preparation of plans and specifications and an environmental assessment, without a feasibility study. It includes appropriate NEPA documentation. The USACE then manages construction of the project.

*Activity 1B.1.2.c. Implement project during fall.*

Substrate enhancement project should be completed in time for spawning season in spring 2009. At that time, the Recovery Team will determine the number of spawners available to utilize the enhanced substrate, making the appropriate allocation of adults between natural spawning and hatchery operations. Consideration should be given to seeding engineered substrate with hatchery produced embryos to increase the likelihood of successful project monitoring and evaluation.

*Activity 1B.1.2.d. Measure physical conditions associated with the rock placement project.*

Physical measurements will include rock pile length, width, and height above the substrate, local velocity and flow field (turbulence) changes around the rock placement site, degree of settling into existing substrate, local scouring and sedimentation of surfaces and interstitial spaces. Evaluations should involve direct measurements, acoustic surveys (ADCP), and remote

photographic or acoustic camera surveys. Attention should also be paid to effects on surrounding habitat resulting from altered hydraulics or hydraulic energy. The subsequent need for small scale lab experiments may arise from this experiment in order to determine details of relevant early life mortality mechanisms.

*Activity 1B.1.2.e. Evaluate project results according to white sturgeon biological response(s).*

White sturgeon biological or behavioural response(s) will be evaluated based on fish attraction, spawning activity, egg incubation, predation, and natural recruitment. Evaluations may involve real time 3-D continuous acoustic tracking of sonic tagged spawners, deployment of egg mats near experimental engineered habitats, visual inspection by divers, and/or by using fixed or ROV-mounted photographic or DIDSON acoustic cameras, embryo seeding, and/or D-ring net sampling for larvae.

*Activity 1B.1.2.f. Identify appropriate operation and maintenance procedures to maintain structure effectiveness based on monitoring results.*

Site maintenance requirements will be unknown until results of the above pilot project and implementation evaluations are completed. The history of site-specific habitat improvement projects in rivers has demonstrated that benefits of engineered habitat gradually decline over time without maintenance if the underlying habitat forming processes are not addressed.

***Measure 1B.2. Velocity and Turbulence Eductors: Evaluate whether mechanical devices can be successfully used at or upstream from existing spawning sites to provide suitable spawning and incubation velocity and turbulence conditions.***

Eductors are portable tubes with attached nozzles and pumps which entrain and propel a directional stream of water. Although no quantitative turbulence characterization has been performed for white sturgeon spawning habitat use, preferred spawning conditions used by other white sturgeon populations include high water velocity and apparent turbulence. Velocities in the current spawning reach are near the low end of those reported for other sturgeon populations. Peak velocities are around 1.2 feet per second (fps) and more typically less than 1 fps. Preferred mean water column velocities for spawning by sturgeon in other areas are typically between 1 and 3 fps (Anders 1991; Parsley et al. 1994; Paragamian et al. 2001; Anders 2002; Golder Associates 2005). Eductors may: 1) increase water velocity and turbulence in current spawning areas, 2) attract spawners to adjacent areas of more suitable habitat, 3) help exclude egg predators, and 4) clean fine material from natural and engineered spawning substrates. Eductors are not proposed as a sturgeon recovery measure, but as a tool to help understand hydraulics associated with spawning and possibly incubation habitat requirements.

Task 1B.2.1. Explore whether mechanical devices can effectively increase local water velocity and turbulence at a scale that contributes to sturgeon habitat restoration by field testing flow eductors under different habitat conditions. (Pilot Study)

Field testing of an eductor system in a river environment is necessary to determine if the equipment can produce a physical effect of sufficient scale to provide useful benefits. Eductor testing will also provide insight into how eductor

performance varies in response to different river depths, velocities, and roughness elements.

*Activity 1B.2.1.a. Field test eductor(s) in the Kootenai River at several combinations of depth, velocity, and orientation.*

Eductors will be set up and run at a series of representative sites on the river. Initial (Pilot project) evaluations will be limited to physical rather than biological effects. If eductors alter local hydraulic conditions to the degree where larger scale application appears feasible and beneficial, then monitoring of potential biological responses by adult spawning sturgeon should be considered. Velocity profiles within the affected area will be mapped at each site before and after the test to identify the effected area and the magnitude of the effect. Test sites should include low, medium, and high depths, and low, medium, and high velocities within the range that is typically available in the meander and straight reaches of the river. Different eductor configurations, depths, and angles may also be explored.

*Activity 1B.2.1.b. Identify and describe criteria and tests of biological response(s) to eductors.*

Results of initial field tests will be used to determine if a larger-scale test is appropriate and to design subsequent tests to monitor and evaluate biological response. Because hydraulic conditions required to attract spawning sturgeon are currently unknown, success criteria from the initial field test are not clear cut. Affected areas may have to be of significant scale to solicit a fish response. Alternatively, field observations may reveal that spawning or pre-spawning sturgeon may be attracted to specific hydraulic conditions in a limited area. Regardless, considerable area of suitable substrate associated with appropriate hydraulics may be needed to re-establish measurable natural recruitment. Limited or confined local effects alone will not warrant further tests.

Task 1B.2.2. Conduct large scale field trials of eductors in current spawning areas to evaluate biological response(s) by pre-spawning and spawning sturgeon.

If eductors appear to provide the desired velocity and turbulence conditions during the pilot study, further tests of a biological response will be subsequently considered. Paragamian (IDFG personal communication) suggested that preliminary results from studies on the Kootenai River indicate that sturgeon are attracted to accelerated velocity zones and greater depths. Biological response tests might initially be conducted in the current spawning reach where fish are available to respond. If fish appear to cue on eductor treatment areas, eductors might be considered for use in areas upstream from current spawning sites to see if fish are attracted to areas of more suitable substrate. The strait reach (Ambush Rock to Bonners Ferry) and the braided channel reach are the closest locations to current spawning sites that appear to offer suitable spawning and incubation substrate. Continuous rock substrates are also available in the Shorty's Island reach, but exist along the toes of the levees rather than in the river channel where naturally produced eggs and embryos are collected and where spawning is thought to occur. Levee toes were armoured with alluvial rock hauled in from terrestrial sources. Field tests of eductors might also evaluate whether fish

spawning in the Shorty's reach can be attracted to spawn along nearby shoreline rock substrates.

***Measure 1B.3. Design, implement, and evaluate a rigorous hydraulic characterization of current sturgeon spawning habitat from the perspective of the fish's sensory ovoid, not another depth, velocity and substrate/HSI study.***

Past Recovery Team discussions have included the notion that spawning white sturgeon in the Kootenai River are "confused" by the current suite of altered environmental cues and spawn haphazardly within the 8 km spawning reach. An alternative hypothesis suggests that the lack of human understanding of sturgeon spawning behaviour in the Kootenai River is explained by transferring the human confusion onto the fish. This alternative hypothesis suggests that the fish are finding suitable hydraulic characteristics for spawning, as confirmed by annually successful production of embryos. However, in the altered post-development Kootenai River the hydraulic cues may have shifted downriver, away from underlying suitable habitat, resulting in successful spawning but failed recruitment.

Recent advances in the emerging field of ecohydraulics and in recent fish behaviour studies indicate that traditional depth, velocity and substrate level investigations often fail to adequately explain empirical fish behaviour, especially for life stage specific events such as spawning. Furthermore, analogue or reference based studies of fish spawning conditions, especially for sturgeons can provide valuable information, but such information is not always transferable among species and rivers for various reasons.

Thus, this Measure addresses an alternative hypothesis to understand current uncertainties about sturgeon spawning behaviour in the Kootenai River based on a finer scaled analysis of hydraulic and flow field conditions, measured at scales relevant to an adult sturgeon's sensory ovoid area.

Task 1B.3.1 Re-analyze egg collection data and recently available hydrologic data from USGS modeling efforts to more accurately define spawning sites at smaller spatial scales.

Task 1B.3.2 Rigorously characterize hydraulics and flow-field dynamics of sturgeon spawning sites determined from Task 1B.3.1 at spatial scales relevant to a sturgeon's sensory ovoid area.

Task 1B.3.3. Test a hypothesis of common quantified hydraulic or flow field features between current spawning location and conditions simulated in the braided and canyon reaches under historical hydrograph conditions.

***Measure 1B.4. Velocity Transition Zone: Explore opportunities for restoration of suitable natural spawning and recruitment conditions through a combination of Kootenay Lake level and Libby Dam.***

A current recruitment failure hypothesis suggests that complex hydrodynamic changes resulting from regulation of Kootenay Lake surface elevation, Libby Dam operations, and levee construction have shifted the location of spawning cues into an area (Shorty's Island to Bonners Ferry) where substrate is generally not suitable for incubation and early rearing. Sturgeon are thought to broadcast eggs over an unstable sand bottom in the gradient transition zone

downstream from Bonners Ferry. This broad zone shifts longitudinally (upstream and downstream) in response to river discharge, elevation and Kootenay Lake elevation. Based on empirical observations (Paragamian et al. 2001; Barton 2004) it is speculated that shifting sand waves may cover and suffocate embryos and/or trap larvae. However, most recent and rigorous empirical velocity and egg collection location analyses (G. Barton, presentation at 10/17/05 Recovery Team meeting) failed to establish predictive value of the location of this zone for spawning.

Recent lab experiments exposing white sturgeon embryos to several treatments of sediment cover depth and duration revealed significant mortality and negative sub-lethal effects to embryos and larvae when inundated by as little as 5 mm of sterilized river sediments (Kock 2004; Kock et al. In Press). Kootenai River sturgeon egg diameter generally ranges from 2 to 3 mm when fertilized.

Eggs deposited over open substrates are also exposed to predation by omnivorous fishes and invertebrates. Individual sturgeon in viable populations elsewhere typically spawn over clean gravel and cobble substrates where the eggs may settle or are washed into rock interstices (Parsley et al. 1993; Anders 2002; Anders et al. 2002) High velocities, turbulence, and nearby eddy or pool areas for staging are also common feature of spawning sites used successfully by other white sturgeon populations.

In the post-development Kootenai River, velocity and turbulence cues that may have previously coincided with upstream rocky substrate may now occur further downstream over a predominantly sand substrate. Changes in hydrodynamics have also increased deposition of fine material in some areas immediately upstream from Bonners Ferry. These areas may have previously provided suitable combinations of substrate and velocity for sturgeon spawning, however, its unknown if sturgeon historically spawned in these areas. Core samples indicate that little rock or gravel exists in the river channel where sturgeon are currently spawning, so it does not appear that these areas ever provided successful recruitment.

Task 1B.4.1 Use empirical data and simulation modeling to characterize the velocity transition zone concept and determine with subsequent analyses: 1) how significant it is hydrologically/hydraulically, and 2) if it predicts any movements and/or spawning behaviours.

Models are being used to predict habitat characteristics under different combinations of river flow and Kootenay Lake elevation. Simulations of the effects of different combinations of lake elevation and Libby discharge can also help determine whether operations might feasibly restore suitable combinations of velocity and habitat for successful sturgeon spawning and recruitment. However, suitability criteria have not been defined for Kootenai River white sturgeon given ongoing recruitment failure. Results might help clarify why recent sturgeon flows have failed to restore recruitment. This work will help identify whether replicating historical conditions is a feasible option given risk to infrastructure and property.

*Activity 1B.4.1.a. Estimate historical habitat conditions in the current spawning reach and upstream under pre-development conditions.*

Historical conditions will serve as a reference point for identifying what factors have changed and what operations and habitat alterations may be

necessary to restore parameters that were historically beneficial for sturgeon recruitment.

*Activity 1B.4.1.b. Compare current and historical habitat conditions.*

Comparisons of current and historical conditions will highlight specific changes in habitat associated with recruitment failure. One key question is whether the velocity transition zone has shifted downstream under current conditions. A second key question is whether current sturgeon flows encourage or discourage selection of upstream spawning sites. Historical lake elevation, spring hydrograph, and floodplain conditions will be modeled to determine if velocities like those currently used by spawning sturgeon historically occurred farther upstream where suitable substrate is located. Historical accounts and photos can also be used to corroborate results and illustrate changes.

*Activity 1B.4.1.c. Identify alternatives to optimize habitat conditions.*

Alternatives will be identified based on a model sensitivity analysis to different combinations of lake elevation and river discharge. One critical response variable may be the downstream location of the velocity transition zone relative to suitable rock spawning substrates. However, recent analyses of the entire empirical sturgeon egg collection database suggest that spawning occurs relatively independently of the location of this zone (Barton et al. 2005, USGS unpublished data).

*Activity 1B.4.1.d. Identify other considerations which might constrain hydro operations of Kootenay Lake and Libby Dam for the benefits of sturgeon (levee soundness, lake and river flooding, power costs, other fish impacts)*

Fundamental physical changes in the Kootenai system mean that it may no longer be realistically feasible to configure hydro operations to restore suitable sturgeon spawning conditions or that large scale changes will have significant costs. For instance, river confinement by levees will limit acceptable risks of high lake elevations or river flows. The hydro modeling will identify the effects of different operations on sturgeon habitat suitability. This task details other factors and constraints that must also be considered in designing an operational program for sturgeon habitat restoration.

Task 1B.4.2. Consider experimental evaluation of the effects of Libby Dam flows and Kootenay Lake elevations on spawning and incubation habitat conditions based on pilot study results.

If analyses suggest that joint management of lake elevations and Libby flows can realistically be used to shift the velocity transition zone upstream to areas of more suitable substrate, and that spawning adults respond to the shift, the next step would be to consider experimental operations. This task includes all activities required to design an experimental evaluation. These would include extensive analyses of costs, risks, and other tradeoffs.

Task 1B.4.3. Implement, monitor, and evaluate appropriate scenarios resulting from Task 1B.4.2.

Project implementation will be contingent on favourable results of previous evaluations. Experimental evaluations should also capitalize on naturally-



occurring conditions, for instance by measuring velocity gradient profiles presented by periodic flood conditions. Project benefits would ultimately be evaluated based on a combination of physical and biological responses. Did the combined operational measures produce the expected physical changes? Were the observed physical changes accompanied by a biological response?

***Measure 1B.5. Braided Reach: Explore opportunities for restoration of suitable migration, spawning, and recruitment conditions in the braided reach upstream from Bonners Ferry.***

The braided river reach may have historically provided suitable conditions for sturgeon spawning but is not currently used for spawning. Changes in hydrodynamics associated with Kootenai Lake regulation, Libby Dam operations, and levee construction have altered habitat forming processes in the braided reach. The river is now shallower and consists of multiple channels formed by convergent and divergent processes, resulting in annual shifts in bed location, excessive deposition, and high rates of bank erosion. It might be possible to physically restore suitable habitat conditions for sturgeon spawning in the braided reach, although effective alternatives have yet to be identified.

**Task 1B.5.1 Identify and evaluate options for providing suitable migration, spawning, and incubation conditions in the braided reach upstream from Bonners Ferry.**

More work is needed to identify which alternatives warrant further consideration.

***Activity 1B.5.1.a. Identify options for providing suitable sturgeon spawning and incubation conditions in the braided reach (Pilot Study).***

Options will be identified based on review of available scientific information and by expert judgment through discussions and interviews among recovery agencies, stakeholders, and others as appropriate. Possibilities could include dredging, in-channel structures, and others as appropriate. Objectives, assumptions, benefits, and constraints will be identified for each option.

***Activity 1B.5.1.b. Evaluate options for providing suitable sturgeon spawning and incubation conditions in the braided reach.***

Includes initial evaluations of appropriate approaches based on computer simulations, physical models, and other analyses.

***Activity 1B.5.1.c. Refine and implement selected options as appropriate.***

Based on results of initial evaluations and progress in other areas of habitat restoration.

***Measure 1B.6. Early life stage translocations: Continue to evaluate physically transplanting hatchery produced white sturgeon embryos to upstream areas where suitable incubation and early rearing habitat is available.***

Sturgeon are not currently spawning in river reaches characterized by suitable cobble and rock substrate, although this habitat is abundant in, and upstream from the braided reach. Contributions to natural recruitment could possibly occur if fish spawned in these upstream areas. Upstream areas are assumed to provide suitable egg incubation and early rearing conditions. Experimental embryo plants can help test this assumption. However, adequate habitat conditions are required and must be in spatial and temporal synchrony with the needs of

naturally produced early life stages as they move downstream during their first six months of life if recruitment is expected.

Task 1B.6.1. Evaluate success of embryo releases over rocky habitats in the canyon and braided reaches upstream from Bonners Ferry.

Experimental embryo releases will help test our understanding of environmental requirements (e.g. substrates and velocities) for spawning, and whether significant numbers of larvae and juveniles can be produced from embryo releases. Sturgeon fecundity exceeds the requirements and space limitations of the hatchery and additional eggs can be used in this experiment. However, it is assumed that these experiments may involve insufficient numbers of embryos to contribute to detectable in-river recruitment.

*Activity 1B.6.1.a. Experimentally release captively fertilized embryos at one or more sites upstream from Bonners Ferry.*

Embryo numbers need to be adequate to detect significant attachment, development, and hatching if it occurs.

*Activity 1B.6.1.b. Monitor success of embryo plants with a combination of egg mats, D-ring nets, ½ m larval nets, and other gear and techniques as appropriate.*

Embryo numbers need to be adequate for detecting significant attachment, development, and hatching if it occurs. Monitoring will occur in the immediate vicinity of release sites. Release numbers are expected to be too small to measure actual recruitment benefits based on catches of YOY or older fish during normal juvenile sampling. Thus, initial success should be gauged by larval collection results. Consider inclusion of existing rock benches at the toes of the levees, as in the eastbank of the Shorty's Island area.

*Activity 1B.6.1.c. Consider additional embryo releases based on results of initial experiments.*

If embryo plants successfully produced high numbers of surviving larvae, embryo plants might help supplement hatchery production of juveniles. Hatchery selectivity risks are minimized by current conservation practices but may be further reduced by sharing the available eggs between hatchery and natural settings. The degree of imprinting and homing of sturgeon to specific sites is unknown, but if significant, fish that hatch in upstream areas might also return to those areas upon maturation. However, the embryo plant option should not be pursued at the expense of hatchery program contribution to year classes.

Task 1B.6.2. Consider additional larval releases based on results and progress of other measures.

In 2000, experimental larval releases occurred to test the larval survival bottleneck hypothesis. A total of 139,000, 3 to 23 day old post-hatch yolk-sac larvae were released in the "Straight Reach" near Ambush Rock (RKM 236; Paragamian et al. 2002). Although sampling immediately downstream of the release site resulted in the collection 33 larvae, these experiments produced no subsequent evidence of post-release larval survival. Fish surviving from these experimental larval releases should have begun recruiting to juvenile sampling

gear in the Kootenai River during 2003 or 2004. No evidence of survival from these release groups has been documented to date.

Task 1B.6.3. Consider additional transplants of ripe fish into upstream areas based on results and progress of other measures.

Transplants of spawning and pre-spawning fish occurred during 2003 and 2004. Post-release fish movements were subsequently monitored using radio telemetry. Late vitellogenic male and female white sturgeon were caught in the meander reach of the Kootenai River downstream from Bonners Ferry, and subsequently transported and released into the “Canyon Reach” upstream with the intent of stimulating spawning over substrates thought to be more suitable for embryo incubation, hatch, and larval survival. Initial “net and jet” experiments produced mixed results. Some fish lingered in upstream areas or even moved upstream but the majority quickly returned to downstream areas. A few eggs (< 10) were collected from one possible spawning event. Subsequent monitoring detected no larvae from this egg release. However, one of the transported fish was actively ovulating eggs before and during transportation, which could have accounted for the collected eggs. Additional tests should be considered depending on the availability of adults and results of other evaluations. Fish availability must be weighed against the needs for hatchery broodstock, opportunities for naturally spawning, and handling risks for individual fish.

***Measure 1B.7. Concurrently investigate alternative options to restore natural recruitment based on further investigations of limiting factors and critical uncertainties.***

Task 1B.7.1. Evaluate alternatives associated with the Riparian Habitat Hypothesis to characterize and restore sturgeon recruitment.

The Riparian Habitat Hypothesis attributes the widespread collapse of resident white sturgeon populations in part to the loss of flooded riparian vegetation, which was hypothesized to provide critical incubation and feeding habitat conditions (Coutant 2004). Over 90% of this historical floodplain habitat in the Kootenai Valley has been lost to a combination of levee construction, Kootenay Lake elevation control, and Libby Dam discharge regulation. This hypothesis suggests that submerged riparian habitat during historical (natural) seasonal high water is needed for egg attachment and other important early life survival functions. Floodplain habitat effects on sturgeon are likely complex. It is currently unclear whether significant functions include egg attachment and early life history. Additional studies can shed some light on the role of flooded riparian habitat in the sturgeon life cycle and related habitat restoration measures that might prove beneficial.

*Activity 1B.7.1.a. Investigate patterns of egg deposition at current spawning sites to determine the extent of thalweg and shallow water distribution.*

This activity involves mapping egg deposition across the river width at Shorty’s Island including seasonally inundated rip rap banks. The relevance of egg smothering and the riparian habitat recruitment failure hypothesis can be tested by determining where eggs end up. Are eggs primarily deposited in the thalweg dunes or are they also distributed into river margins? Are eggs

being deposited such that they end up on the apparently suitable rock substrate along the levee toes?

*Activity 1B.7.1.b. Investigate suitability of different surfaces for egg incubation using laboratory studies.*

Lab studies would address the suitability of different substrates for egg adhesion, embryo settling, and incubation success to identify. A variety of newly wetted and submerged substrate materials and interstitial space treatments would be examined including rock surfaces, rock interstices, periphyton covered rock, rock with a dusting of fine sediments, large wood, periphyton covered large wood, submerged aquatic vegetation, and submerged riparian vegetation.

*Activity 1B.7.1.c. Conduct field tests of the benefits of riparian vegetation or structure for egg deposition and incubation by placing suitable material (e.g. Christmas trees) along the shoreline near current spawning sites.*

To be considered if initial field studies suggest that sturgeon are depositing eggs in shallow seasonally flooded habitat and newly flooded substrates and laboratory studies indicate current rock substrates are less suitable than other substrates. Addition of cover or structural complexity could also be considered for appropriate areas of the thalweg downstream from known spawning areas.

*Activity 1B.7.1.d. Investigate ontogenic, feeding, and dispersal behavior of larval sturgeon using laboratory studies.*

These might include habitat preference studies at various developmental stages, feeding studies of larvae presented with uneven distributions of food, and controlled starvation studies to identify critical periods.

*Activity 1B7.1.e. Use habitat preference and dispersal data from lab studies as well as computer flow models to identify egg/embryo dispersal locations based on observed or estimated spawning locations.*

It is possible that eggs were historically distributed into river margins but are no longer because turbulent flow conditions are no longer prevalent. This activity would also evaluate the extent of available habitat in current rearing locations and help drive sampling to capture early life stages.

*Activity 1B7.1.f. Evaluate use of riparian vegetation or structure in lower Columbia as an analog for the Kootenai River*

Fund a study of egg deposition on riparian vegetation and other structure along either side of the lower Columbia near Ives Island, WA, and/or other suitable location(s), per suggestion of Parsley (USGS, pers. comm, Dec. 2004). Determine whether and where eggs deposit in floodplain, time of inundation of eggs prior to recession of flow, and if possible, retention and hatching success.

Task 1B.7.2. Conduct further evaluations of alternative hypotheses for recruitment failure including egg smothering, predation, turbidity, and environmental contamination

The following proposed alternatives are included here for further consideration by the recovery team.

*Activity 1B.7.2.a. Conduct laboratory studies to examine egg dynamics in dunes*

Do eggs roll with the flow or do they get buried? Recent studies indicate that smothering will result in mortality but that experiment involved confined eggs (Kock 2004; Kock et al. In press). In a natural setting, eggs can move with the current and may remain relatively close to the surface of the sediment. The eggs have a specific gravity that is lighter than sand, so they may tend to stay on top of the dunes rather than become buried. On the other hand adhesion to sand or mechanical abrasion may also affect survival in a more natural experimental protocol. Fine particle adhesion to incubating sturgeon embryos is commonly observed in field collections where fines are prevalent. Many or most of these embryos were viable after removing particles under a dissecting microscope. However, in the Kootenai River sufficient particle adhesion could increase mortality by increasing egg or embryo mass to a point where suffocation could be more likely or inevitable.

*Activity 1B.7.2.b. Conduct predation simulation modeling using empirically supported ranges of embryo and predator abundance and embryo ingestion rates to determine if predation on eggs is capable of wiping out an entire cohort*

KR spawning and incubation habitat and predator-prey abundance ratios may have been altered at the expense of natural recruitment. This investigation does not provide remedial recommendations. Rather, it is intended to assess the severity of predation and its putative role in recruitment failure.

Naturally produced eggs and embryos have been collected from the Kootenai River during most years from 1990 through 2005. However, no larvae have been collected during those years with gear and techniques that reliably collect larval white sturgeon in other rivers. This indicates recruitment limitation or failure prior to the larval stage. Predation simulations can provide order of magnitude estimate comparisons between numbers of eggs available and consumed. If conservative estimates of egg/embryo consumption exceed estimated numbers available by many orders of magnitude, predation at these early life stages could be a significant contributor to recruitment failure.

*Activity 1B.7.2.c. Conduct a controlled field study to determine if predation on eggs is capable of wiping out an entire cohort (Implementation conditional based on outcomes of Activity 1.B.6.2.b.)*

It is possible that not enough eggs are going into the environment or into refugia to swamp the available predators, thus creating a predation trap. This experiment might involve placing eggs in the environment and monitoring their numbers over time and/or the activities of predators (using video or acoustic cameras). Empirical evidence indicated instantaneous consumption of up to 70 sturgeon eggs by catostomids and cyprinids, with hundreds of

eggs collected from omnivorous fishes in the Kootenai River (Miller and Beckman 1996; Anders et al. 2002).

*Activity 1.B.7.2.d Consider implementing a shore-based target fishery for egg consuming fishes during the spawning season in the spawning reach where eggs are routinely collected with egg mats. Consider the same effort downstream from embryo release experiments as an index of predation. Implementation of this activity is conditional, depending on the outcomes of Activity 1.B.7.2.b*

Implemented with agency and tribal employees and/or with assistance from interested public groups, these efforts could provide empirical egg/embryo consumption rate data for use in predation simulation modeling and recruitment failure assessments.

*Activity 1.B.7.2.e Sponsor a local annual non-game fish harvest derby in the Kootenai River as part of community outreach and education activities for sturgeon recovery*

*Activity 1B.7.2.f. Consider the effects of decreased turbidity.*

Involves a literature and data review to assess relative level of turbidity in Kootenay as compared to other systems with and without recruitment. Variability in turbidity may be monitored from year to year. This effort could also include behavioral assessments. If significant trends are identified in reviews, consider initiating a program to plan, receive environmental approvals and implement turbidity application.

*Activity 1B.7.2.g. Continue to explore the prevalence and effects of environmental contaminants as appropriate.*

In 1989, the IDFG and the Kootenai Tribe of Idaho began assessing contaminant concentrations in white sturgeon (Apperson and Anders 1991). A more intensive assessment and monitoring study was initiated in 1997, using biomarker research to determine potential physiological effects of bioaccumulated metal and organochlorine compounds in juvenile and adult Kootenai River white sturgeon (Kruse 2000; Kruse and Scarnecchia 2002a, Kruse and Scarnecchia 2002b).

A biomarker approach incorporates tissue and environmental contaminant residue information with measures of physiologic functions in organisms. Bioaccumulated contaminants can result in a range of lethal and sublethal impact on fish, which can be expressed at the individual or population level (Heath 1995). Physiologic biomarker research is an effective method for determining contaminant effects in aquatic ecosystems (Ward 1998). Kruse and Scarnecchia (2002a) reported that the potential exists for sublethal effects on reproduction and other physiological functions due to contaminant bioaccumulation in Kootenai River white sturgeon. They also noted a significantly higher mortality rate in white sturgeon eggs coated with Kootenai River bottom sediment. The sediment-coated eggs also contained higher concentrations of copper and the PCB Aroclor 1260 than eggs coated with suspended solids (collected from the Kootenai River) or Fullers Earth (a deadhesion media derived from diatom shells).

Recommendations for appropriate future contaminant research, monitoring and evaluation will be provided in the KTOI proposal (BPA Project 1988-0064) submitted by January 10, 2006 during the BPA FY07-09 proposal solicitation process.

*Activity 1B.7.2.h Evaluate effects of turbidity in lab studies as it affects predation efficiency of visual predatory or omnivorous fishes.*

## **1C. Ecosystem Restoration**

Many alterations to the Kootenai River occurred at various ecological scales and contributed to a decline in the sturgeon population as well as to declines in many other fish species. Ecosystem level changes related to loss of floodplain habitats, reduced productivity, and other physical and biological changes likely had an effect on sturgeon long before complete recruitment failure occurred (Figure 4 in Paragamian et al. 2005). Natural recruitment abruptly declined throughout the 1950s and never reestablished, with the exception of a limited amount of recruitment during a few years immediately after Libby Dam completion (Figure 4 in Paragamian et al. 2005). Because of the large scale nature of these threats, a number of habitat restoration and research projects in other forums are currently underway to provide remediation. These projects are important to the continued health of current and future the sturgeon population and its required habitat. The SRT provides support for these ecosystem level projects where possible. However, detailed work plans will not be included in this document as this planning is completed in other forums. For a broader context of ongoing and planned habitat and population restoration in the Kootenai/Kootenay Basin, see Appendix A (Walters et al. 2005) and the Kootenai River Subbasin Plan ([www.nwcouncil.org/fw/subbasinplanning/kootenai/plan](http://www.nwcouncil.org/fw/subbasinplanning/kootenai/plan)).

### ***Measure 1C.1. Pursue opportunities to restore floodplain habitats and connectivity.***

#### **Task 1C1.1. Implement Kootenai River Floodplain Reconnection Project (BPA# 2002-008-00, KTOI)**

- Activity 1C1.a. Complete, assess and utilize orthographic and topographic surveys (LiDAR) for DTM.*
- Activity 1C1.b. Utilize topographic data and Digital Terrain Model (DTM) to develop cross sections and longitudinal profiles at key points to facilitate hydraulic modeling.*
- Activity 1C1.c. Estimate floodplain volumes, stage-storage-area relationships and areas as a function of the existing topography and a series of water surface elevations represented as flat planes.*
- Activity 1C1.d. Characterize soil, depth to groundwater and static groundwater level with monitoring wells.*
- Activity 1C1.e. Continue monitoring baseline biological sampling of slough, side channels and wetlands consistent with Biomonitoring protocols established by Kootenai River Resident Fish project (1994-049-00).*

- Activity 1C1.f. Coordinate with local communities, agencies, and landowners on access, study design and feasibility.*
- Activity 1C1g. Generate site location recommendation for river-floodplain connectivity concept, and identification of alternatives to cover the range of potential river-floodplain connection actions.*
- Activity 1C1.h. Estimate floodplain volumes, stage-storage-area relationships and areas as a function of the existing topography and a series of water surface elevations represented as flat planes.*
- Activity 1C1.i. Coordinate and oversee technical peer-review process, fieldwork, surveys, biomonitoring, sampling for project completion and QA/QC evaluation process.*

**Task 1C1.2. Implement Kootenai River Floodplain Operational Loss Assessment (BPA# 2002-011-00, KTOI)**

- Activity 1C.2.a. Continue to assist in the coordination of natural resource technical committee (KVRI) on the comprehensive process for the collaborative approach in focusing on resource issues.*
- Activity 1C.2.b. Coordination, oversight and organization of the RDRT meetings and integration of the International Kootenay River Ecosystem Rehabilitation Team (IKERT)*
- Activity 1C.2.c. Refinement of the operation loss assessment framework (Kootenai River Action Plan) and evaluate methodologies for a regionally applicable operational loss assessment for the Kootenai River ecosystem*

**Task 1C1.3. Implement Geomorphology and Hydrologic Assessments (KTOI)**

- Activity 1C1.3.a. Combine pre- and post-dam reference hydrologic scenarios*
- Activity 1C1.3.b. Use digital image and LiDAR technology to model physical processes in floodplain*

**Task 1C1.4. Implement Aquatic Nutrient and Trophic Level Assessments (BPA 1994-049-00, KTOI)**

- Activity 1C1.4.a. Coordinate with Kootenai River Resident Fish programs the ecosystem restoration project (1994-049-00) to assess nutrient and trophic levels and related Biomonitoring program.*



***Measure 1C.2. Restore an appropriate nutrient balance in the river and lake to enhance system productivity.***

Task 1C.2.1: Initiate a controlled, large-scale nutrient restoration effort in the mainstem Kootenai River, downstream of the Montana-Idaho border.

*Activity 1C.2.1.a. Determine Kootenai River mixing zone length downstream from the controlled nutrient addition point (Leonia, MT/ID Border).*

*Activity 1C.2.1.b. Purchase agricultural grade Nitrogen and Phosphorus*

*Activity 1C.2.1.c. Cover biomonitoring cost associated with adding a new site downstream of nutrient addition point*

Task 1C.2.2: Monitor key water quality parameters, with an emphasis on macro-nutrients needed for in-river biogenic development. (Biomonitoring Program, Part one; BPA 94-49; ongoing)

*Activity 1C.2.2.a. Take local weekly and system-wide monthly water quality samples and analyze macro-nutrients and selected heavy metal concentrations at selected Kootenai River sites.*

Task 1C.2.2: Monitor and evaluate in-river productivity of the Kootenai River before, during, and after large-scale ecosystem experiments. (Biomonitoring Program, Part Two, BPA 94-49; ongoing)

*Activity 1C.2.2.a. Monitor chlorophyll a concentration & periphyton biomass*

*Activity 1C.2.2.b. Monitor algal species composition*

*Activity 1C.2.2.c. Monitor macroinvertebrate species, biomass, density, & community attributes*

*Activity 1C.2.2.d. Monitor fish species/community dynamics & abundance*

Task 1C.2.3: Identify, assess, protect, and rehabilitate critical stream segments within tributaries of high importance relative to the lower Kootenai River ecosystem.

*Activity 1C.2.3.a. Protect and maintain prime, functioning tributary habitat (identified as Class 1 in - In conjunction with appropriate management and regulatory agencies, create new or use existing mechanisms to protect and maintain Class 1 streams or reaches (including but not limited to title acquisition, conservation easements, and long term leases). Periodically evaluate and update habitat condition. Implement actions necessary to maintain Class 1 status.*

*Activity 1C.2.3.b. Restore riparian habitats to levels equivalent to the QHA-generated riparian condition habitat restoration scores of reference streams.*

- Activity 1C.2.3.c. Reduce the delivery of fine sediments to a level equivalent to the QHA-generated fine sediment habitat attribute scores of reference streams or reaches.*
- Activity 1C.2.3.d. Improve channel stability to a level equivalent to the QHA-generated channel stability scores of reference and Class 1 streams.*
- Activity 1C.2.3.e. Protect and revegetate riparian areas to maintain shading and cool water temperatures.*
- Activity 1C.2.3.f. Improve the thermograph to a level equivalent to the QHA-generated thermograph scores of reference and Class 1 stream.*
- Activity 1C.2.3.g. Protect habitat diversity in Class 1 streams and reaches.*
- Activity 1C.2.3.h. Improve habitat diversity to a level equivalent to the QHA-generated habitat*
- Activity 1C.2.3.i. Improve hydrographs so they are equivalent to the QHA-generated high/low flow habitat restoration scores of reference streams.*
- Activity 1C.2.3.j. Determine opportunities for altered hydro operations to remove delta blockages from tributary streams.*
- Activity 1C.2.3.k. Restore and provide passage to migratory fish by removing potential man caused barriers, i.e. impassable culverts, hydraulic headcuts, water diversion blockages, landslides, and impassable deltas.*

**Task 1C.2.4: Mitigate costs of nutrient addition in the Kootenai River ecosystem (Kootenay Lake), as mandated by the USFWS Biological Opinion, due to lost system productivity caused by construction and operation of Libby Dam.**

- Activity 1C.2.4.a. Fully fund fertilizer acquisition costs to implement, monitor and evaluate proven nutrient addition methods to improve the Kootenai River ecosystem (Kootenai River, ID, and South Arm Kootenay Lake, BC).*

***Measure 1C.3. Protect and restore other key elements of the native community including kokanee.***

The following section from Andrusak et al. (2004) summarizes kokanee restoration activities:

The goal of Kootenai/y basin kokanee restoration involves restoration of system productivity and the fish community of Kootenai River and the downstream Kootenay Lake. Restoration of the fish community and supporting ecological conditions in Kootenay Lake’s South Arm requires a series of ecological changes, including: 1) ample restored, available kokanee spawning habitat; 2) adequate nutrient availability for in-lake fish growth and maturation; 3) identification of kokanee stock distinction and potential stock structure; 4) design and implementation of appropriate monitoring and evaluation plans; and, 5) public support.

Because native fishes of the Kootenai/y River spend portions of their lives rearing and maturing in Kootenay Lake's South Arm before returning upstream to spawn, nitrification of the South Arm is expected to enhance fisheries in upstream portions of the river in addition to South Arm Kootenay Lake. In addition, 2005 is the first year of a five year adaptive nutrient restoration experiment for the Kootenai River in Idaho, with a single nutrient addition site just downstream from the Idaho/Montana border.

Task 1C.3.1. Evaluate and restore kokanee and rainbow trout spawning habitat.

Adequate amounts of suitable, available kokanee spawning habitat are required for successful South Arm kokanee population restoration. Kokanee may be from several potential sources (remnant native South Arm stock, entrained fish from Lake Koochanusa (an admixed Okanagan stock), or introduced North Arm (Meadow Creek) stock). South Arm kokanee rear and mature in the lake. This program is designed to rebuild or produce runs that can ascend the Kootenai/y River to spawn in upstream tributaries in BC, Idaho and possibly Montana, in accordance with local fish management programs.

*Activity 1C.3.1.a. Review and summarize historic file data*

*Activity 1C.3.1.b. Conduct habitat assessments*

*Activity 1C.3.1.c. Prioritize stream restoration*

*Activity 1C.3.1.d. Restore existing stream habitat and consider engineered-natural streams and or channels.*

Task 1C.3.2 Review/develop and implement appropriate methodologies for stream classification to ensure integration of Idaho and BC stream classification systems.

Task 1C.3.3 Evaluate and restore South Arm productivity.

Current productivity in South Arm Kootenay Lake will be documented to serve as a pre-treatment baseline against which to compare post-fertilization productivity. Experimental nutrient loading rates will be determined by review and update of past and current nutrient loading rates and by the use of the Kootenay Lake Ecosystem Model to simulate desired restoration results.

*Activity 1C.3.3.a. Update Kootenai River phosphorus loading rates*

*Activity 1C.3.3.b. Simulate South Arm nutrient additions*

*Activity 1C.3.3.c. Develop fertilization loading rate targets*

*Activity 1C.3.3.d. Fertilize South Arm Kootenay Lake*

*Activity 1C3.3.e. Monitor and adaptively manage South Arm Kootenay Lake fertilization*

Task 1C.3.4 Identify kokanee stocks in the South Arm and upstream Idaho spawning tributaries, and implement kokanee eyed-egg plants.

Identification of kokanee stock and potential stock structure is required to determine best choice of stocks for population enhancement (e.g., eyed-egg plants). Currently, kokanee in the South Arm could include remnant native South Arm stock, entrained fish from Lake Kootenai (an admixed Okanagan stock), or North Arm (Meadow Creek, Lardeau) stocks traversing the length of the lake.

*Activity 1C.3.4.a. Perform meristic screen*

*Activity 1C.3.4.b. Perform genetic analysis (nDNA: microsatellites)*

*Activity 1C.3.4.c. Evaluate wild and hatchery stock structure, availability*

*Activity 1C.3.4.d. Evaluate the genetic component of kokanee enhanced by nutrient addition in South Arm and Kootenai River.*

Task 1C.3.5 Implement kokanee egg plants

Eyed kokanee egg plants into some of the Idaho streams have been made in anticipation of South Arm fertilization increasing the lake carrying capacity. Artificially increased numbers of stream produced fry due to the egg plants should result in increased escapements in future years. Recommendations include continuation of South Arm fertilization as well as kokanee egg plants in Idaho streams and in some South Arm streams. Long term recovery of kokanee spawners into South Arm and Kootenai River tributaries will require stream habitat restoration work to increase stream productivity.

The following future natural production goals are provided as part of this 5-year plan:

- Document greater than 50 adult spawning kokanee in each tributary by 2007.
- Document greater than 100 adult spawning kokanee in each tributary by 2020.
- Develop a multi-year average of 250 adult spawning kokanee in each tributary by 2030.

***Strategy 2. Use conservation aquaculture to prevent extinction and rebuild a demographically and genetically viable population.***

A conservation hatchery program was initiated in 1990 as a stopgap measure to preserve the remaining Kootenai sturgeon population (Ireland et al. 2002a, 2002b). This program spawns wild brood stock and rears juveniles for release at up to 1 or 2 years of age. The hatchery currently provides the only significant source of recruitment to the Kootenai river white sturgeon population. If natural recruitment is not restored soon the next generation will be produced primarily or entirely by the conservation hatchery program. The hatchery currently provides the only means to conserve the native genetic material, begin rebuilding a healthy age class structure, and prevent extinction. If fish managers had not initiated a conservation hatchery program as a contingency for habitat improvement measures, the current white sturgeon generation would have been the last. Hatchery strategies and measures are further detailed in the Adaptive Multidisciplinary Conservation Aquaculture Plan for Endangered Kootenai River White Sturgeon (KTOI 2004).

**2A. Production**

***Measure 2A.1. Maintain production adequate to maximize annual effective population numbers, re-establish age-class structure and population abundance, avoid further demographic and genetic bottlenecks, and contribute to long-term population viability and persistence.***

Task2A.1.1. Produce families each year from up to 12 wild females mated with multiple wild males per female, all collected from and returned to the Kootenai River.

The original program goal was to spawn up to 6 females and 15 to 18 males (Kincaid 1993). Beginning in 2004, brood stock goals were doubled in anticipation of future declines in broodstock availability and the need to avoid a genetic founder effect in the next sturgeon generation.

*Activity 2A.1.1.a. The hatchery gets first priority for any suitable broodstock that are needed during the next 20 years even if it means that no ripe fish are available to spawn in the wild or for the upstream transport experiment.*

This priority will continue until repeated natural recruitment of a magnitude to invalidate the hatchery is restored. Any ripe sturgeon not appropriate or needed for the hatchery, as determined by hatchery program personnel, may be released into areas of suitable habitat.

*Activity 2A.1.1.b. Minimize reuse of broodstock in the same or different years where alternatives are available.*

Reuse broodstock as necessary to fully utilize the available hatchery space and to maximize genetic diversity of broodstock and progeny groups.

*Activity 2A.1.1.c. Half-sibling family use is appropriate.*

As with brood stock reuse, there will be times when there are not enough males or females to produce unique family groups. It is typically easier to get males than females due to shorter reproductive periodicity (more males available/year), so each female may be spawned with several different males

so that all available males contribute to progeny groups. This approach may better mimic the natural white sturgeon gene flow or reproductive model than imposing a paired mating system derived from salmonid aquaculture on a communal broadcast spawner like white sturgeon.

*Activity 2A.1.2.d. Consider temporary suspension of hatchery broodstock collection under limited circumstances where necessary to facilitate natural recruitment restoration research, which may require leaving all available spawning fish in the river.*

The highest priority for available broodstock will continue to be for use in the hatchery which annually provides year classes produced from more than a dozen different broodstock each year. When improved natural spawning conditions are restored it might be appropriate to maximize natural spawning in the river to take advantage of those conditions to evaluate their suitability and contribution to natural recruitment. If this activity is deemed to place long term population diversity at risk, then the experimental evaluation will be deferred until the next generation of spawners becomes mature, or until risks of suspending production of a year class in the hatchery are less than potential benefits of alternative in-river effort.

Task2A.1.2. Rear and release up to 10,000 fish per family for release in fall at age 0+ or the following spring at age 1 in order to establish and maintain abundance, annual spawner numbers, and age and genetic diversity of the population.

Use of batch marks allows the hatchery to release fish at smaller sizes and to produce more fish from the available facilities.

*Activity 2A.1.2.a. Minimize detrimental genetic or behavioral impacts of artificial propagation by out-planting fish at the earliest point consistent with acceptable survival and evaluation requirements.*

*Activity 2A.1.2.b. Allow for release of family groups of varying numbers up to the family release goal.*

*Activity 2A.1.2.c. Fish produced in excess of agreed upon restoration and research-stocking purposes and other uses may be humanely euthanized where stocking risks could have disproportionate effects on the future diversity of the population in the wild.*

Hatchery fish reared in excess of stocking needs will be used to establish a failsafe population, appropriate applied research and public information/education purposes.

*Activity 2A.1.2.d Continue to mark hatchery-reared juveniles so that hatchery and naturally-produce may be distinguished.*

Hatchery fish may be batch marked with CWTs rather than individually-coded PIT tags. Representative groups of hatchery fish may be marked with individual PIT tags to facilitate continued evaluations of performance.

*Activity 2A.1.2.e Distribute releases of hatchery fish throughout British Columbia, Idaho, and Montana portions of the river to avoid potential local competition. Distributed releases will allow fish to capitalize on all available habitats.*

*Activity 2A.1.2.e Develop a failsafe sturgeon population by release of additional hatchery fish in a natural water body where attendant risks to the current wild population and other sensitive species is minimal.*

Consideration of developing an experimental non-essential population is based on the need to reduce extinction risk associated with a single extant population.

***Measure 2A.2. Use hatchery produced progeny to address critical uncertainties regarding limiting life stages, underlying causes of recruitment failure, and potential alternatives for recovery.***

Task 2A.2.1. Conduct a series of controlled releases of hatchery-produced larval, post-larval, and YOY stages to collect empirical data on limiting life stages and factors.

Early life history research stocking allows focused empirical research on specific critical uncertainties currently jeopardizing short or long-term population recovery.

Task 2A.2.2. Provide eggs, larvae, or juveniles for experimental work as required.

Hatchery fish in excess of production needs provide a ready source for other evaluations of behaviour, physiology, pathology and other studies that can help improve success of recovery efforts.

## **2B. Facilities**

***Measure 2B.1. Use facilities at the Kootenai Tribal Sturgeon Hatchery in Idaho and the Kootenay Trout and Sturgeon Hatchery in British Columbia to produce Kootenai sturgeon.***

Task 2B.1.1. Rear unique families at the KTOI and Kootenay hatcheries.

The Canadian Kootenay Hatchery program was initially developed as a backup facility to rear duplicate family groups in case of problems at the Idaho facility. Subsequent hatchery advancements have minimized the chances of catastrophic losses at both facilities and rearing different families at each facility maximizes numbers of families produced and the collective future founder population size.

***Measure 2A.2. Develop additional facilities required to ensure conservation of current genetic diversity and to meet production requirements for next sturgeon generation.***

Task 2B.2.1. Develop master plan and initiate NPCC 3-step hatchery evaluation process.

Additional adult holding and juvenile rearing facilities may be required to meet conservation aquaculture program needs.

Task2B.2.2. Evaluate streamside hatching and rearing systems.

Streamside hatching and rearing systems are being used for other sturgeon species to address issues of spawning site fidelity. Experimentation with this conservation aquaculture approach could be experimentally implemented in the canyon reach the interest of producing spawners that might return to this upstream reach where substrates appear suitable for spawning, early life stage survival, and natural recruitment.

## **2C. Hatchery Practices**

### ***Measure 2C.1. Employ appropriate conservation aquaculture practices.***

Task 2C.1.1. Avoid hatchery incubation, rearing, grading, and release practices that select for unrepresentative subsets of each family group.

Performance traits such as growth and survival may be differentially adaptive for in the hatchery and in the wild. Therefore, it is critical that hatchery practices do not intentionally or unintentionally select for specific traits based on performance in the hatchery (e.g. fast growth).

Task 2C.1.2. Implement best available hatchery protocols to minimize mortality of wild broodstock and hatchery-reared juveniles.

Involves appropriate handling, rearing density, water quality, and fish health protocols.

Task 2C.1.3. Verify health status of hatchery fish prior to release to avoid increasing health risks to the wild population.

A representative sample group will be examined using virology, histology, bacteriology, and parasitology tests (See 2004 Hatchery Plan, page 31 for more details; KTOI 2004).

Task 2C.1.4. Operate the hatchery to avoid impacts to Kootenai River water quality.

Includes nutrient and pathogen effects.

Task 2C.1.5. Develop cryopreservation techniques and implement as available to preserve representative samples from the current population and provide opportunities for inter-generational gene flow.

Techniques are currently under development, with some success accruing (up to 50% fertilization using thawed sperm (John Siple, KTOI, personal communication). Initial success with sperm extender solutions and applications should be verified.

## **2D. Hatchery Monitoring and Evaluation**

### ***Measure 2D.1. Continue to implement annual scientific monitoring and evaluation activities to guide implementation of the hatchery program.***

Involves adaptation and refinement of hatchery objectives, facilities, and practices as new information becomes available.



Task 2D.1.1. Monitor genetics of hatchery broodstock and the wild population to guide and track success of the conservation aquaculture program.

Involves microsatellite DNA analysis of all broodstock.

*Activity 2D.1.1.a. Compare genetic characteristics of parents and offspring to evaluate basic assumptions regarding sturgeon genetics and allelic representation of the wild population in the hatchery broodstock and progeny group*

*Activity 2D.1.3.b. Developing Kootenai River white sturgeon gene library to generate additional high resolution microsatellite loci.*

Recent microsatellite analysis of wild Kootenai River white sturgeon, hatchery broodstock, and hatchery progeny groups revealed inadequate resolution of existing microsatellite loci to accurately assign recaptured juveniles to families of origin (Rodzen et al. 2004). Releases of eggs, embryos and larvae are part of current evaluation programs but identification of batches associated with experimental releases is not currently possible. Thus, a genetic system to identify recaptures would be extremely useful, and in fact essential to accurate determination of experimental results. Improved accuracy of genetic identification could also address issues such as minimum numbers of contributing adults to annual embryo (post-neurulation) and subsequent natural fish collections.

Task 2D.1.2. Monitor survival, growth, condition, and disease history of individual family groups in the hatchery.

These monitoring activities provide guidance for egg take and facility requirements as well as post-release performance. Activities include pre-release length and weight measurements of representative subsamples.

*Activity 2D.1.2.a Sample all relevant biological parameters to evaluate health and condition of hatchery-reared progeny groups prior to release.*

Task 2D.1.3. Monitor post-release performance of representative subgroups of hatchery fish including survival, growth, and condition.

Sample groups of sturgeon will be individually and batch marked prior to release and sampled in subsequent juvenile assessment tasks identified in the core monitoring program under Strategy 3.

Task 2D.1.4. Evaluate trends in population growth and fish condition over time to evaluate potential limitations in receiving in-river habitat capacity for sturgeon.

Uncertainties in sturgeon survival rates and unknown system capacities mean that an experimental approach is the only viable alternative for determining the carrying capacity of the Kootenai system for sturgeon. This involves continued stocking of significant numbers of fish and monitoring for a population response. Trend analysis will be required to distinguish a true response from sampling and inter-annual variability

*Activity 2D.1.4.a. Consider future revisions to stocking rates as appropriate based on fish condition and habitat capacity evaluations.*

Current stocking rates are based on current empirical survival estimates, population rebuilding targets (KTOI 2004), and densities of surviving fish that do not appear to negatively affect growth, survival, or biological condition. However, hatchery program personnel understand the need to adjust stocking rates should significant and consistent density-dependent annual reductions in these parameters be observed.

### ***Strategy 3. Sturgeon recovery and ecosystem restoration monitoring***

A systematic monitoring program is critical for evaluating sturgeon status and the effects of restoration measures and sturgeon recovery. Monitoring program assessments address natural spawning, juvenile and adult population status, distribution and movement patterns, and data coordination/analysis. Many monitoring program elements provide beneficial data and information for a variety of recovery applications, including regular status assessments and evaluations of specific sturgeon recovery and habitat restoration actions. For instance, juvenile sampling provides information on juvenile population size, natural recruitment, and performance of hatchery fish. The following measures, tasks, and activities identified under this strategy include ongoing core monitoring program elements.

#### **3A. Natural Spawning Assessments**

***Measure 3A.1. Conduct annual assessments of sturgeon spawning activities to index spawning activity, identify spawning periods, and cue sturgeon flow requests.***

Task 3A.1.1. Implement standardized substrate mat sampling at index sites in known spawning areas.

*Activity3A.1.1.a. Provide within-year naturally produced egg and embryo collection data during the collection year for use in analysis and modeling.*

Task 3A.1.2. Implement standardized D-ring net larval sampling at index sites downstream from known spawning areas.

*Activity3A.1.1.a. Provide within-year naturally produced larval collection data during the collection year for use in analysis and modeling.*

#### **3B. Wild Adult Assessments**

***Measure 3B.1. Conduct annual adult sturgeon assessments to estimate population status and obtain spawners for the hatchery program.***

Task 3B.1.1. Capture adults during spring and early summer in areas of concentration downstream from Bonners Ferry using setlines, gillnets, and angling. Provide information on captures (methods, locations, dates, tag identification) to IDFG in accordance with established procedure to allow a single database of individual adults to be maintained.

Task 3B.1.2. Biological and mark-recapture sampling to estimate abundance, survival, and other population characteristics.

Task 3B.1.3. Use ripe spawners for hatchery broodstock or other applications as appropriate. See hatchery plan for more details (KTOI 2004).

Task 3B.1.4. Tag adults with radio or acoustic and release for monitoring of spawning behaviour and movement patterns.

Implement acoustic tagging of agreed upon numbers of adults to maximize opportunities for future monitoring. Although this alternative has been made possible by the unobtrusive small size of acoustic tags, tag life estimated in years, and the fixed telemetry array, broodstock use remains top priority for pre-spawning adults (KTOI 2004). Transmitters should be avoided in a given year on any fish that are destined for the hatchery as broodstock.

Task 3B.1.3. Annual wild population and brood stock genetics sampling.

Annually sample wild population over time for archives in order to characterize population genetics of remnant wild population. Characterization of wild population genetics may provide insight into target goals for conservation aquaculture program's population rebuilding goals, and provide a potential comparative benchmark.

### **3C. Juvenile Assessments**

***Measure 3C.1. Conduct periodic juvenile sturgeon assessments to estimate population status, index natural recruitment, and monitor hatchery program performance.***

Task 3C.1.1. Capture juveniles during summer at standardized, spatially-stratified index sites throughout the U.S. and Canadian portions of the river using gillnets.

Task 3C.1.2. Biological and mark-recapture sampling to estimate abundance and survival.

Task 3C.1.3. Index natural recruitment based on marked-unmarked ratios.

Includes assessments of wild recruitment events and recruitment from egg release and habitat enhancement projects.

Task 3C.1.4. Evaluate dispersal from release sites, subsequent movements, habitat use, growth and survival of hatchery reared juveniles.

See Hatchery Plan for more details (KTOI 2004).

Task 3C.1.5. Incorporate pectoral fin ray sampling from recaptures of large hatchery fish for aging method validation assessment.

See Hatchery Plan for more details (KTOI 2004).

### **3D. Telemetry**

***Measure 3D.1. Monitor distribution and movements of a representative sample of acoustic-tagged juveniles and adults to assess juvenile and adult habitat use and movements and monitor biological response of adult sturgeon to spawning habitat enhancement projects.***

Task 3D.1.1. Maintenance and operation of Vemco receiver arrays.

Task 3D.1.2. Juvenile telemetry to define dispersal from hatchery release sites and subsequent juvenile habitat use, movements, and migration.

Task 3D.1.3. Adult telemetry to define adult movements and habitat use in current spawning sites and the area of interest for habitat creation above Ambush Rock in Idaho.

Task 3D.1.4. Installation and maintenance of a 3-D telemetry tracking array (acoustic positioning system) to monitor wild adult behavior near enhancement project structures.

Task 3D.1.5. Focused program to monitor the 3D movements of these fish in the small piece of river comprising the Substrate Enhancement Pilot Project.

### **3E. Habitat Assessment & Monitoring**

***Measure 3E.1. Measure and monitor physical conditions in critical habitat and potential spawning areas.***

Task 3E.1.1. Map depth, velocity, and substrate in critical and potential spawning reaches to document baseline conditions.

Task 3E.1.2. Develop detailed computer hydraulic models of current and potential spawning reaches and calibrate to Kootenai River habitat conditions.

Task 3E.1.3. Periodically monitor changes in critical habitat parameters over time.

### **3F. Data Management & Reporting**

***Measure 3F.1. Maintain a central repository for data collected by various organizations to facilitate systematic applications.***

Developing and maintaining a central database is crucial for data and program accountability and facilitating proper analyses and data storage.

Task 3F.1.1. Annual data storage and management for adult and juvenile index monitoring and tagging programs.

*Activity 3F.1.1.a integrating data into IKERT relational database*

Task 3F.1.2. Periodic updates and reporting of estimates of adult population size and available breeders, population and hatchery genetics, and numbers and survival of hatchery and natural juveniles.

***Strategy 4. Update and revise recovery plan criteria and objectives.***

***Measure 4.1. Use this implementation plan and schedule to guide sturgeon recovery activities consistent with strategies identified in the Recovery Plan until a revised and updated Recovery Plan is available.***

The goal and strategies identified in the Recovery Plan continue to guide sturgeon recovery efforts although specific measures have evolved since the plan was first completed. Some measures have been achieved (e.g. hatchery upgrades) while new measures have been identified in several areas based on new information gained from actions implemented as part of the original plan.

***Measure 4.2. The Recovery Team will be maintained as a standing body to facilitate plan implementation and adaptation as appropriate.***

The Kootenai River White Sturgeon Recovery Team serves at the pleasure of the U.S. Fish and Wildlife Service, who maintains ultimate authority of recovery activities as mandated by the U.S. Endangered Species Act.

***Measure 4.3. Use information contained in this implementation plan and schedule to guide drafting and completion of a new Recovery Plan for Kootenai River white sturgeon.***

Additional information, data, and testable hypotheses regarding recovery have been generated since the completion of the existing Recovery Plan (USFWS 1999). The existing Recovery Plan stipulated that an updated Plan will be provided after five years. This implementation plan and schedule can help guide drafting and completion of a new Recovery Plan for Kootenai River white sturgeon as mandated in the existing Recovery Plan (USFWS 1999).

***Measure 4.4. Kootenai Valley Resource Initiative forum will be employed for purposes of public education and outreach and input associated with plan implementation.***

The mission of KVRI is to act as a locally based effort to improve coordination, integration, and implementation of existing local, state, and federal programs that can effectively maintain, enhance, and restore the social, cultural, and natural resource bases in the community. The KVRI membership and its partners include the KTOI, who initiated the initiative, federal, state, and provincial fisheries and water regulatory agencies, regional city and county governments, private citizens, landowners, environmental advocacy groups, and regional representatives of business and industry. The Kootenai Valley Resource Initiative (KVRI) was formed under a Joint Powers Agreement (JPA) between the Kootenai Tribe of Idaho (KTOI), the City of Bonners Ferry, and Boundary County, dated October 2001. Under the JPA, the KVRI is empowered to restore and enhance the resources of the Kootenai Valley and foster community involvement and development. The KVRI Burbot Committee was later formed as a subset of the KVRI to pursue coordinated burbot conservation and management.

***Measure 4.5. Recovery Plan elements as described by this implementation plan and schedule will form the basis for other planning efforts and consultations including the Hydro system Biological Opinion and NPCC Subbasin planning.***

This 5-year Plan is intended to guide implementation, coordination, and accomplishment of research and recovery activities for Kootenai River white sturgeon and elements of their habitat as presented in the Recovery Plan (USFWS 1999).

## Kootenai River White Sturgeon Recovery Implementation Schedule (2005-2010)

### Strategy 1. Natural Recruitment Restoration

Measure/Task/Activity	Project		Calendar year					Participating Agencies, Comments
	Core	Pilot	2005	2006	2007	2008	2009	
<b>1A. Flow Augmentation</b>								
1. Annual normative hydrograph	X		X	X	X	X	X	USACE, RT, IKERT
2. Annual Libby sturgeon operations	X		X	X	X	X	X	USACE, RT
3. Design flows based on water year	X		X	X	X	X	X	USACE, RT
4. Control flooding risks	X		X	X	X	X	X	USACE, BC Hydro
5. Adapt guidelines new information	X		X	X	X	X	X	USACE, RT, IKERT, BC Hydro
<b>1B. Habitat Restoration</b>								
1. Rock Fill in current spawning areas (Pilot project)		X	X	X	Implement a larger scale project based on 05-06 pilot project success			(KTOI-BPA Project 200200200) RT, USACE (05-06) (KTOI-BPA Project 200200200) RT, USACE 1135 (07-09)
1.1. Assess feasibility of rock addition		X	X	X	Assess feasibility of larger scale project(s) based on 05-06 pilot project success			RT, USACE, KTOI (BPA) funded (Project 200200200)
a. Computer hydraulic modeling		X	X	X	(X)	(X)	(X)	USGS, RT, (I and E 05 and 06)(07-09 conditional)
b. Physical hydraulic modeling		X		X	(X)	(X)	(X)	USGS, RT, (I and E 05 and 06)(07-09 conditional)
c. Exploratory geotechnical sampling		X	X	X	(X)	(X)	(X)	USGS, RT input
d. Permitting		X	X	(X)	(X)	(X)	(X)	All relevant entities (06-09 conditional)
e. Rock placement experiment		X	X	X	(X)	(X)	(X)	I,E RT (KTOI, USGS, IDFG, BCMoE, SPC&A)
f. Physical evaluations		X	X	X	(X)	(X)	(X)	USGS, RT
g. Measure biological response		X		X	(X)	(X)	(X)	USGS, IDFG, MoE, RT
h. Develop alternative, cost estimates based on pilot project success				X	X	(X)	(X)	USGS, USACE, RT
1.2. Future large-scale rock introduction project (11-35, FWS, as extension of existing pilot project)					(X)	(X)	(X)	Contingent on pilot project success, RT recommendations. USACE point on 1135 (Feasibility and design 07, implementation and evaluation 08-09)
a. Funding					(X)	(X)	(X)	USACE 1135; KTOI-BPA project 200200200
b. Design, permitting & contracting					(X)	(X)	(X)	USACE to provide details
c. Implementation					(X)	(X)	(X)	
d. Physical evaluations					(X)	(X)	(X)	
e. Biological evaluations					(X)	(X)	(X)	
f. Operation and maintenance					(X)	(X)	(X)	



Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
<i>2. Velocity and Turbulence Eductors</i>		X	X	X	(X)	(X)	(X)	Implementation USGS, SPC&A, (Paul Anders, Dave Smith) MFWP (Brian Marotz) Natural Solutions (Gordon Burns), (BPA Mark Reller?) KTOI-(BPA project 200200200 funding)
2.1. Feasibility assessment		X	X	X	(X)			
a. Field tests		X	X	X	(X)	(X)	(X)	
b. Biological response criteria development and test evaluation		X	X	X	(X)	(X)	(X)	
2.2. Design, implement, and evaluate larger-scale eductor test(s)					(X)	(X)	(X)	USGS, SPC&A, (Paul Anders, Dave Smith) MFWP (Brian Marotz) Natural Solutions (Gordon Burns), (BPA Mark Reller?) KTOI-(BPA project 200200200 funding) Implementation depends on success of small scale pilot project eductor test results.
<i>3. Spawning habitat hydraulic and flow field characterization</i>				X	X	X	X	SPC&A,
3.1. Fine scale definition of spawning sites				X	(X)	(X)	(X)	USGS, SPC&A, IDFG
3.2. Characterize hydraulics and flow fields at spawning sites relative to sensory ovoid				(X)	X	X	X	SPC&A, USGS
3.3. Test hypotheses, evaluate current and past conditions relative to current spawning habitat characteristics, simulation modeling				(X)	X	X	X	SPC&A, USGS (Others?)
<i>4. Explore ways to restore natural production involving Velocity-Depth Transition Zone</i>		X			(X)	(X)	(X)	
4.1. Model hypothesis		X	X		(X)	(X)	(X)	USGS, SPC&A, RT input, oversight (I,M&E during 07-09 depends on outcomes during 05-06)
a. Historical baseline		X	X		(X)	(X)	(X)	
b. Current conditions		X	X		(X)	(X)	(X)	
c. Model alternatives		X	X	X	(X)	(X)	(X)	
d. Other considerations		X	X	X	(X)	(X)	(X)	
4.2. Feasibility analysis				X	(X)	(X)	(X)	RT oversight, USGS, BPA, USACE, BC Hydro
4.3. Implement, monitor and evaluate appropriate scenarios from 4.2					(X)	(X)	(X)	RT oversight, USGS, BPA, USACE, BC Hydro
<i>5. Braided Reach</i>		X	X	X	(X)	(X)	(X)	RT oversight and input, USGS, (I,M&E during 07-09 depends on outcomes during 05-06)
5.1. Evaluate alternatives		X	X	X	(X)	(X)	(X)	USGS, RT
a. Identify options to provide spawning in the braided reach		X	X	X	X	(X)	(X)	USGS, RT; Model development, simulations 05-07 (additional refinements if needed 08-09)

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
b. Evaluation likelihood of providing identified options from a. (above)		X		X				USGS, RT
c. Refine and implement appropriate options from a. and b. (above)		X		X	X	(X)	(X)	USGS, RT, managing agencies
d. Corps PRP involving feasibility and sustainability of incised channel			X	X				USACE, USGS, RT
<i>6. Early life stage translocations</i>			X	X	X	(X)	(X)	KTOI, IDFG, BC MoE (Experimental 05-07; revisit in 07; modify/and or continue during 08-09 if successful)
6.1. Embryo releases (for several yrs during nutrient addition)(late use later lifestages) evaluate ways to increase embryo #'s for addition			X	X	X	(X)	(X)	KTOI, IDFG, BC MoE
a. Experimental embryo releases			X	X	X	(X)	(X)	KTOI, IDFG, BC MoE
b. Monitor success			X	X	X	(X)	(X)	Monitoring required each year early life stage translocation and release(s) occur
c. Consider implementation					(X)	(X)	(X)	KTOI, IDFG, BC MoE
6.2. Adult net & jet						(X)	(X)	KTOI, IDFG, BC MoE (reconsider in 08-09)
6.3. Larval releases (include as option)				(X)	(X)	(X)	(X)	KTOI, IDFG, BC MoE; RT input and discussion
<i>7. Investigate recruitment restoration alternatives and reduce recruitment failure uncertainties</i>	X		X	X	X	(X)	(X)	All relevant agencies, RT input and discussion
<i>7.1. Riparian Habitat Hypothesis</i>								
a. current egg distribution			X	X	(X)	(X)		USGS, IDFG, SPC&A
b. lab substrate attachment studies				X				USGS-BRD
c. consider field tests of added riparian vegetation			(X)	(X)				
d. lab larval studies (predation)			X	X	07-09			USGS-BRD
e. model early life stage dispersal patterns								USGS, SPC&A (merge USGS in-river data, models and results from Kynard, McAdam (substrate preferences)
f. lower Columbia riparian search		X		X?	X?			USGS-BRD
g. Contaminants (KTOI )								KTOI, FRAQR
h. Turbidity								KTOI, USGS-BRD, SPC&A, UI-ERG?

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
<b>1C. Ecosystem Restoration</b>								
<i>1. Floodplains</i>	X		X	X	X	X	X	KTOI, SPC&A, UI-ERG
<i>2. Nutrients</i>	X		X	X	X	X	X	KTOI, IDFG, SPC&A, BC MoE, Ward and Associates
<i>3. Kokanee</i>	X		X	X	X	X	X	KTOI, BC MoE, IDFG

## Strategy 2. Conservation Aquaculture

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
<b>2A. Maintain production</b>								All following conservation aquaculture measures, tasks, and activities performed, monitored and evaluated by the KTOI and its subcontractors unless otherwise noted.
<i>1. Annual numbers</i>	X		X	X	X	X	X	
1.1. Wild broodstock	X		X	X	X	X	X	
a. hatchery priority	X		X	X	X	X	X	
b. broodstock reuse	X		X	X	X	X	X	
c. half-sibling families	X		X	X	X	X	X	
d. natural spawning experiments								To be determined by RT
1.2. Release goals	X		X	X	X	X	X	Period review by KTOI, SPC&A, RT discussions
a. size & time	X		X	X	X	X	X	
b. surplus production	X		X	X	X	X	X	
c. marking	X		X	X	X	X	X	
d. locations	X		X	X	X	X	X	
e. failsafe population			X	X	(X)	(X)	(X)	KTOI, SPC&A, RT discussions
<i>2. Research applications</i>								
a. limiting life stages and factors			X	X	X	X	X	KTOI, IDFG, BC MoE, other relevant agencies (See Measure 1B.6 and subsequent tasks and activities for more details)
b. other experiments			X	X	X	X	X	
<b>2B. Facilities</b>								KTOI and FFSBC and appropriate subcontractors, RT
<i>1. KTOI &amp; Kootenay programs</i>	X		X	X	X	X	X	
1.1. Unique families	X		X	X	X	X	X	
<i>2. Additional facilities</i>								
2.1. Master planning			X	X	(X)	(X)	(X)	
2.2. Evaluate streamside hatching and rearing systems			X	X	(X)	(X)	(X)	KTOI, SPC&A, other relevant agencies
<b>2C. Hatchery Practices</b>								KTOI and FFSBC and appropriate subcontractors, RT
<i>1. Appropriate practices</i>	X		X	X	X	X	X	
1.1. Selectivity	X		X	X	X	X	X	
1.2. Minimize mortality	X		X	X	X	X	X	
1.3. Fish health	X		X	X	X	X	X	
1.4. Water quality	X		X	X	X	X	X	
1.5. Cryopreservation	X							
<b>2D. Hatchery Monitoring and Evaluation</b>								KTOI and FFSBC and appropriate subcontractors, RT
<i>1. Implementation guidance</i>	X		X	X	X	X	X	

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
1.1. Genetics	X		X	X	X	X	X	
a. evaluate assumptions								
b. develop gene library				X	X			SPC&A, UC Davis, subcontracted molecular genetic firm
1.2. In-hatchery performance	X		X	X	X	X	X	
a. pre-release sampling	X		X	X	X	X	X	
1.3. Post-release performance	X		X	X	X	X	X	
1.4. System capacity	X		X	X	X	X	X	
a. stocking revisions	X		X	X	X	X	X	

### Strategy 3. Recovery Monitoring

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
<b>3A. Natural Spawning Assessments</b>								IDFG, KTOI, BC MoE, RT discussion and oversight
<i>1. Annual spawning</i>	X		X	X	X	X	X	IDFG
1.1. Index egg/embryo sampling	X		X	X	X	X	X	IDFG
a. annually provide egg/embryo data for analysis and modeling								IDFG
1.2. Index larval sampling				(X)	(X)	(X)	(X)	IDFG (General performed only during years of early life stage releases )
b. annually provide larval data for analysis and modeling								IDFG
<b>3B. Wild Adult Assessments</b>								IDFG, KTOI, BC MoE, USGS-BRD
<i>1. Annual adult sampling</i>	X		X	X	X	X	X	
1.1. Capture	X		X	X	X	X	X	
1.2. Sampling	X		X	X	X	X	X	
1.3. Hatchery broodstock	X		X	X	X	X	X	
1.4. Telemetry tagging	X		X	X	X	X	X	
1.5. Genetic sampling	X		X	X	X	X	X	
<b>3C. Juvenile Assessments</b>								
<i>1. Periodic juvenile sampling</i>	X		X	X	X	X	X	
1.1. Capture	X		X	X	X	X	X	
1.2. Sampling	X		X	X	X	X	X	
1.3. Natural recruitment	X		X	X	X	X	X	
1.4. Hatchery releases	X		X	X	X	X	X	
1.5. Age validation								As needed, SPC&A, other relevant agencies
<b>3D. Telemetry</b>								
<i>1. Distribution &amp; movements</i>	X		X	X	X	X	X	
1.1. Receiver arrays	X		X	X	X	X	X	
1.2. Juveniles								
1.3. Adults	X		X	X	X	X	X	
1.4. Spawning behaviour								
1.5. 3-D Positional tracking system to monitor rock substrate addition experiment				X	(X)	(X)	(X)	
<b>3E. Habitat restoration response</b>								
<i>1. Spawning areas</i>	X		X	X	X	X	X	
1.1. Habitat baseline								

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
1.2. Computer models								
1.3. Periodic monitoring	X		X	X	X	X	X	
<b>3F. Data Management &amp; Reporting</b>								
<i>1. Data repository</i>	X		X	X	X	X	X	
1.1. Annual data management	X		X	X	X	X	X	
a. IKERT relational database integration				X	X	X	X	All relevant agencies and Statistical Consulting Services Inc.
1.2. Periodic reporting	X		X	X	X	X	X	All relevant entities

#### **Strategy 4. Recovery Implementation**

Measure/Task/Activity	Core	Pilot	2005	2006	2007	2008	2009	Participating Agencies, Comments
<i>1. Implementation planning</i>	X	X	X	X	X	X	X	All participating agencies where appropriate.  See relevant text sections and Recovery Plan for more details (USWFS 1999).
<i>2. Recovery Team</i>	X	X	X	X	X	X	X	
<i>3. Produce updated Recovery Plan</i>	X	X	X	X	X	X	X	
<i>4. Education &amp; outreach</i>	X	X	X	X	X	X	X	
<i>5. Other planning, regulatory consultations</i>	X	X	X	X	X	X	X	

## References

- Anders, P.J. 1991. White sturgeon (*Acipenser transmontanus*) movement patterns and habitat utilization in the Kootenai River system, Idaho, Montana, and British Columbia. MS Thesis. Eastern Washington University. Cheney, WA. 153 pp.
- Anders 2002. Biological characterization of white sturgeon (*Acipenser transmontanus*). Chapter 1 (Pages 1-32) in: Anders, P.J. 2002. Conservation Biology of White Sturgeon. Ph.D. Dissertation, University of Idaho, Aquaculture Research Institute, Center for Salmonid and Freshwater Species at Risk. Moscow, ID. 221 pp.
- Anders, P. and D. Richards. 1996. Implications of Ecosystem Collapse on White Sturgeon (*Acipenser transmontanus*) in the Kootenai River, Idaho, Montana, and British Columbia. In: Proceedings of the International Congress on the Biology of Fishes, San Francisco State University, CA. July 14-18, 1996. pp. 27-40.
- Anders, P. J., D. L. Richards, M. S. Powell. 2002. The First Endangered White Sturgeon Population (*Acipenser transmontanus*): Repercussions in an Altered Large River-floodplain Ecosystem. Pages 67-82 In: W. Van Winkle, P. Anders, D. Dixon, and D. Secor, eds. Biology, Management and Protection of North American Sturgeons. American Fisheries Society Symposium 28.
- Anders, P., W. Van Winkle, and L. Hildebrand. 2004. How much is enough? Assessing stock limitation in empirical white sturgeon populations in the US and Canada. Page 74 In: Proceedings from the 143<sup>rd</sup> Annual Meeting of the American Fisheries Society. Madison, WI., August 22-26, 2004.
- Andrusak, H., P. Slaney, and L. Fleck. 2004. Status of kokanee in the South Arm of Kootenay Lake and assessment of select tributary streams with restoration potential for spawning kokanee and rainbow trout. 2004 Annual Report prepared for the Kootenai Tribe of Idaho. Redfish Consulting, Nelson, BC. Canada. 66 pp.
- Coutant, C. C. 2004. A riparian habitat hypothesis for successful reproduction of white sturgeon. Reviews in Fisheries Science 12(1): 23-73.
- Duke, S., P. Anders, G. Ennis, R. Hallock, J. Hammond, S. Ireland, J. Laufle, R. Lauzier L. Lockhard, B. Marotz, V. L. Paragamian, and R. Westerhof. 1999. Recovery plan for the Kootenai River white sturgeon (*Acipenser transmontanus*). Journal of Applied Ichthyology 15:157-163.
- Golder Associates. 2005. Analysis of white sturgeon spawning in relation to the Waneta Dam white sturgeon flow augmentation program. Final Report to Teck Cominco Metals Ltd., Trail BC. 33pp. plus appendices.
- Heath, A.G. 1995. Water pollution and fish physiology. CRC Press, Boca Raton Florida.
- Ireland, S.C., R.C.Beamesderfer, V.L. Paragamian, V.D. Wakkinen, and J.T. Siple. 2002a. Success of hatchery-reared juvenile white sturgeon (*Acipenser transmontanus*) following release in the Kootenay River, Idaho, USA. Journal of Applied Ichthyology. 18, 642-650.
- Ireland, S. C., P. J. Anders, and J. T. Siple. 2002a. Conservation aquaculture: An adaptive approach to prevent extinction of an endangered white sturgeon population. Pages 211-222 in: W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, editors. Biology, Management, and Protection of North American sturgeon. American Fisheries Society,



Symposium 28, Bethesda, Maryland.

- Kincaid, H. 1993. Breeding plan to preserve the genetic variability of the Kootenai River white sturgeon. U. S. Fish and Wildlife Service Report to Bonneville Power Administration. Portland, OR. BPA Project No. 93-27.
- Kock, T.J. 2004. Effects of sedimentation and water velocity on white sturgeon (*Acipenser transmontanus*) embryo survival. MS Thesis, University of Idaho, Moscow. 57 pp.
- Kock, T. J., J. Congleton, and P. J. Anders. Recruitment failure of white sturgeon *Acipenser transmontanus* in the Kootenai River, Idaho: Empirical evidence for an embryo suffocation hypothesis. *In Press*. Transactions of the American Fisheries Society.
- Kruse, G.O. 2000. The effects of contaminants on reproduction, embryo development and related physiological processes in Kootenai River white sturgeon, *Acipenser transmontanus* Richardson. Masters Thesis, University of Idaho, Moscow, Idaho.
- Kruse, G.O. and D.L. Scarnecchia. 2002a. Assessment of bioaccumulated metal and organochlorine compounds in relation to physiological biomarkers in Kootenai River white sturgeon. *J. Appl. Ichthyol.* 18:430-438.
- Kruse, G.O. and D.L. Scarnecchia. 2002b. Contaminant uptake of white sturgeon embryos. *American Fisheries Society Symposium* 28:151-160.
- KTOI (Kootenai Tribe of Idaho) 2004. Ireland, S.C., P. J. Anders and Ray C. P. Beamesderfer eds. An Adaptive Multidisciplinary Conservation Aquaculture Plan for Endangered Kootenai River White Sturgeon. Management Plan prepared by the Kootenai Tribe of Idaho with assistance from S. P. Cramer and Associates. 56 pp.
- Miller, A. I., and L.G. Beckman. 1993. A recruitment index for white sturgeon in the Columbia River downstream from McNary Dam. Pages 141-166 *in* R.C. Beamesderfer and A.A. Nigro, eds. Status and habitat requirements of the white sturgeon populations in the Columbia River downstream from McNary Dam. Vol. 2. Final Report to Bonneville Power Administration, Portland, OR.
- Miller, A. I., and L. G. Beckman. 1996. First record of predation on white sturgeon eggs by sympatric fishes. *Transactions of the American Fisheries Society* 125:338-340.
- Paragamian, V. L., G. Kruse, and V. Wakkinen. 2001. Kootenai River white sturgeon spawning and recruitment evaluation. Report of Idaho Department of Fish and Game (Number 01-27) to Bonneville Power Administration. Portland.
- Paragamian, V. L., G. Kruse and V. D. Wakkinen. 2002. Kootenai River white sturgeon investigations. Idaho Department of Fish and Game. Prepared for Bonneville Power Administration. Annual Progress Report, Project 88-65, Boise.
- Paragamian, V., V. Whitman and V. Wakkinen. 2002. Kootenay River White Sturgeon Spawning and Recruitment Evaluation – Annual Progress Report January 1, 2000 – March 31, 2001. Idaho Department of Fish and Game. 02-15.
- Paragamian, V. and R. C. Beamesderfer. 2004 Growth estimates from tagged white sturgeon suggests that ages from fin rays underestimate true age in the Kootenai River, USA and Canada 132:895-903.

- Paragamian, V. and V.D. Wakkinen. 2002. Temporal distribution of Kootenai River white sturgeon spawning events and the effect of flow and temperature. *Journal of Applied Ichthyology*. 18, 542-549.
- Paragamian, V. L., R. C. P. Beamesderfer, and S. C. Ireland. 2005. Status, population dynamics, and future prospects of the endangered Kootenai River white sturgeon population with and without hatchery intervention. *Transactions of the American Fisheries Society* 134:518-532.
- Parsley, M. J., and L. G. Beckman. 1994. White sturgeon spawning and rearing habitat in the lower Columbia River. *North American Journal of Fisheries Management* 14:812-827.
- Rodzen, J. B. May, P. Anders and S. Ireland. 2004. Initial microsatellite analysis of wild Kootenai River white sturgeon and subset brood stock groups used in a conservation aquaculture program. Report prepared for the Kootenai Tribe of Idaho and the U.S. Department of Energy, Bonneville Power Administration, Portland, OR. Contract No. 88-64. 36 pp.
- USFWS. 1994. Determination of endangered status for the Kootenai River White sturgeon population. *Federal Register* 59(171): 45989
- USFWS. 1996. Draft Recovery Plan for the White Sturgeon (*Acipenser transmontanus*): Kootenai River Population. U.S. Fish and Wildlife Service, Portland, Oregon. 96 pp. plus appendices.
- USFWS. 1999. Recovery Plan for the White Sturgeon (*Acipenser transmontanus*): Kootenai River Population. U.S. Fish and Wildlife Service, Portland, Oregon. 96 pp. plus appendices.
- Ward, C.H. 1998. Building scientific consensus on endocrine disruptors. *Environmental Toxicology and Chemistry* 17(1):1-2.
- Walters, C., J. Korman, P. Anders, C. Holderman, and S. Ireland. 2005. Draft Kootenai River Adaptive Management Plan. Report prepared for the Kootenai Tribe of Idaho. 11 pp.