5.0 RECOVERY

5.1 Goal and Objectives

The goal of the recovery program defined in this plan is to ensure the persistence and viability of naturally-reproducing populations of white sturgeon in the upper Columbia River and restore opportunities for beneficial use if feasible.

Short, medium, long term objectives were identified consistent with the need to phase in and modify recovery measures based on fish status updates, results of initial efforts, and constraints on implementing a large and potentially-expensive effort.

The short term objective is to assess population status and act to prevent further reductions in white sturgeon distribution, numbers, and genetic diversity within the current geographic range. For purposes of this plan, short term refers to next 5 years following adoption. The range extends from Grand Coulee Dam upstream to the Columbia River headwaters excluding the Kootenay drainage downstream of Lower Bonnington Dam.

The medium term objective is to determine survival limitations (bottlenecks) for remaining supportable populations and establish feasible response measures to reduce or eliminate limitations. For purposes of this plan, medium term refers to the next 10 years.

The long term objective is to re-establish natural population age structure, target abundance levels, and beneficial uses through self-sustaining recruitment in two or more recovery areas. For purposes of this plan, long term refers to the next 50 years.

Initial efforts will focus on recovery areas within the historic geographic range that continue to provide suitable habitat. Potential recovery areas include the upper transboundary reach from HLK Dam to the international boundary, the lower transboundary reach from the boundary to Grand Coulee Dam, and Arrow Lakes Reservoir (Revelstoke Dam to HLK Dam). Recovery areas may be added, subtracted, or modified following further data collection. Further investigation of sturgeon distribution and movement patterns will determine whether the transboundary reach constitutes one or two recovery areas. Future efforts will also consider Kinbasket Reservoir. Kinbasket was initially not included because of its large size and unknown (but probably small) current population, and because initial efforts are focused on areas which optimize opportunities for success and evaluation. Recovery efforts may also involve the establishment of one or more “fail safe” populations of acceptable genetic diversity which can be used as a future source to support population abundance and diversity. Fail safe populations may be established in areas of suitable habitat that no longer contain sturgeon or support a non-sustainable sturgeon stock.

Long term objectives involve recovery of naturally-reproducing sturgeon populations and restoration of opportunities for beneficial use including subsistence harvests. The degree to which natural populations will be able to support harvest or impacts of a catch and release fishery will depend on the success of efforts to restore habitat conditions suitable for natural spawning and rearing.

5.2 Targets

Recovery targets are interim benchmarks by which progress toward recovery will be measured. Targets identified in this plan are based on population viability guidelines identified in the scientific literature and are similar to those adopted in recovery plans for other vulnerable sturgeon populations. Targets for upper Columbia River white sturgeon include:

1. Minimum adult population sizes of 2,500 adults per area in two recovery areas (5,000 total).

   The desired adult population size of 2,500 per area for more than one area is based on (COSEWIC) criteria. Numbers are also consistent with fish population viability guidelines applied in U.S. Endangered Species Act assessments. For instance, genetic guidelines generally suggest a minimum effective population size of at least 500 adults and a census population of several times the effective population size to avoid loss of genetic diversity (Thompson 1991). Numbers are interim targets pending studies of habitat carrying capacity in designated recovery areas and may change based on actual capacity assessments. The two populations need not be genetically unique. For instance, two separate populations established from a composite upper Columbia River broodstock would satisfy this target.

2. Naturally-produced recruitment and juvenile population sizes sufficient to support desired adult population sizes in at least 2 recovery areas.

   Multiple recovery areas provide the spatial diversity necessary to protect the species from local impacts.

3. Stable or increasing trends in adult and juvenile numbers.

   Stable or increasing trends require recruitment rates that exceed natural and human-caused mortality rates. Greater mortality rates generally require more juveniles to ensure that adult population sizes remain stable or increase. A minimum of 25+ years will be required to approach recovery targets because of the long life spawn and generation time of sturgeon.

4. Stable size and age distributions in each population.

   Stable numbers demonstrate effective long term recovery effects. Stable sizes, and ages reflect the longevity and normal population structure of sturgeon as well as providing the population resilience needed to sustain these fish over the long term.

5. Genetic diversity (including rare allele frequencies) similar to current levels.

   Stable genetic diversity similar to existing levels ensures that sufficient variability is preserved to allow sturgeon to use the available array of environments, protect against short-term spatial and temporal changes in the environment, and provide the raw material for surviving long term environmental changes (McElhany et al. 2000).

6. Long term fishery objectives will be reached when natural production rates are sufficient to support at least minimal subsistence harvests and recreational fishery uses.

   Natural reproduction rates sufficient to provide harvest or withstand other fishery impacts recognize a desire to restore historic fishing opportunities that have been foregone in recent years. Reproduction rates that provide a harvestable surplus also provide an additional safety factor from long term risks to population viability.

This recovery plan does not identify specific ecosystem function targets or benchmarks but recognizes that efforts to restore significant sturgeon populations through natural production are also likely to benefit many other components of the native aquatic community.

5.3 Strategy

Recovery objectives will be addressed using five basic strategies. First, direct sources of adult mortality must continue to be controlled. Control of direct mortality is critical to meeting short and medium term objectives. Population status is currently too tenuous to support any additional anthropogenic mortality sources. Even a small increase in adult mortality would jeopardize recovery. Continuing fishery restrictions are a key element of this strategy.

Second, immediate hatchery intervention is necessary to preserve the remaining population diversity in the face of almost complete collapse of recruitment of young sturgeon. Hatchery methods, risks, and benefits will require consistent and careful review at regular intervals throughout the recovery process to control genetic risks. Hatchery intervention is currently envisioned as a short to medium term strategy. Without aggressive hatchery measures, the existing population of aging, mature fish will steadily decline toward certain extinction. The current generation of sturgeon will be the last as fish die from natural causes and are not replaced. Genetic and life history diversity will rapidly be lost such that the productivity of the remaining fish could be too low to sustain the population even if suitable habitat conditions are restored at a future date. Hatchery-spawned and reared offspring of wild adults can bypass the current recruitment bottleneck to provide a source of new fish in existing populations and failsafe populations. Hatchery fish can also serve as test subjects in the wild or the laboratory to experimentally investigate natural recruitment limitations, mortality factors, critical habitats, and feeding.

Third, white sturgeon recovery will require effective improvements in recruitment and survival based on habitat, flow, and/or water quality restoration. Restoration of natural recruitment is key to meeting long term recovery objectives. Necessary measures might involve modifications to the annual hydrograph in the Columbia and Pend d'Oreille rivers or enhancement of critical habitats (e.g., rearing or spawning areas). Long term preservation of upper Columbia sturgeon is not assured without restoration of natural production. The history of hatchery programs is not consistent with long-term preservation of an undomesticated fish population. Continued reliance on a hatchery program risks gradual erosion of sturgeon diversity and productivity, and may ultimately only delay the disappearance of native sturgeon populations from the upper basin.

Fourth, continuing adaptation of the recovery program based on research and monitoring of sturgeon status, limiting factors, and potential recovery actions is warranted to address short, medium, and long-term objectives. Currently, long-term recovery planning is hampered by a lack of understanding of sturgeon status and limiting factors. This lack precludes identification and selection of appropriate water management and habitat restoration measures. In many cases, we generally understand what changes have affected sturgeon but it is unclear what specific and feasible actions will be effective. Research and evaluation efforts need to be aggressive because of the critical status of remaining subpopulations and the inherent time lag in implementation of research findings. For instance, assessments of survival limitations need to be initiated immediately in order to establish feasible response measures to reduce or eliminate limitations within the next ten years. Experimental evaluations of alternatives based on carefully-designed flow and habitat manipulations hold more promise for rapid application than basic mechanistic research although an ideal program will include both approaches. Hatchery sturgeon may provide effective test subjects for many of these research and evaluation studies.

Finally, recovery plans must incorporate safety factors to address the considerable uncertainty in current population status, prospects for restoring natural production, and risks associated with initial reliance on a hatchery to preserve existing population diversity into the next sturgeon generation. For instance, it is unclear whether restoration of natural recruitment is feasible, broodstock numbers will continue to be sufficient to support hatchery stopgap measures as the existing wild population declines, and current hatchery release numbers will be sufficient to produce a significant adult population given the lack of information on actual survival rates. Thus, every reasonable effort should be undertaken to develop contingencies should any of the assumptions underlying proposed measures prove fallacious. Safety factors include rearing of juvenile sturgeon in at least two hatchery facilities as a contingency for unforeseen problems at one site. Safety factors also include establishing an adult failsafe population by release of hatchery fish in an area separate from existing recovery areas. Genetic and demographic risks of to existing wild populations can be minimized by establishing the failsafe population where the potential for straying can be controlled and monitored.

5.4 Expected Response

Sturgeon recovery efforts will ideally produce a population trajectory like that depicted in Figure 15. Numbers were produced with a simple age-structure population demographic model using hypothetical hatchery and wild sturgeon recruitment rates with current data on abundance, growth, maturation, and adult survival. This exercise highlights the long term commitment required by this program. Projections optimistically assume that natural recruitment can be restored within 20 years. Hatchery releases cease when natural recruitment is restored. Because of the approximate 30 year age of full maturation, adult numbers are projected to decline to very low levels over the next 30 years even with the immediate release of hatchery-reared juveniles. After that, adult numbers build rapidly as hatchery sturgeon mature. Significant adult recruitment of naturally-spawned fish occurs after 50 years and hatchery releases are scaled back as natural numbers increase. A stable adult population is reached at about 50 years with naturally-produced adults comprising an increasing percentage of the total from 50-100 years.

The next 5-20 years represent the most critical period in recovery of upper Columbia River sturgeon because of the current lack of juvenile and subadult fish and the corresponding decline in numbers of potential female spawners (Figure 16). The extended interval of low adult numbers will result in a very low population reproductive potential and much-reduced chances of being able to collect mature fish for spawning broodstock.

Restoration of a stable sturgeon age distribution can be expected in approximately 40 to 50 years (Figure 17). The population will be dominated by juvenile sturgeon and subadult sturgeon in the intervening period.

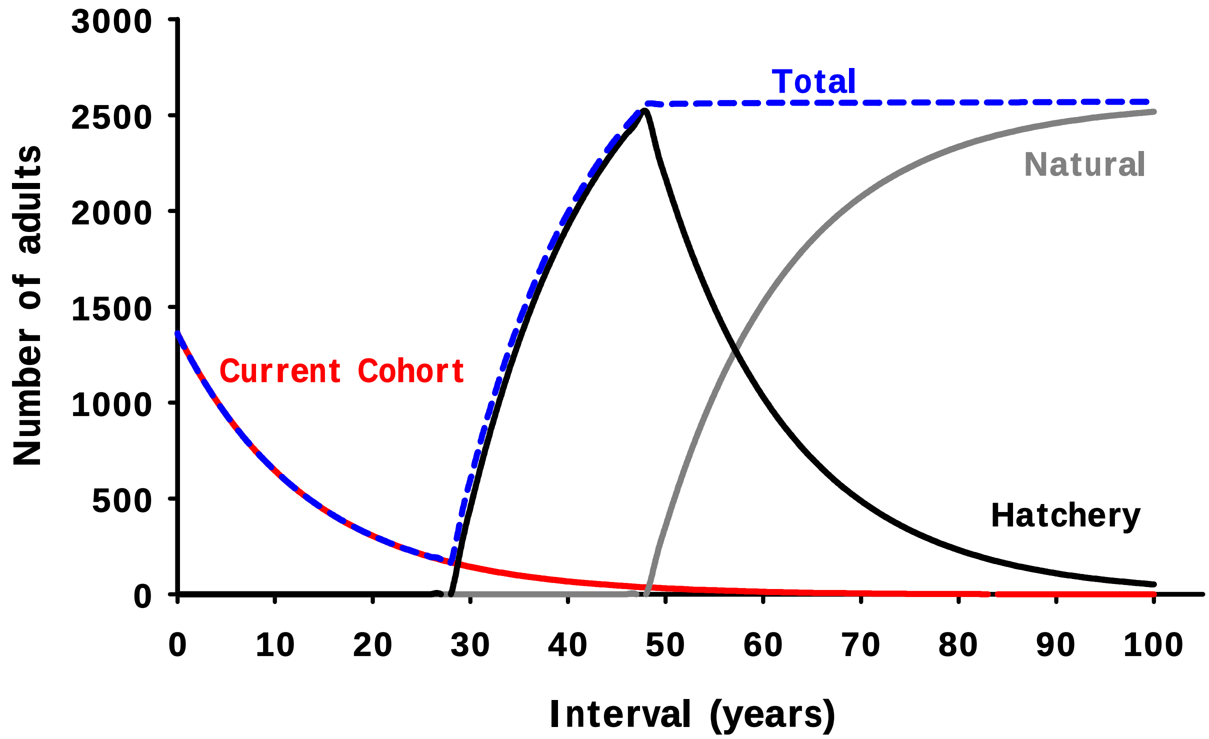

Figure 15. Hypothetical future wild and hatchery sturgeon numbers in the transboundary recovery area.

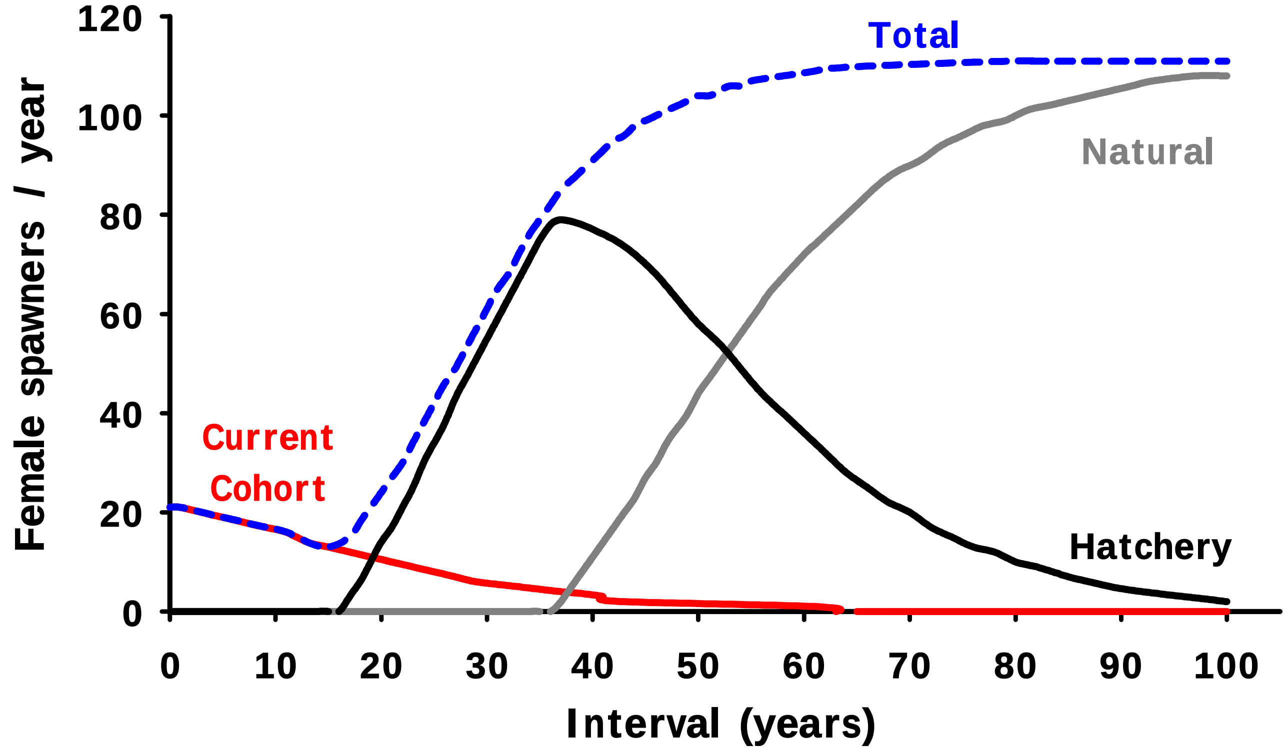

Figure 16. Future reproduction potential of sturgeon based on implementation of hatchery-based sturgeon recovery measures and restoration of natural production.

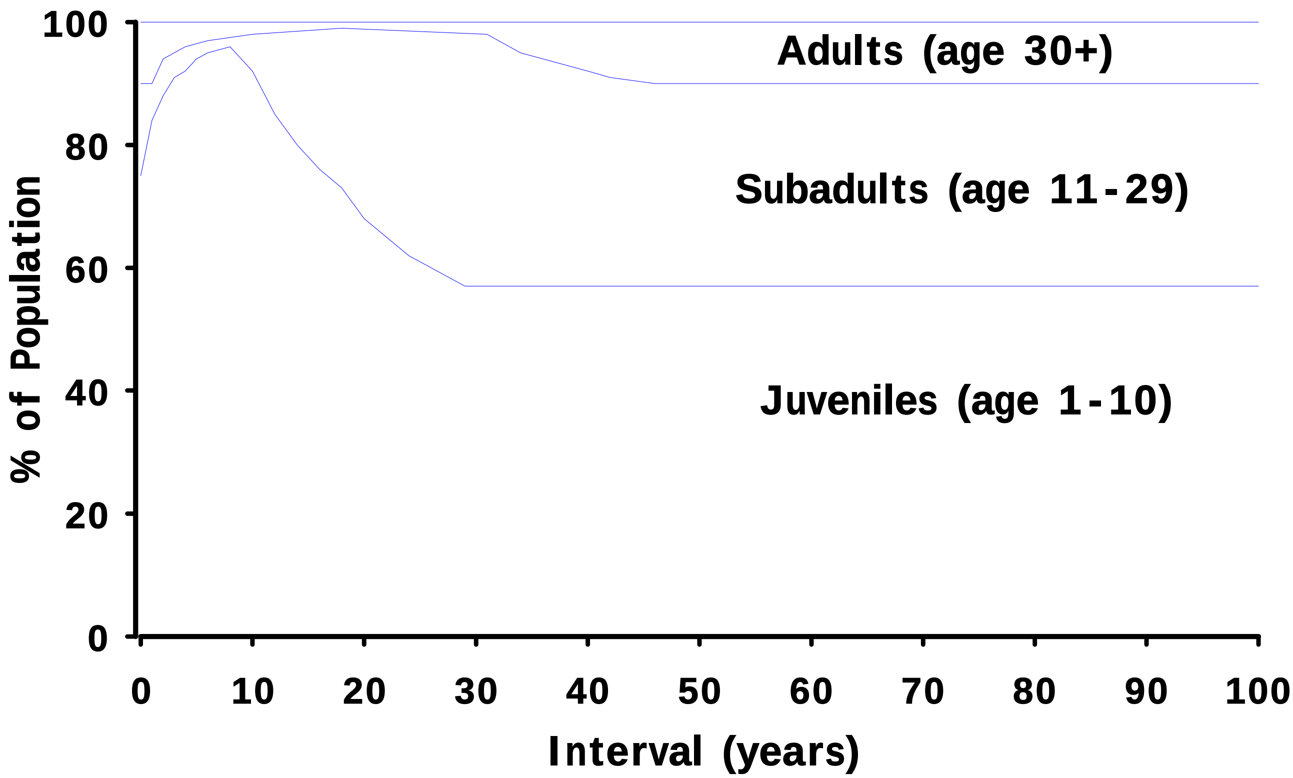

Figure 17. Hypothetical changes in sturgeon age composition following implementation of hatchery-based sturgeon recovery measures and restoration of natural production.

5.5 Measures

Specific measures consistent with goals, objectives, and strategies were developed by recovery team subcommittees and adopted by the full recovery team.

5.5.1 Harvest/Bycatch

1) Continue to prohibit fishing for and retention of sturgeon.

All fishing for sturgeon in U.S. and Canadian waters of the upper Columbia River is currently prohibited and must remain so. Limited mortality will likely result from setline activities associated with sampling and broodstock collection. However, the current population status and productivity are not consistent with any additional fishing mortality.
Schedule: Short to long term

2) Continue to monitor and limit incidental impacts and illegal harvest of sturgeon.

With current closures of the sturgeon fishery in the U.S. and Canada, the primary fishery threats are from incidental capture with bait in the increasingly popular walleye or trout fisheries. Incidental handling of small sturgeon in these fisheries is likely to increase as hatchery fish are introduced or natural recruitment is restored. Education and enforcement initiatives will be required to minimize these impacts.
Schedule: Medium to long term

3) Consider resumption of subsistence and recreational fisheries for sturgeon as recovery occurs.

Restoration of fishable population levels of white sturgeon is a significant goal of many of the parties to the development of this plan. The feasibility of this goal is currently unclear but will depend on progress in restoring natural recruitment and stock productivity. At such time as recovery measures, evaluations, and monitoring indicate as appropriate, and consistent with sturgeon conservation intent, opportunities for fisheries will be considered.
Schedule: Long term

5.5.2 Entrainment

1) Continue to monitor occurrence of sturgeon mortalities.

Sturgeon mortalities are periodically observed in the upper Columbia River and the public is encouraged to report carcasses to the B. C. Ministry of Water, Land, and Air Protection or the Washington Department of Fish and Wildlife. Reports are currently investigated in an attempt to ascertain the cause of mortality and to obtain appropriate samples.
Schedule: Short to long term

2) Identify the potential for entrainment and implement operational opportunities to prevent significant mortality or downstream displacement.

Entrainment does not currently appear to be a significant issue in the upper Columbia in part because of low numbers of sturgeon upstream from system projects. Entrainment has been identified as a significant concern in some lower Columbia River facilities, primarily in relation to periodic maintenance activities. For instance, large numbers of sturgeon may enter turbine outfalls following shut downs and can be trapped when there is a significant delay in placing stop logs. Similar problems can be avoided in the upper Columbia by monitoring and responding to potential problems as they are identified. Entrainment can also result in consistent erosion of a source population if fish are displaced into downstream areas. However, entrainment might also help counteract the isolating effect of a dam (albeit in one direction). This importance of entrainment may increase and require further investigation as young fish are introduced into the system and begin to disperse downstream. If significant entrainment is identified through monitoring activities, specific protocols can reduce or eliminate the risk.
Schedule: Medium to long term

5.5.3 Culture/Stocking

1) Pursue an aggressive fish culture strategy to conserve existing population diversity.

Hatchery operations will be conducted in a manner that recognizes the critical status of upper Columbia River sturgeon and a shrinking window of opportunity for preservation. Hatchery-reared juveniles produced from wild parents will be released into the wild to replace failed natural recruitment until such time as natural recruitment is restored. Hatchery intervention is currently the only demonstrated alternative for preserving the upper Columbia River white sturgeon population.
Schedule: Short-Medium term

2) Employ strict genetics guidelines for the conservation-based fish culture program.

Preservation of existing genetic diversity is a primary goal of the hatchery program but selective hatchery and rearing practices can reduce genetic diversity. Genetic risks can be minimized by

careful design and implementation of hatchery practices. Care must be taken in broodstock collection, mating protocols, and release to maintain existing genetic diversity of the source population. Plans should ensure that a) the founder population spawned in the hatchery will be large enough to preserve existing genetic diversity (including frequencies of rare alleles) and b) contributions of each family group in the next generation are balanced so as to avoid swamping the population with a few families.
Schedule: Short-Medium term

3) Use hatchery-reared offspring of wild adults to assist in research.

Hatchery releases will be used to provide experimental fish consistent with recovery plan objectives. Hatchery releases may provide one of the most effective alternatives for identifying the cause of current recruitment failures and feasible alternatives for restoration of suitable conditions for natural recruitment. Release experiments can be designed to help identify limiting life stages and critical habitats. Comparisons among different release groups can help fine tune out-planting strategies to optimize survival. Hatchery releases may also provide fish for ascertaining limiting food habits and contaminant uptake.
Schedule: Short-Medium term

4) stablish failsafe adult population(s) where feasible and acceptable.

Failsafe populations provide a reserve of fish as a contingency for future recovery efforts. These populations, based on releases of hatchery-reared offspring of wild adults, will be established in areas where suitable conditions for natural spawning and recruitment are not likely to be restored, but adults can be expected to persist. Extra eggs are typically obtained from broodstock spawned in the hatchery but the available rearing space limits the numbers of juveniles that can be reared to optimal release sizes. In addition, careful management of risks to the existing wild population require limitations on release numbers to balance genetic effects and the potential for overseeding of the available rearing area. Release of these “surplus” fish into a separate area would provide an additional population as a contingency for future needs and also avoids the apparent contradiction inherent in the sacrifice of fish from a sensitive species that is subject to intensive and expensive recovery efforts. Sites for consideration should ideally be within the historic range of upper Columbia River white sturgeon, provide significant food resources, and be buffered from remaining significant wild populations. Failsafe population management must consider genetic risks consistent with conservation goals but the lack of natural spawning conditions may provide some flexibility in hatchery release and marking strategies.
Schedule: Short-Medium term

5) Mark hatchery-reared fish to differentiate from wild stock.

Effective monitoring of natural recruitment requires marking of hatchery fish. Marking will also provide for evaluations of hatchery fish survival, contributions of different release groups, and regulation of future broodstock use. The initial practice will be to mark yearling sturgeon with uniquely-numbered ISO compliant 134.2 kHz PIT tags and year-specific scute removal patterns. PIT tagging will allow identification of individuals and families. Scute marks will provide a rapid indication of hatchery origin and brood year. Alternative methods are required for any sub-yearling fish less than the 15 g minimum for PIT tagging. A combination of scute removal (to indicate brood year) and CWT under specific dorsal scute (family identification) may have potential but remains untested at this time.
Schedule: Short-Medium term

6) Refine hatchery release goals consistent with the recovery objective based on monitoring and evaluation.

An intensive monitoring and evaluation program will help determine whether the hatchery program is providing the intended benefits. Initial release goals and methods are based on the best available information at the time of this plan but in many cases a lack of data required assumptions to be made. Monitoring and evaluation of survival rates, dispersal patterns, system carrying capacity, and ecosystem effects will provide necessary information for adaptive management of the hatchery program as it unfolds.
Schedule: Medium-Long term

7) Identify and develop opportunities for sturgeon propagation in the United States for use in the transboundary reach.

Existing hatchery facilities in Canada may be too small to address sturgeon recovery throughout the transboundary reach. Canadian releases may be insufficient to restore a significant sturgeon population in U.S. waters because of limited release numbers and possible low rates of downstream dispersal. In addition, multiple sturgeon propagation facilities will provide a population failsafe should problems arise at a single facility. Development of a U.S. hatchery program will be contingent on results of comprehensive stock assessments of adult and juvenile sturgeon populations and habitat from the border to Grand Coulee Dam.
Schedule: Short-Medium term

8) Consider expanding the Canadian conservation fish culture program for use in Arrow Lakes and transboundary recovery areas.

The Hill Creek hatchery sturgeon program provides an excellent foundation for sturgeon recovery efforts, but it is recognized that because of limitations in the existing rearing space and groundwater supply, the production capability of this pilot facility may be too small to meet recovery needs. Opportunities for developing a stand-alone facility in the Castlegar area and/or piggybacking on to the existing Kootenay sturgeon facility should be examined.
Schedule: Short-Medium term

9) Continue to investigate, implement, and refine a variety of alternative hatchery methods.

Sturgeon conservation efforts involving hatcheries have only recently been implemented and remain largely experimental in nature. Continuous efforts to explore alternative methods will optimize long term effectiveness and efficiency. For instance, alternative broodstock collection methods include fish collected ripe during spawning, fish collected green prior to spawning, and eggs collected directly from natural spawning areas. Initial experimentation with methods for collecting broodstock, rearing, feeding, disease control, and other activities will help determine the optimum approach or combination.
Schedule: Short-Medium term

10) Investigate the feasibility of cryopreservation techniques to preserve white sturgeon sperm.

Cryopreservation of sperm can provide a contingency for the hatchery program in the event that continued declines in the wild population make it difficult to ensure that ripe males and females are available at the same time. The sperm supply is currently not limited but this technique must be developed proactively.
Schedule: Short-Medium term

11) Develop rigorous fish health protocols to limit disease risks in hatchery and wild populations.

Fish health protocols should address testing and cross-border movements.
Schedule: Short-Medium term

5.5.4 Water Management

1) Evaluate the feasibility of restoring natural recruitment using flow augmentation while minimizing impacts on other uses of basin waters.

Sturgeon recovery would likely be assisted by alterations to current operations of dams above and including Grand Coulee Dam. A complete return to the natural hydrograph of the system would likely be prohibitive in terms of economic (power) and social (flooding) costs and, as such, would not likely be considered a viable option. The feasibility of a partial return to natural conditions (i.e., to the extent possible), should be investigated.

There is a need for power producing entities and agencies to carefully examine current operational practices and assess the feasibility of modifying flows in a manner that will benefit white sturgeon and other fish species. This may involve specific water storage and flow augmentation during spawning and early life-stage development periods to approximate the natural hydrograph. The feasibility assessments must consider water availability, Columbia River Treaty limitations (and opportunities), other constraints (e.g. Kootenay Lake IJC Order), costs (reduced power revenues), and impacts on other ecosystem components.

Water Use Plans mandated by the British Columbia government are currently being developed for the major Canadian Columbia River Treaty storage dams (and associated generating plants.) These plans provide an opportunity to assess the feasibility of experimental flow augmentation for the transboundary reach.
Schedule: Short term

2) Define flow requirements that promote natural spawning, incubation, rearing, recruitment, and survival of Columbia River white sturgeon.

Specific flow requirements for successful recruitment are unclear. In the one documented spawning area, this issue is complicated by the combined effects of flows from the Pend d'Oreille River that are essential to spawning success, and flows in the Columbia River that dictate conditions in maturation, spawning, staging, rearing, feeding, and overwintering habitats. Additional information is required to determine what flow conditions are required in both systems to promote the natural recruitment of Columbia sturgeon. The required information will be developed in two ways: (i) initially from the results of the spawning and juvenile studies suggested for implementation; and (ii) subsequently, from an experimental flow augmentation program. The experimental flow augmentation program will be designed with consideration of the magnitude of potentially feasible flow increases, the ability to detect changes in early life stage survival rates and opportunities associated with unusually high and low discharge years. Consideration needs to be given to the alternative of experimental turbidity augmentation (see water quality recovery measures)
Schedule: Medium term

3) ***Modify dam operations to achieve flow requirements for natural spawning, incubation, rearing, recruitment, and survival of Columbia River white sturgeon in most years.***

The Columbia River and many of its tributaries are regulated by dams for economic benefits of flood control, hydropower, irrigation, water supply, and recreation. Agreements must be developed with the power producers and regulatory agencies to operate dams in a manner that optimizes benefits to all resource needs. All riverine fish species, including white sturgeon, evolved with the cycle of precipitation and runoff inherently part of the climate and geography of the basin or subbasin. Reproduction of predator and prey also was timed with this pattern of water discharge. These temporal and spatial patterns must be at least partially restored if the goal is to promote natural reproduction and consistent recruitment success for white sturgeon. Additional research in development of simulation models will refine alternative operation scenarios that will best meet the needs of white sturgeon and other beneficial uses, using information from research programs and monitoring the effects of experimental flow treatments. Considerations of flow changes should be based on a comprehensive feasibility assessment that weighs biological effects, other costs, and impacts on other ecosystem components.
Schedule: Medium-Long term

4) ***Assess impacts of reservoir operations on white sturgeon early life stages.***

High summer levels of the Roosevelt and Arrow reservoirs may impair the dispersal of white sturgeon eggs and/or larvae to suitable incubation or rearing habitats. Low levels of these reservoirs in the winter may result in de-watering of rearing habitats for sub-yearling and yearling sturgeon. The de-watering may affect white sturgeon juveniles directly or by reducing food production and availability. A research program, involving a combination of literature reviews to determine habitat preferences, laboratory and/or mesocosm studies, and habitat inventory and mapping should be implemented to assess these impacts and provide a basis for recommendations for altered reservoir management regimes.
Schedule: Medium term

5) ***Evaluate restrictions on Revelstoke Generating Station daily load-shaping operations to reduce impacts on white sturgeon early life stages.***

In some years, Revelstoke generating capacity may be used for load factoring operations during the sturgeon spawning period, with the result that flows are reduced, in some cases to zero powerplant discharge, during the evening and maintained at these levels through the night. Potential impacts of zero or low discharge operations include: (i) delayed or inhibited spawning; (ii) stranding or dessication of eggs; (iii) increased egg predation rates, and (iv) reduced transport of larvae to suitable rearing areas.

Revelstoke load-shaping restrictions are being considered within the development of Water Use Plans for the Mica, Revelstoke and Arrow facilities, for the benefit of white sturgeon and other fish species. A monitoring and research program should be designed and implemented, possibly involving experimental load-shaping restrictions mandated through Water Use Planning, to determine minimum summer flows required to support consistent spawning and adequate levels of egg and larval survival.
Schedule: Short-Medium term

5.5.5 Water Quality

1) ***Assess the effects of altered thermal regimes on the timing of spawning, and metabolic rates, growth, and survival of egg through juvenile stages.***

River regulation (possibly in combination with other influences such as logging and climate warming) may have altered natural thermal regimes prior to and during spawning, and may have impacted juvenile survival, growth, and maturation through effects on seasonal metabolic rates. The potential to provide warmer waters in the summer and cooler waters in the winter should be explored including research on (i) the impacts of low water temperatures on spawning and egg and larval development and survival; (ii) the effects of high winter water temperatures on metabolic demand, growth, egg maturation/release and survival; (iii) the feasibility of using higher reservoir levels in the winter to increase downstream warming rates in the spring, and iv) the practicality and design of multi-level release structure to provide thermal controls.
Schedule: Short-Long term

2) ***Evaluate and consider implementation of methods to improve early life stage survival by restoring natural turbidity to spawning, incubation, larval drift, and early juvenile habitats.***

Available evidence strongly suggests that the construction and operation of dams and storage reservoirs has resulted in substantial reductions in turbidity levels in sturgeon spawning, egg incubation and larval rearing areas, and that predation rates on sturgeon eggs and larvae are very high at prevailing levels of turbidity. Mainstem Columbia River dams have trapped natural glacial sediments in reservoirs and bank stabilization efforts have reduced erosion in riverine reaches.

Investigations should document natural erosion sources, assess the effects of increased turbidity on existing ecosystems, and identify opportunities to restore turbidity to the system, at least during life stages which require cover from predators. Options could include the use of (i) freshet spikes to increase erosion, (ii) natural erosion sources to cover introductions of larval sturgeon, and (iii) natural but artificially-introduced substances to increase turbidity. The feasibility of increasing turbidity above threshold levels through the addition of turbidity-inducing substances (e.g. bentonite) should be investigated including quantities required, handling and dispersion, costs and impacts to downstream aquatic communities, and regulatory concerns. The potential benefits and costs of turbidity or flow augmentation programs should then be considered in choosing one for implementation on a carefully designed experimental basis.

Schedule: Short-Long term

3) ***Investigate impacts of high dissolved gas concentrations on larval white sturgeon and continue to implement measures that reduce total gas pressure.***

Measures to reduce dissolved gas levels would likely benefit sturgeon directly by increasing survival during the larval stage and indirectly by increasing productivity of the entire river ecosystem. Possible measures include: (i) increased generating capacity to reduce spill; (ii) spillway modifications; (iii) preferential use of low-TGP producing spill routes; and (iv) altered system operations to reduce spill.

In addition, increased summer flows designed to benefit sturgeon early life stage survival will likely cause increased dissolved gas concentrations given the current and near-term future configuration of turbine capacity and spill routes. Laboratory investigations should be implemented to determine lethal and sublethal TGP thresholds and dosage for drift larvae and juveniles. Subsequently, summer flow augmentation must be considered with consideration for potential dissolved gas impacts and means for mitigating these impacts.
Schedule: Short-Long term

5.5.6 Contaminants

1) ***Determine concentrations of organic and inorganic contaminants in sturgeon, their foods, and habitats.***

The Columbia River Integrated Environmental Monitoring Program (CRIEMP) and various Canadian and U.S. government agencies have conducted studies on water and sediment quality in the Columbia River between HLK and Grand Coulee Dam. Recent contaminant data in water, sediment, and tissues (fish and other aquatic organisms) will be reviewed to identify key contaminants including metals, organics, and inorganics. Tissues will be collected from eggs, adult and juvenile sturgeon (where feasible) in order to test for bioaccumulated levels of contaminants. Data about food chain organisms and habitats from ongoing studies will also be used to develop an understanding of contaminant bioaccumulation in aquatic organisms in the Upper Columbia River.
Schedule: Short term

2) ***Influence responsible agencies to identify all point and nonpoint sources of potential contaminants.***

Data gaps and focus areas will be identified for analysis, "clean-up" or pollution reduction. Much of this information will be obtained from historic data and more recent studies being conducted on the Columbia River by various agencies and groups, such as CRIEMP.
Schedule: Short term

3) ***Assess potential effects of environmental and bioaccumulated contaminants on Upper Columbia River white sturgeon.***

The lethal and sublethal effects of water and sediment chemical constituents are still largely undetermined for all life stages of white sturgeon. Evaluations will require a combination of existing and new protocols. Initially, data on contaminant concentrations in various media can be compared to similar data for other white sturgeon populations. Additional investigations where elevated contaminant concentrations are identified would include contaminant bioassays to evaluate the effects of selected chemicals on growth, survival, and reproduction; and assessments of effects on physiological function of contaminants and contaminant mixtures. Other methods including genotoxicity assessments will be considered where applicable. . Evaluations may require laboratory studies on using eggs, larvae, and juveniles (preferably using cultured stocks) and additional analyses of sediment, periphyton, and suspended sediment samples.
Schedule: Medium – Long term

4) ***Remediate sources of environmental contaminants.***

After identifying contaminants that are potentially affecting white sturgeon recovery, an effort must be made to remove or reduce the source of problem contaminants. Remediation efforts will be applied where feasible, primarily through the B. C. Ministry of Water, Land, and Air Protection, the Washington Department of Ecology, and other agencies with legislative jurisdiction. Feasibility will depend on degree of damage, cost, and location. Critical or important habitats should be identified and given top priority for protection from contaminant sources.
Schedule: Long term

5) ***Influence responsible agencies to develop a program to monitor contaminant levels.***

A long-term monitoring program will provide baseline data and determine the effects of "clean-up" and pollution reduction efforts. Periodic re-evaluation (i.e. on a 5-year basis) of information and data gathered (through this and other monitoring or research projects), available literature, analytical methods, and technological advances will provide for a thorough and scientifically based monitoring program.
Schedule: Long term

5.5.7 Habitat Diversity, Connectivity, & Productivity

1) ***Project future impacts and limitations associated with continuing large scale habitat changes associated with basin development.***

Changes in fluvial geomorphology associated with basin development and especially flow regulation can be expected to have continuing effects. Impacts can be identified by a comparison of pre and post development conditions to understand what habitat types may have been lost. Baseline conditions need to consider effects of other pre-dam influences including logging. Future changes can be forecast based on observed trends.
Schedule: Medium – Long term

2) ***Investigate the feasibility and methodology of restoring habitats and natural functions of the Columbia River where beneficial to sturgeon while also minimizing impacts on other uses of the river.***

Reservoirs on the upper Columbia River and bed degradation below dams have reduced the occurrence of overbank flows to the floodplain. As a result, side-channels, wetlands, and oxbows that were once connected to the main channel are now separated. When connected, these floodplain habitats provided important nursery areas for native fishes. Opportunities to restore river flows to presently-isolated floodplain habitats should be investigated. Options may include the creation of off-channel, side-channel, or slough habitats for rearing by early life-stages of white sturgeon. Another habitat enhancement option that may be considered is the provision of clean coarse substrate in white sturgeon spawning areas. This technique has been employed successfully to increase spawning success for lake sturgeon where these substrates were limiting.
Schedule: Medium - Long term

3) ***Consider passage alternatives for restoring free movements of sturgeon at such time as new information demonstrates the feasibility, benefits, and lack of risk.***

Restoration of population connectivity would theoretically benefit white sturgeon where dams have impeded migration to and from traditional spawning areas and other important seasonal habitats. However, effective passage measures are unclear and passage risks likely exceed potential benefits at this time. Risks include passage of undesirable species such as walleye or movement of sturgeon into suboptimal habitats. Passage measures are not proposed at this time but may be reconsidered if warranted by new information.
Schedule: Long term

4) ***Evaluate feasibility, benefits, and risks of increasing sturgeon population productivity by increasing nutrient availability.***

Alternatives are currently unclear and warrant further investigation. Alternatives include controlled nutrient releases from point sources, localized embayment nutrient additions, and expansion of large lake or reservoir nutrient addition programs. The value of such programs is unclear for sturgeon and will require considerable research including site evaluations, modelling of response mechanisms, and pilot testing.

Schedule: Long term

5) Assess the feasibility, benefits, and risks associated with alternative means of controlling predators, particularly exotic predators, of juvenile sturgeon.

Alternatives may include (i) the use of increased flows (possibly in combination with artificial turbidity procedures) during incubation to early juvenile life history stages to exclude predators from key habitats, and (ii) selective removal of predators using captur/population control programs. The former will require evaluations of flow management options in addition to turbidity investigations. The latter is currently being evaluated in the U.S., however, predator control programs for other species have been notably unsuccessful.

Schedule: Short – Medium term

6) Assess options for control/capping of toxic/abrasive sediments in suitable rearing habitats.

Juvenile sturgeon utilize slow velocity areas which also accumulate toxic and physically abrasive substrates. These sediments may directly impact the juveniles as they interact with the bottom, or may indirectly impact growth and survival by reducing invertebrate prey abundance. Alternative response measures include (i) recontouring of select habitats especially where they associate with flushing flows from localized sources and (ii) capping of sediments with more suitable substances in high value habitat areas. A priority in these investigations would be the documentation of dynamics of sediment distribution and movement, and the impact on ecosystem components of existing sediments and their further disturbance.

Schedule: Short - Long term

5.5.8 Population Assessment, Monitoring, & Research

1) Conduct periodic adult stock assessments.

Population status and trends in all recovery areas should be monitored with periodic stock assessments based on mark-recapture studies. Assessments should include basic biological information needed to monitor population productivity but limit invasive procedures to must have information. Assessments should be repeated at least every 5 years but may also be conducted annually in association with broodstock collection efforts. Baseline information has been collected in the Canadian portion of the transboundary reach but comparable information for U.S. waters is lacking.

Schedule: Short - Long term

2) Complete a sturgeon population assessment in the U. S. portion of the recovery area.

Comprehensive studies should be initiated immediately between Grand Coulee Dam and the border to resolve the unclear status of sturgeon in the U. S. portion of the transboundary reach. Studies should assess the status of juvenile and adult sturgeon, identify key habitats, and resolve questions regarding interactions with fish in the Canadian portion of the transboundary reach.

Schedule: Short term

3) Conduct assessments of potential remnant populations in Kinbasket and Revelstoke reservoirs in conjunction with monitoring of failsafe populations, at such time as those populations might be established.

Additional stock and habitat assessments of remnant sturgeon populations throughout the upper basin can be completed in conjunction with monitoring of failsafe populations at such time as they are established in those areas. Current numbers appear to be too low for cost effective assessments. Extensive stock assessments are not necessary in these reservoirs prior to reintroduction of additional sturgeon.
Schedule: Medium term

4) Conduct regular spawning investigations at key spawning sites.

Sturgeon spawning at the Pend d'Oreille-Columbia confluence should be monitored annually to identify spawning cues, frequency, and success. This work would be an extension of monitoring that has been conducted at this site annually since 1993 using artificial substrate mats and D-ring drift nets to collect white sturgeon eggs and larvae. Annual spawning data should be compared with information obtained from the proposed studies on juvenile abundance to identify physical factors that contribute to or inhibit recruitment success. Physical habitat parameters at egg collection sites should be measured annually, including water depth, temperature, substrate type, and mean water column velocity. Predator fish species in the spawning area should be captured and stomach contents examined for the presence of white sturgeon eggs and larvae.
Schedule: Short - Long term

5) Conduct regular juvenile indexing.

Standardized sampling protocols should be developed to provide a juvenile white sturgeon year-class abundance index. The success of annual spawning events should be assessed by means of larval YOY and/or juvenile capture programs at representative sites throughout the transboundary reach. This information is also necessary to document the effect of remedial actions such as flow modifications on annual white sturgeon recruitment, and also to detect significant difference in year-class abundance and condition factor attributable to physical or biological factors.
Schedule: Short - Long term

6) Identify essential habitats.

Essential habitats important to each life stage (spawning, rearing, feeding, staging, overwinter) should be identified, along with the characteristics of these habitats, and their present availability in the various reservoirs and free-flowing river sections. Studies of habitat use might rely on telemetry for juvenile through adult stages and catch rate data for younger life stages. Habitat use curves should be prepared and compared to available aquatic habitat through the use of methodologies such as the Instream Flow Incremental Methodology (IFIM). Knowledge of critical life-cycle requirements will be used to evaluate and direct habitat enhancement efforts.
Schedule: Long term

7) Determine recruitment bottlenecks.

Conduct research to identify early life history stages where juvenile recruitment is failing. This investigation should use a combination of experimental releases of hatchery-reared juveniles at various stages of development, encapsulated egg or larval samples planted near spawning locations as *in situ* bioassays, sonic telemetry, spawning investigations, juvenile indexing, and habitat analyses.
Schedule: Short – Medium term

8) Compile genetic baseline data.

Identify genetic characteristics of sturgeon subpopulations (genetic divergence within range, genetically meaningful management units, extent of hybridization) using electrophoretic and/or DNA analysis. Existing data allows general comparisons among widely distributed white sturgeon populations but does not provide the detailed data needed to monitor genetic characteristics for changes associated with continued population declines or hatchery-based recovery methods. Detailed genetic data may also provide critical data on numbers of parent contributing to spawning events and effective population sizes, and risks of inbreeding depression in these artificially isolated populations. Genetic evaluations should include the population genetics an genetic structure of hatchery families (brood and progeny).
Schedule: Short – Medium term

9) Develop and improve population analysis methods.

Additional work is needed to address limitations in current assessment methods that have significant impacts on population prospects and recovery plan implementation including a) validity of age estimates based on fin ray sections, b) population estimates based on mark-recapture methods, c) egg development rates used to back-calculate spawning date and to identify physical conditions that coincided with spawning, and d) impact assessment and response tools including computer production models for use in evaluating population viability and potential recovery actions.
Schedule: Short – Medium term

10) Improve the understanding of ecological interactions.

Population productivity and habitat capacity depend in part on food availability and predation mortality. Additional work is needed to evaluate potential limitations resulting from a) predation by native (rainbow trout, suckers) and non-native (walleye) fish species, and b) resulting from food habits and feeding behaviour. Predation during critical early life history periods can be investigated by sampling potential predators near spawning sites. The availability of hatchery-released juveniles will provide the opportunity in future years to obtain diet data without risk to wild fish. The monitoring program should also evaluate the effects of the stocking of large numbers of hatchery juveniles on other fish species. Appropriate actions will be considered as interactions are identified.
Schedule: Medium - Long term

11) Improve the understanding of parasitism and disease mechanisms.

Identify potential pathogens and effective methods for determining the extent of parasitism and disease in the wild population and in fish of hatchery-origin.
Schedule: Medium – Long term

5.5.9 Information/Education

1) Increase public awareness of the need to protect Columbia River white sturgeon by developing and distributing information and education materials on the plight of the sturgeon and its ecosystem.

- Maintain an updated supply of various communication materials i.e., information brochures, educational mementoes, Power Point (youth/adult-oriented) educational presentations, video media etc., to help disseminate information about the Initiative.

- Identify needs and opportunities for public action and stewardship, and encourage and support necessary stewardship action.
- Provide travel and expense support to assist volunteers in providing public education and outreach at community events.
- Utilize various communications strategies and mechanisms to provide awareness of the upper Columbia white sturgeon, and the support necessary to bring this ancient fish back from the brink.
- Ensure ongoing commitment of resources to administer and support the facilitation of the Action Planning Group or action-based public group supporting recovery efforts for white sturgeon.

Schedule: Short - Long term

2) ***Develop a coalition of interested stakeholders, including federal, provincial, and local governments, First Nations, public and industrial, US regulatory and tribal agencies, to be directed toward enhancing recovery actions.***

- Involve a representative implementation group of the Action Planning Group to provide key communications, public education and outreach to actively communicate and obtain community, in-kind and financial support of the Recovery Plan.
- Encourage coalition to seek out in-kind and financial support to further ongoing recovery efforts.

Schedule: Short- Long term

3) ***Pursue opportunities to link Upper Columbia River Sturgeon recovery activities with other efforts.***

- Co-ordinate UCWSRI efforts with Initiative partners, local communities and organizations, and other white sturgeon Recovery Initiatives (Kootenay and Nechako rivers) through co-shared meetings, linked web sites, information brochures, recovery strategies followed, etc.
- Participate in Basin and transboundary events i.e., symposia, conferences, workshops, through public presentations, booth displays and outreach.
- Assist with integration of Recovery Plan information into other local and transboundary Columbia Basin planning efforts i.e., Water Use Planning, local development plans, as well as in sharing data exchanges with relevant basin area studies i.e., CRIEMP, Columbia Power Corporation Environmental Approvals for dam power house upgrades, etc.

Schedule: Short- Long term

4) ***Implement regular recovery progress reporting to government, aboriginal communities, local agencies, communities, and the general public.***

- Develop a standardised reporting regime to communicate efforts being made to recover the upper Columbia white sturgeon population.

Schedule: Short- Long term

5) ***Utilize communications plan developed by the Action Planning Group as a template for promoting and educating communities about the status of the endangered Upper Columbia white sturgeon population.***

- Maintain Inter-Agency Communications plan, now updated to November 2002. This document is included in separate Recovery Plan technical appendices volume.
- Use Communications Plan to seek funding support for activities and provide guideline for communication tasks proposed and funded.

Schedule: Short- Long term

5.5.10 Planning, Coordination, & Implementation

1) ***Organize and maintain three standing committees to oversee plan implementation.***

Effective implementation of this plan will be accomplished through international (Canada and U.S.) and inter-agency cooperation and participation. The recovery process will be guided by three committees whose roles will range from facilitating stakeholder support for the initiative through to project implementation. Two of these committees, the Action Planning Group (APG) and the Recovery Team (RT), are already in place and will be maintained to provide ongoing support. These two committees are expected to meet annually (likely during October or November) to review progress, review annual budget proposals, and provide overall direction and support for the program.

The APG will include representation from any party with interests in Upper Columbia sturgeon recovery. Current membership includes regulatory agencies, tribal/First Nations agencies, public representation and industrial stakeholders. The APG will facilitate recovery plan implementation by seeking funding, providing local and traditional knowledge, addressing potential social and economic impacts of proposed recovery strategies, and communicating issues and findings to respective constituencies. An equivalent Action Planning Group will also be developed in Washington.

The RT will establish study priorities, review study plans, evaluate study results, and develop financial support procedures. As new information is gathered and recovery actions are implemented, the group will address additional research and management needs concurrent with white sturgeon recovery activities. New questions and data needs will likely arise during implementation of the Recovery Plan. The group will meet to develop specific proposals to address these data gaps.

A third committee, the Implementation Team (IT), will provide guidance to the wide range of projects planned under the recovery initiative. The IT is a working subcommittee of the recovery team and will be delegated responsibility for day-to-day decisions relating to recovery projects and contract delivery. IT membership will represent the technical, financial and logistical issues involved in program delivery. A small group of 4-5 individuals with the ability to communicate easily and regularly is recommended.

Initially, membership will consist of:

Biologist for Rare & Endangered Fish	Ministry of Water, and Air Protection, Nelson, B.C. (Chair)
Environmental Coordinator	B. C. Hydro, Castlegar, B.C.
Director	Canadian Columbia River Intertribal Fisheries Commission, Cranbrook, B.C.
Senior Fish Bio. /Manager	Golder Associates, Castlegar, B.C.
Fish Biologist	Spokane Tribe of Indians, Wellpinit, WA.
Recovery coordinator	As appropriate

The implementation team will also develop an annual budget and recommend project priorities consistent with available funds. This annual budget and proposal will be forwarded to the full Recovery Team for review and approval.

2) Develop a detailed implementation action plan to guide activities and funding for the next 3-5 years.

The Implementation Team in cooperation with representatives of the Action Planning Group will guide development of a detailed action plan based upon appropriate scientific advice and direction provided by the Recovery Team. The Action Planning Group includes stakeholders with jurisdictional responsibility for species recovery/management, those expected to contribute the resources to conduct the activities, and those who would be significantly impacted by the actions. The action plan should also include consideration of an equitable sharing of costs, particularly where individual stakeholder rights and interests would be negatively impacted.

Schedule: Short term

3) Establish a dedicated recovery coordinator position to facilitate committee activities and plan implementation.

Recovery plan implementation will be facilitated by establishment of a half to full time technical program coordinator. This coordinator will assist the three committees with tasks as delegated including tracking of project and program process, facilitation and liaison for the Recovery Team and Action Planning Group, and information/education activities. Affiliation, oversight, and detailed duties of this position are to be determined.
Schedule: Short- Long term

4) Develop coordinated data and reporting systems to facilitate program implementation.

Large numbers of tagged fish will be involved in this recovery effort. Given these numbers, the length of time over which recovery efforts will take place, and the number of different agencies/consultants involved in the program, a coordinated approach to data management and reporting will be required. This will include a comprehensive fish tag database, in which all marked fish and subsequent recaptures of these fish are tracked, along with descriptions to assist with interpretations of growth, survival, and habitat use. Web-based alternatives for maintaining and accessing this information should be examined. This effort will be integrated with other provincial tagging databases as appropriate.
Schedule: Short- Long term

5) Use available regulatory mechanisms and planning processes to protect white sturgeon and their habitats.

A variety of existing regulatory and planning processes affect sturgeon and their habitats. Sturgeon considerations identified by this recovery plan should be incorporated into appropriate

processes including water use and subbasin planning. Sturgeon risks should also be evaluated prior to introductions of new industries or developments.
Schedule: Short-Long term

6) Balance white sturgeon recovery measures with requirements for other aquatic species and recreational fisheries and with other water uses throughout the upper Columbia River basin.

A variety of constraints exist on white sturgeon recovery and this plan recognizes the need to balance efforts for white sturgeon, salmon, burbot, bull trout, and other species. Water uses for fish and non-fish applications (e.g. flood control, municiple, industrial) need to be considered.
Schedule: Short- Long term

Table 4. Summary of schedule for recovery objectives, strategies, and measures.

	Schedule		
Measure	Short	Medium	Long
5.5.1 Harvest/Bycatch			
(1) *Prohibit fishing*	X	X	X
(2) *Incidental impacts*		X	X
(3) *Resumption of Fisheries*			X
5.5.2 Entrainment			
(1) *Monitor mortalities*	X	X	X
(2) *Monitor Entrainment*		X	X
5.5.3 Culture/Stocking			
(1) *Hatchery Strategy*	X	X	
(2) *Hatchery-reared Offspring*	X	X	
(3) *Fail-safe Populations*	X	X	
(4) *Genetic Guidelines*	X	X	
(5) *Hatchery Marking*	X	X	
(6) *Hatchery Goals*		X	X
(7) *U.S. Propogation*	X	X	
(8) *Hill Creek Hatchery*	X	X	
(9) *Hatchery Methods*	X	X	
(10) *Cryopreservation*	X	X	
(11) *Health Protocols*	X	X	
5.5.4 Water Management			
(1) *Flow Augmentation*	X		
(2) *Flow Requirements*		X	
(3) *Dam Operations*		X	X
(4) *Reservoir Operations*		X	
(5) *Load-Shaping Operations*	X	X	
5.5.5 Water Quality			
(1) *Temperature*	X	X	X
(2) *Restore Turbidity*	X	X	X
(3) *Gas Concentrations*	X	X	X
5.5.6 Contaminants			
(1) *Concentration*	X		
(2) *Sources*	X		
(3) *Physiological Effects*		X	X
Measure	Short	Medium	Long
(4) *Remediation*			X
(5) *Contaminant Monitoring*			X
5.5.7 Habitat			
(1) *Habitat Changes*		X	X
(2) *Habitat Restoration*		X	X
(3) *Passage Alternatives*			X
(4) *Nutrient Availability*			X
(5) *Predator Control*	X	X	
(6) *Sediment Control*	X	X	X
5.5.8 Population assessment			
(1) *Adult Stock Assessment*	X	X	X
(2) *U.S. Population*	X		
(3) *Remnant Populations*		X	
(4) *Spawning Investigations*	X	X	X
(5) *Juvenile Indexing*	X	X	X
(6) *Essential Habitats*			X
(7) *Recruitment Bottlenecks*	X	X	
(8) *Genetic Baseline*	X	X	
(9) *Population Analysis Methods*	X	X	
(10) *Ecological Interactions*		X	X
(11) *Parasitism & Disease*		X	X
5.5.9 Information/Education			
(1) *Public Awareness*	X	X	X
(2) *Stakeholder coalition*	X	X	X
(3) *Link Activities*	X	X	X
(4) *Progress Reporting*	X	X	X
(5) *Communications Plan*	X	X	X
5.5.10 Planning			
(1) *Committees*	X	X	X
(2) *Action Plan*	X		
(3) *Recovery Coordinator*	X	X	X
(4) *Data Systems*	X	X	X
(5) *Regulatory Mechanisms*	X	X	X
(6) *Balance Other Species Needs*	X	X	X