

**UPPER COLUMBIA WHITE STURGEON
RECOVERY PLAN**



November 28, 2002

DISCLAIMER

Recovery plans delineate reasonable actions that are believed necessary to recover or protect the species. This plan has been prepared as a cooperative effort among Canadian and U.S. Federal, Provincial, and State agencies, Canadian and U.S. tribes, and other stakeholders. Objectives will be obtained and any necessary funds made available subject to budgetary and other constraints affecting parties involved, as well as the need to address other priorities. The recovery plan does not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation. The plan is subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

EXECUTIVE SUMMARY

White sturgeon are a unique and precious component of the biodiversity and cultural heritage of the upper Columbia River but are currently threatened with extinction in this geographic area unless rigorous restoration measures are implemented. The current population of approximately 1,400 adult white sturgeon in the transboundary reach of the upper Columbia River is substantially less than the endangered status criteria of 2,500 identified by the World Conservation Union. With an almost complete failure of natural recruitment, it is estimated that severe population bottlenecks will occur within the next 10 years and the population will become functionally extinct by year 2044.

The long life span of sturgeon requires a long-term perspective but the critical status of the upper Columbia population demands immediate action. Recruitment failures two decades past were only recently recognized and opportunities for effective intervention are rapidly being lost as the population continues to decline. Too few fish will soon remain to take advantage of suitable natural recruitment conditions if they occur and it will become increasingly difficult to capture ripe spawners needed to sustain a hatchery program.

This plan is the product of an Upper Columbia White Sturgeon Recovery Initiative by Canadian, U. S., and aboriginal governments, industrial and environmental organizations, stewardship groups, and citizens. The plan was prepared by a Recovery Team that included technical representatives from involved parties and an Action Planning Group that served as a public liaison with the broader community of affected and interested parties. The recovery plan is also intended to serve as a master plan for sturgeon restoration efforts in the U.S. portion of the river upstream from Grand Coulee Dam consistent with implementation of the Columbia Basin Fish and Wildlife Program under the 1980 Northwest Power Act. Implementation of this plan represents a proactive approach to species recovery and may provide an effective alternative to formal listing under a Canadian Species at Risk Act or the U.S. Endangered Species Act.

This recovery plan describes objectives, targets, strategies, measures, and a schedule for arresting the decline of white sturgeon in Canadian and U.S. portions of the Columbia River upstream from Grand Coulee Dam, ensure the persistence and viability of naturally-reproducing populations, and restore opportunities for beneficial use if feasible. Viability refers to the ability to sustain a diverse, naturally-reproducing population as a functional component of the river ecosystem. The efficacy of restoration of natural spawning and rearing habitats will determine whether natural populations can support subsistence or recreational fishing. To provide a context for recommended recovery actions, this plan also reviews the biology and status of upper Columbia River white sturgeon, reasons for decline, and existing conservation measures.

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. The medium-term objective is to determine survival limitations (bottlenecks) for remaining supportable populations and establish feasible response measures. 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.

Recovery targets include: minimum adult population sizes of 2,500 adults per area in two recovery areas (5,000 total); naturally-produced recruitment and juvenile population sizes sufficient to support desired adult population sizes; stable or increasing trends in adult and juvenile numbers; stable size and age distribution; and genetic diversity similar to current levels.

This plan also recognizes that efforts to restore significant sturgeon populations through natural production are also likely to benefit many other components of the native aquatic community.

Recovery objectives will be reached using four basic strategies. First, direct sources of adult mortality including fisheries and entrainment must continue to be controlled. Second, immediate hatchery intervention is necessary to preserve the remaining population diversity in the face of almost complete collapse of recruitment of young sturgeon. Third, white sturgeon recovery will require improvements in recruitment and survival based on habitat, flow, and/or water quality restoration. Finally, effective implementation of the recovery program will require continuing adaptation based on research and monitoring of sturgeon status, limiting factors, and potential recovery actions. Specific recovery measures are identified consistent with these recovery strategies for fishery regulation, entrainment, hatchery production, water management, water quality, contaminants, habitat diversity, population connectivity, system productivity, assessment, monitoring, research, information, education, planning, coordination, and implementation.

With continued commitment to a conservation hatchery program and restoration of natural recruitment within the next 20 years, at least 50 years will be required to rebuild a stable adult population and 100 years for restoration of a stable naturally-produced population. A minimum of 25+ years will be required to approach recovery targets because of the long life span and generation time of sturgeon. Long term prospects for sturgeon preservation will ultimately depend on identification and implementation of effective habitat measures for restoring natural recruitment. However, restoration of a significant white sturgeon population supported solely by natural recruitment might ultimately be precluded by the extent of habitat changes in the system.

Upper Columbia River White Sturgeon Recovery Team

First	Last Name	Job Title	Affiliation	Address	City	PC/ZIP	Phone/Fax	E-Mail
Ray	Beamesderfer	Contractor	S.P. Cramer & Associates Inc.	39330 Proctor Blvd	Sandy, OR	97055	(t) 503-475-0660 (c) 503-475-0660	beamesderfer@spcramer.com
Julia	Beatty	Head, Environ. Section	Min. of Water, Land & Air Protection	Suite 401 – 333 Victoria Street	Nelson, BC	V1L 4K3	(t) 250-354-6750 (f) 250-354-6332	Julia.Beatty@gems4.gov.bc.ca
Scott	Bettin	Fish Biologist	Bonneville Power Admin.	PO Box 3621 Mail Stop KEWR-4	Portland, OR	97208	(t) 503-230-4573 (f) 503-230-4564	swbettin@bpa.gov
Gary	Birch	Environ. & Social Issues Mgr.	BC Hydro	601 – 18 th Ave	Castlegar, BC	V1N 4G7	(t) 250-365-4569 (f) 250-365-4559	gary.birch@bchydro.bc.ca
Bill	Green	Director	CCRIFC	7468 Mission Road	Cranbrook, BC	V1C 7E5	(t) 250-417-3474 (f) 250-489-5760	ccrffc@cyberlink.bc.ca RT Alternate: Mark Tiley
Bob	Hallock	Deputy Field Sup.	USFWS Spokane Office	11103 East Montgomery Dr.	Spokane, WA	99206	(t) 509-893-8013 (f) 509-891-6748	bob_hallock@r1.fws.gov
Larry	Hildebrand	Senior Fish Bio. /Manager	Golder Assoc. Ltd.	201 Columbia Ave	Castlegar, BC	V1N 1A2	(t) 250-365-0344 (f) 250-365-0988	lhildebrand@golder.com
Brad	James	Fish Biologist	Wash. Dept of Fish and Wildlife	2108 Grand Boulevard	Vancouver, WA	98661	(t) 360-906-6716 (f) 360-906-6776	jamesbj@dfw.wa.gov
Bryan	Ludwig	Manager, Fish Culture Section	Min. of Water, Land & Air Protection	PO Box 9359 Station Prov. Govt.	Victoria BC	V8W 9M2	(t) 250 387-9681 (f) 250-387-9750	Bryan.Ludwig@gems9.gov.bc.ca
Jerry	Marco	Senior Fish Biologist	Dept Fish & Wild. Colville Confed. Tribes	Box 150	Nespelem, WA	99155	(t) 509-634-2114 (f) 509-634-2126	cctfish@mail.wsu.edu
Steve	McAdam	Hydroelectric Impacts Biologist	Ministry of Water, Land and Air Protection	PO Box 9363 Station Prov. Govt.	Victoria, BC	V8W 9M1	(t) 250-356-7217 (f) 250-387-9750	Steve.McAdam@gems7.gov.bc.ca
Mike	Parsley	Research Fisheries Biologist	USGS Western Fisheries Research Center	5501A Cook-Underwood Road	Cook, WA	98605-9717	(t) 509-538-2299 Ext 247 (f) 509-538-2843	michael_parsley@usgs.gov
Deanne	Pavlik	Fish Biologist	Spokane Tribe of Indians	PO Box # 480	Wellpinit, WA	99040	(t) 509-258-7020 Ext 24 (f) 509-258-9600	deanne@spokanetribe.com
Dan	Sneep	Habitat Assess. Bio. (Co- Chair)	Fisheries and Oceans Canada	Suite 360 - 555 West Hastings St	Vancouver, BC	V6B 5G3	(t) 604-666-7199 (f) 604-666-0292	sneepd@pac.dfo-mpo.gc.ca or sneep@interchange.ubc.ca
Colin	Spence	Endangered Species Biologist (Co-Chair)	Min. of Water, Land and Air Protection	Suite 401 – 333 Victoria Street	Nelson, BC	V1L 4K3	(t) 250-354-6777 (f) 250-354-6332	Colin.Spence@gems3.gov.bc.ca
Molly	Webb	Faculty Research Associate	Oregon State University	Dept. of Fisheries & Wildlife, Nash Hall	Corvallis OR	97331	(t) 541-737-2463	webbm@onid.orst.edu

Jay Hammond (Water, Land and Air Protection) held the position of Chair, Recovery Team from December 2000 – June 2002, while Keith Underwood, Spokane Tribe of Indians, was a member from December 2000 – summer 2002.

Upper Columbia River White Sturgeon Action Planning Group

Name	Last Name	Job Title	Company / Affiliation	Address	City	PC/ZIP	Phone	E-Mail
Ted	Down	Mgr Aquatic Ecosystem Science Section (Chair)	Ministry of Water, Land and Air Protection	Stn. Prov Govt. PO Box 9363	Victoria BC	V8W 9M2	250- 387-9715	Ted.Down@gems7.gov.bc.ca
Steve	Macfarlane	Regional Water Use Manager (Vice Chair)	Fisheries and Oceans Canada	#360 - 555 West Hastings Street	Vancouver BC	V6B 5G3	604-666-5529	macfarlanes@dfo-mpo.gc.ca
Hugh	Smith	Mgr, Strategic Asset Management	BC Hydro	6911 Southpoint Drive (E16)	Burnaby BC	V3N 4X8	604-528-3426	Hugh.Smith@bchydro.bc.ca
Margaret	Trenn	Environmental Technician	Aquila Networks Canada	Box # 130	Trail BC	V1R 4L4	250-368-0488	Margaret.Trenn@aquila.com
Bill	Duncan	Senior Biologist	Teck Cominco Ltd. (Trail Operations)	PO Box # 1000	Trail BC	V1R 4L8	250-364-4336	Bill.Duncan@teckcominco.com
Fiona	Mackay	Environment Superintendent	Celgar Pulp Company	1921 Arrow Lakes Drive	Castlegar BC	V1N 2W1	250-365-4249	fionam@celgar.com
Llewellyn	Matthews	Director, Environ. Affairs	Columbia Power Corp.	Suite 200 – 445 - 13 th Avenue	Castlegar BC	V1N 1G1	250365-9932	Llewellyn.Matthews@columbiapower.org
Rena	Vandenbos	Renewable Resources Instr.	Selkirk College	Box # 1200 Frank Beinder Way	Castlegar BC	V1N 3J1	250-365-7292 Ext 318	rvandenbos@selkirk.bc.ca
Maureen	DeHaan	Project Coordinator	Columbia Basin Fish and Wildlife Compensation Program	#103-333 Victoria Street	Nelson BC	V1L 4K3	250 352-6874	Maureen.dehaan@bchydro.bc.ca
Fred	Salekin	Member	Castlegar and District Wildlife Association	Box # 82	Robson BC	V0G 1X0	250-365-5539	<i>Post all information as no fax or e-mail available.</i>
Joan	Snyder	Member	West Kootenay Naturalists	Site 2 Comp 12 RR # 1	Slocan Park BC	V0G 2E0	250-226-0012	snowdance@telus.net
Suzanne	Rorick	Public Member		1115 – 7 th Avenue	Castlegar BC	V1N 1S5	250-365-7817	rorick@telus.net
Gerard	Nellestijn	President and Coordinator	Salmo Watershed Streamkeepers	Box 718	Salmo BC	V0G 1Z0	250-357-2630	gerry@streamkeepers.bc.ca
Dwayne	D'Andrea	Resource Person	Mountain Valley Sports Fishing	2612 - 4th Avenue	Castlegar BC	V1N 2R9	250-365-5771	mtvalley@telus.net
Sabrina	Curtis	CBT Spending Coordinator,	Columbia Basin Trust	103 Gould's Is.	Golden BC	V0A 1H0	250-344-7872	scurtis@cbt.org
Chris	Beers	Stewardship Coordinator	Columbia Koot. Fish. Renew. Partnership	PO Box 2008	Revelstoke BC	V0E 2S0	250-837-2124	chrisbeers@revelstoke.net
Clancy	Boettger	Member	Revelstoke Rod and Gun Club	PO Box # 757	Revelstoke BC	V0E 2S0	250-837-4126	boxey@telus.net
Andy	Dunau	Contractor	Lake Roosevelt Forum & projects for Spokane Tribe of Indians	1404 N. Thor Court, #112	Spokane WA	99202	509-535-7084	andy@dunau.com

David de Git (Columbia Power Corporation) and Kindy Gosal (Columbia Basin Trust) were members during December 2000 – September 2002.

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Figure 1. Columbia River white sturgeon captured, tagged, and released to estimate population status.

1.0 INTRODUCTION

1.1 Background

White sturgeon are a unique and precious component of the biodiversity and cultural heritage of the upper Columbia River but are currently threatened with extinction or extirpation from this area unless rigorous restoration measures are implemented. This species is an integral component of the native riverine ecosystem and historically supported productive traditional and recreational fisheries.

Sturgeon are at risk almost everywhere they occur in temperate river systems of North America, Europe, and Asia, and white sturgeon in the upper Columbia River are no exception. Habitat fragmentation, habitat degradation, and historic fisheries have combined to drastically reduce the range and numbers of this ancient species that has survived the last 175 million years. The upper Columbia River white sturgeon population now consists of several known or suspected subpopulations that have been isolated from each other and from historical critical habitats. Collectively, these populations are considered distinct from other populations in the basin and in other western river systems. Natural recruitment has failed for all upper Columbia River subpopulations which now consist solely of aging cohorts of mature fish that are gradually declining as fish die and are not replaced. Only the longevity of this species and complete fishery closures have forestalled extinction that will be inevitable without effective intervention.

White sturgeon are the largest, longest-lived freshwater or anadromous fish in North American (Scott and Crossman 1973) and are highly adapted to the large river systems in which they evolved. The largest white sturgeon on record, weighing approximately 682 kg (1,500 lbs.), was taken from the Snake River near Weiser, Idaho in 1898 (Simpson and Wallace 1982). Ages as great as 104 years have been reported (Rien and Beamesderfer 1994.) Large size and

opportunistic behavior allowed them to range widely to take advantage of widely-scattered and seasonally-available resources in these dynamic river mainstem habitats and in the ocean. Longevity and high fecundity allowed them to outlast variable environmental conditions and to capitalize on favorable spawning conditions when they occurred.

Population attributes that have proven adaptive for millions of years are now a liability (Beamesderfer and Farr 1997). Large size and high fecundity makes sturgeon a valuable fishery commodity but longevity and delayed maturation make them extremely vulnerable to overfishing. Long life span and benthic feeding also makes sturgeon susceptible to bioaccumulation of industrial and community pollutants with potentially detrimental effects on health, growth, maturation, and recruitment. Critical habitats have been altered. Dam construction has blocked movements and restricted sturgeon to river fragments that may no longer provide the full spectrum of habitats necessary to complete the life cycle. Flow regulation has limited seasonal and annual fluctuations that provide behavior cues and suitable spawning or rearing conditions. All of these changes favor a much different aquatic community of prey, predators, and competitors.

White sturgeon were designated as vulnerable in 1990 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Columbia River population in British Columbia was assigned to the provincial Red List in 1993 based on a B. C. Conservation Data Centre (CDC) status review that described the species as “critically imperilled.” The Kootenay River (spelled Kootenai in the U.S.) population of white sturgeon was listed in 1994 as endangered under the U.S. Endangered Species Act (ESA). Upper Columbia River white sturgeon are not currently listed under the U.S. ESA but might qualify for listing if considered. A Species at Risk Act (SARA) is currently in the final stages of legislation by Canada and might similarly apply to upper Columbia River white sturgeon if adopted.

This recovery plan describes strategies and measures to arrest the decline of white sturgeon in the Upper Columbia River Basin, prevent extinction, remove threats to long-term survival, and restore opportunities for beneficial use if feasible. Implementation of this plan represents a proactive approach to species recovery. The structure of this plan is designed to be compatible with Canadian Species at Risk Act (SARA) legislation and the U.S. Endangered Species Act (ESA), such that the plan could be considered the official recovery strategy should upper Columbia white sturgeon be listed in either country.

This plan includes white sturgeon in Canadian and U.S. portions of the Columbia River above Grand Coulee Dam. The subject area is the Columbia River mainstem and its tributaries from Columbia Lake to Lake Roosevelt, the lower Kootenay River from Lower Bonnington Dam to the Columbia River confluence, the Slocan system, and the lower Pend d’Oreille River (spelled Pend Oreille in the U.S.) from Boundary Dam to the Columbia River confluence. A separate recovery plan has been prepared for white sturgeon in Kootenay Lake and River by the U.S. Fish and Wildlife Service (USFWS 1999). The selection of Lower Bonnington Dam as the separation point between the Kootenay and Columbia rivers ecosystems reflects the location of Bonnington Falls which was an impassable barrier to upstream fish passage into the remainder of the Kootenay River system. Activities outside this recovery area are also considered if they impact upper Columbia River sturgeon.

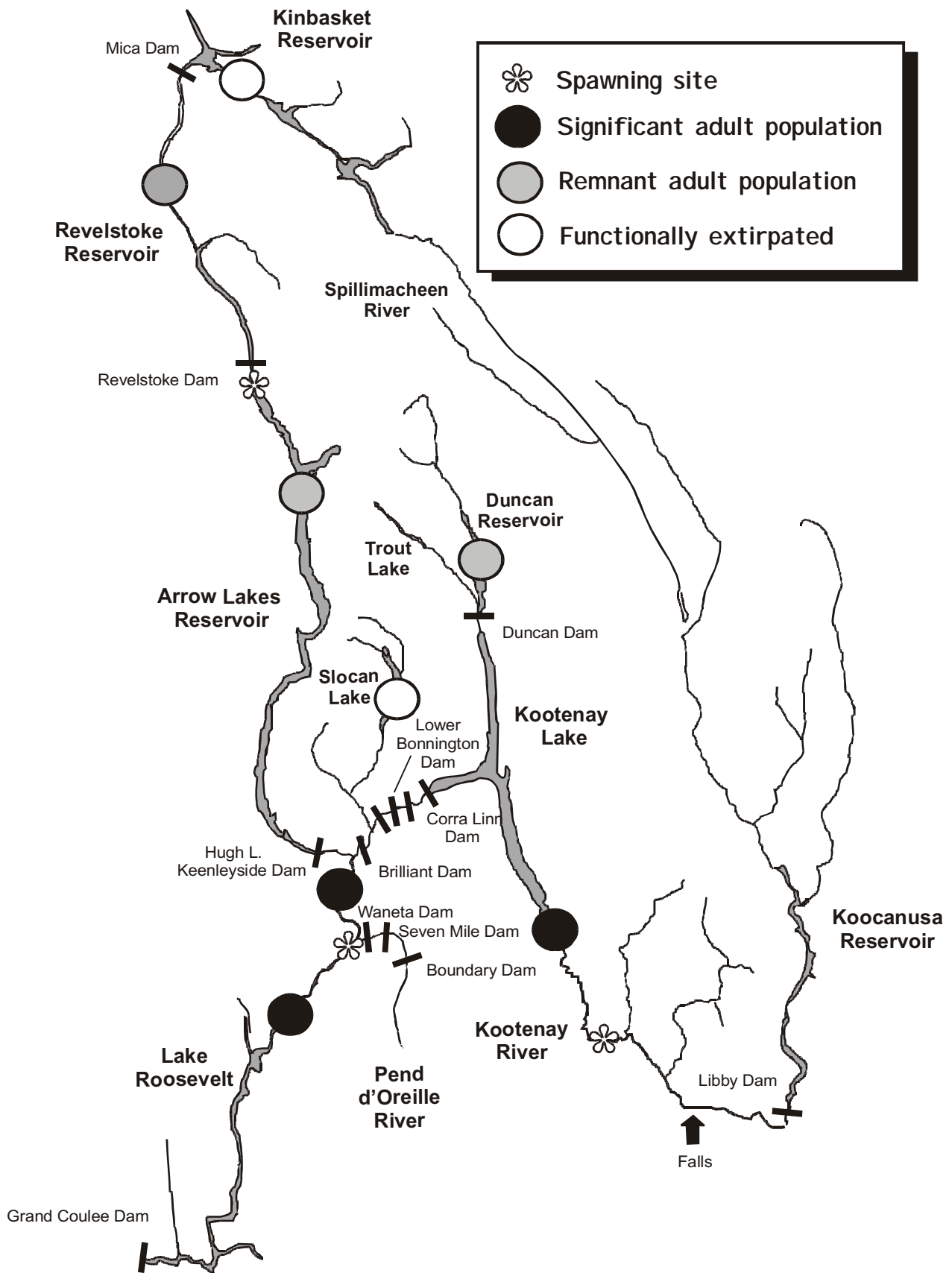


Figure 2. Distribution of white sturgeon in the upper Columbia River basin.

Although white sturgeon are the main subject of this plan, actions proposed for their stabilization could also benefit other native aquatic species and further contribute to overall health of the upper Columbia River ecosystem.

1.2 Outlook Without Intervention

The current population estimate of approximately 1,400 adult white sturgeon in the transboundary reach of the upper Columbia River is substantially less than the endangered status criteria of 2,500 identified by the World Conservation Union (IUCN 1994) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 1998). With the almost complete failure of natural recruitment, current data indicates that the population will decline by an additional 50% within 10 years and 75% within 20 years (Figure 3).

The upper Columbia white sturgeon population will decline below critical thresholds from which recovery may be difficult without immediate, aggressive, and effective intervention. Adult numbers of 500 and 50 have been identified as population benchmarks associated with irreversible consequences in U. S. Endangered Species assessments (Thompson 1991, McElhany et al. 2000, Rieman and Allendorf 2001). Numbers less than 500 result in bottlenecks that rapidly reduce genetic diversity. Numbers less than 50 result in severe genetic impacts related to inbreeding. The population of white sturgeon in the upper Columbia River is projected to decline to less than 500 adults within 14 years and will become functionally extinct around the year 2044 as numbers fall below 50 fish.

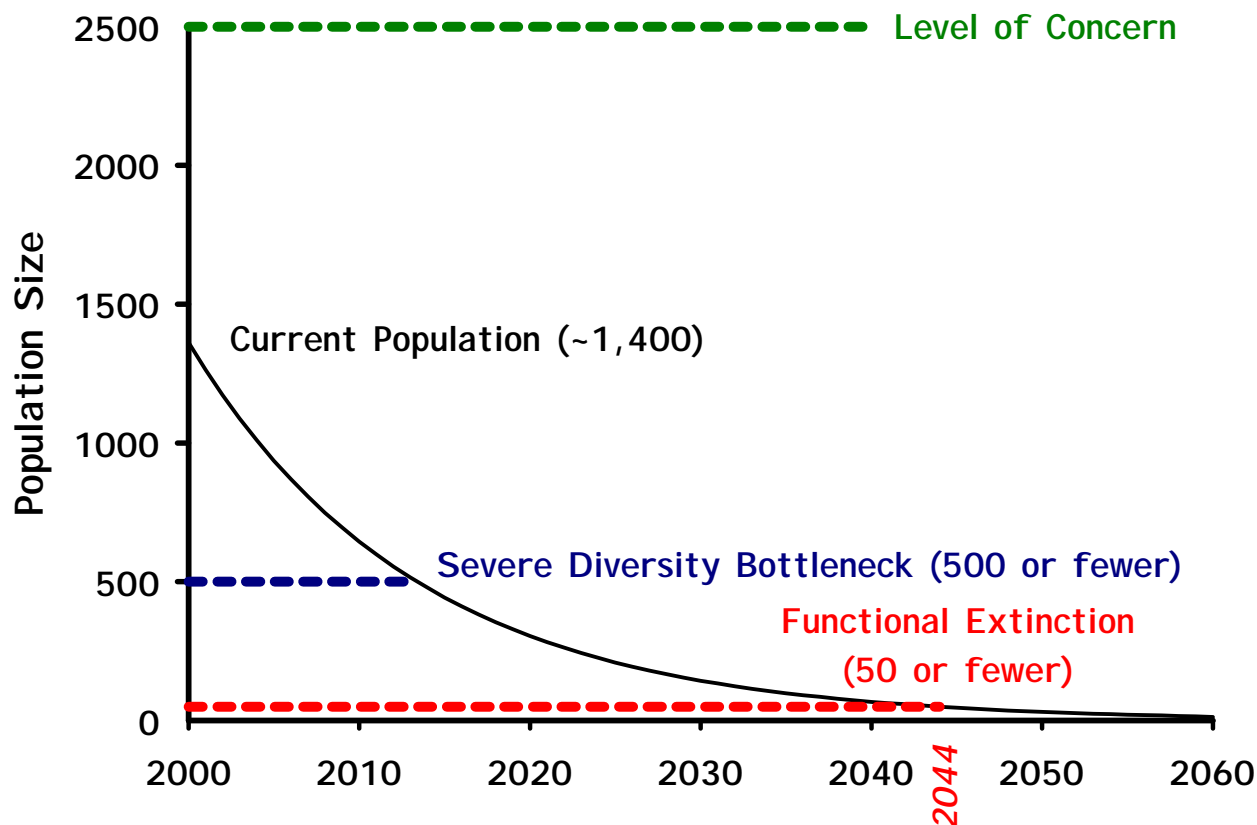


Figure 3. Projected population trajectory without intervention based on current population size and mortality rate.

The long life span of sturgeon requires a long-term perspective but the critical status of the upper Columbia population demands immediate action. The ongoing decline began with recruitment failure at least two decades ago but was not immediately recognized. Opportunities to arrest this decline will be lost well before extinction occurs. Too few fish will remain to take advantage of suitable natural recruitment conditions if they occur and it will become increasingly difficult to capture ripe spawners needed to sustain a hatchery program. Significant uncertainty about the nature of the natural recruitment problems will delay identification of potential solutions. High costs and difficulty of some potential solutions will require consideration of alternatives and risk further delays in implementation. The current critical status of upper Columbia River sturgeon belies a notion that their longevity provides an extended opportunity for implementation of this recovery plan. In fact sturgeon longevity ensures that near term actions or inaction will have long term consequences.

1.3 The Upper Columbia White Sturgeon Recovery Program

The wide distribution and trans-boundary movements of upper Columbia River white sturgeon require effective inter-jurisdictional coordination of recovery efforts. This recovery plan is the product of a cooperative effort by Canadian and U.S. governmental aboriginal, industrial and environmental organizations, stewardship groups, and citizens. A recovery team included technical representatives from Federal, Provincial, and State resource management agencies and from Canadian and U.S. tribes. Plan development also involved an Action Planning Group with representation by the Province, Fisheries and Oceans Canada, regional governments, First Nations, members of the public, environmental and industrial stakeholders, U. S. regulatory and tribal agencies.

The planning process was initiated by Canadian organizations and built upon a Canadian Columbia River white sturgeon stock stabilization document (Hildebrand and Birch 1996). A common commitment to a recovery program was formalized by Fisheries and Oceans Canada, B.C. Environment, B. C. Fisheries, and B. C. Hydro (BCH) with an August 17, 2000 Letter of Understanding. The letter outlined the approach to be taken for recovery planning and described agreements on how available funding was to be used for development and delivery of a recovery strategy. The agreement also defined a process for engaging First Nations and stakeholders (interested parties) in recovery planning in order to build understanding and support for the plan and to explore possible sources of funding for full implementation of the plan. This process led to active U.S. participation by the Spokane Tribe, Colville Tribes, U.S. Fish and Wildlife Service, Bonneville Power Administration, and the State of Washington.

The formal recovery planning process for the Upper Columbia white sturgeon stock was initiated with a September 16, 2000 workshop in Castlegar, B.C. which introduced the proposal for a recovery plan and committee development. Information was presented on the roles and responsibilities of the involved parties; species-at-risk legislation and issues in British Columbia; population dynamics and stock status of Upper Columbia River white sturgeon; human effects and causes for decline; stabilization options for consideration; and other white sturgeon recovery initiatives in North America.

The Action Planning Group and the Recovery Team were organized in late 2000, as an outcome of the September 16 workshop. These groups interacted but were not be hierarchically organized and their respective roles and responsibilities were described in a working draft “terms of reference.”

The Action Planning Group (APG) constituted the ‘main table.’ Their primary tasks were to develop a common vision for sturgeon recovery and to act as a public liaison with the broader community of affected and interested parties. Specific responsibilities included:

1. achieving consensus on the goals and objectives for white sturgeon recovery;
2. providing input to the Recovery Team on local and traditional knowledge of Upper Columbia white sturgeon;
3. providing advice to the Recovery Team on the potential social and economic impacts of proposed recovery strategies;
4. communicating issues and findings back to their respective constituencies;
5. supporting and promoting recovery plan implementation;
6. encouraging all parties involved in the decline of white sturgeon populations to support implementation of a recovery plan;
7. addressing how to best implement the actions identified by the Recovery Team;
8. and, striving to develop a “contract” in regards to contributions for the development and implementation of the Recovery Plan so that all partners were aware of their obligations.

The Recovery Team was comprised of individuals with technical expertise in relevant areas (sturgeon biology and fish culture, recovery of endangered species, genetics, hydraulic operation of Upper Columbia hydro facilities, and habitat remediation). The overall role of the Recovery Team was to develop and oversee implementation of the Recovery Plan. The plan is a technical document produced through discussion and consensus. Public input into the plan was achieved through on-going communication with and feedback from the APG. Specific responsibilities of the Recovery Team included:

1. assembling accurate baseline data and reviewing reasons for population declines;
2. defining the recovery goal and short, medium and long-term objectives for white sturgeon recovery;
3. establishing criteria to evaluate the recovery plan and to define success;
4. designing technical strategies, measures, and supporting research programs to achieve recovery goals and objectives;
5. and, establishing priorities for recovery implementation based on technical criteria and input from the Action Planning Group.

The Recovery Team designated sub-committees for habitat restoration, water management, contaminants, fish culture, and genetics. The water management subcommittee provided information to the Recovery Team regarding potential measures affecting river flows (and/or stages), reservoir elevations, and water quality measures. The habitat restoration subcommittee provided information on habitat losses that could have impacted life stage survival, opportunities for habitat restoration, and long-term habitat management, and restoration measures. The contaminants subcommittee provided information regarding potential impacts of contaminants on sturgeon and alternatives for further exploration. The fish culture subcommittee provided information related to the options, capabilities, and costs of the conservation fish culture program consistent with the recovery team outline for production requirements. The genetics subcommittee provided information regarding genetic risk assessment/management, genetic data needs, and other potential genetics issues, and developed a breeding plan which outlines appropriate hatchery practices.

1.4 Northwest Power Planning Council Fish and Wildlife Program

At the same time sturgeon recovery planning efforts were being developed in Canada, U.S. sturgeon recovery efforts in the upper Columbia River were being organized under the Northwest Power Planning Council Fish and Wildlife Program. The Upper Columbia River Recovery Program provided the opportunity to develop a comprehensive plan for both sides of the border.

This recovery plan is intended to guide sturgeon recovery efforts in the U.S. portion of the river upstream from Grand Coulee Dam consistent with implementation of the Columbia Basin Fish and Wildlife Program under the 1980 Northwest Power Act. This recovery plan is not intended to replace the formal planning process for the U.S. Columbia River Basin Fish and Wildlife Program but should provide a technical basis for sturgeon recovery strategies and measures addressed in that program. This recovery plan may also serve as a master plan for any hatchery-based recovery measures identified for the U.S. portion of the upper Columbia River.

The Pacific Northwest Electric Power Planning and Conservation Act was passed by the U.S. Congress in 1980 and authorized the states of Idaho, Montana, Oregon, and Washington to create the Northwest Power Planning Council (NPPC 2000). The Act directs the Council to prepare a program to protect, mitigate, and enhance fish and wildlife of the Columbia River Basin that have been affected by the construction and operation of hydroelectric dams while also assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply. The Act also directs the Council to inform the public about fish, wildlife, and energy issues and to involve the public in its decision-making.

Through its Fish and Wildlife Program, the Council provides guidance and recommendations on hundreds of millions of dollars per year of Bonneville Power Administration revenues to mitigate the impact of hydropower on fish and wildlife. A series of fish and wildlife programs have been adopted, revised, or amended between 1982 and 2000. In the current Fish and Wildlife Program, specific measures are to be detailed in more than 50 subbasin plans developed locally and amended into the program by the Council. White sturgeon are included in the mainstem subbasin plan.

White sturgeon planning, research, and restoration measures or goals have been included in all recent fish and wildlife programs. The 2000 Fish and Wildlife Program includes white sturgeon in its resident fish section which identifies the following objectives:

1. Complete assessments of resident fish losses throughout the basin resulting from the hydrosystem, expressed in terms of the various critical population characteristics of key resident fish species.
2. Maintain and restore healthy ecosystems and watersheds, which preserve functional links among ecosystem elements to ensure the continued persistence, health, and diversity of all species including game fish species, non-game fish species, and other organisms.
3. Protect and expand habitat and ecosystem functions as the means to significantly increase the abundance, productivity, and life history diversity of resident fish at least to the extent that they have been affected by the development and operation of the hydrosystem.

4. Achieve population characteristics of these species within 100 years that, while fluctuating due to natural variability, represent on average full mitigation for losses of resident fish.

2.0 BIOLOGY AND STATUS

2.1 Species Description

The white sturgeon (*Acipenser transmontanus*) is one of seven North American and 23 total sturgeon species that inhabit temperate large river systems throughout the Northern Hemisphere (Robins et al. 1980). The white sturgeon was initially described by Richardson in 1863 from a specimen collected in the Columbia River near Fort Vancouver, Washington (Scott and Crossman 1973). Green sturgeon (*Acipenser medirostris*) are also found in the Columbia River but are restricted to coastal areas (Scott and Crossman 1973, Brown 1989).

All sturgeon are characterized by a cartilaginous skeleton and persistent notochord (Scott and Crossman 1973). They possess a tube-like mouth and four barbels located on the ventral surface of a hard protruding snout. All sturgeon have five rows of bony plates (scutes): one dorsal, two ventral, and two lateral (Scott and Crossman 1973). Denticles make the skin feel rough between the rows of scutes. The arrangement and number of scutes are diagnostic for white sturgeon: 11 to 14 dorsal, 36 to 48 lateral, and 9 to 12 ventral scutes (Scott and Crossman 1973). Bajkov (1955) also described white sturgeon with seven rows of scutes. About 3% of the specimens examined displayed this characteristic and were collected downstream from Bonneville Dam, the lowermost dam on the Columbia River. White sturgeon with seven rows of scutes also have been recorded in the Columbia River.

Several authors have noted snout dimorphism in white sturgeon (Crass and Gray 1982; Brannon et al. 1986). Landlocked forms appear to have more pointed snouts than those with access to the ocean (Brannon et al. 1986). Different snout shapes may reflect different temperatures or other factors that individuals experience during development (Ruban and Sokolov 1986, Brannon et al. 1987) or perhaps an adaptation to fast moving water.

2.2 Distribution & Movements

White sturgeon are a facultative anadromous species that inhabits large rivers, estuaries, and the near-shore ocean from Ensenada, Mexico to the Aleutian Islands (Figure 4). Significant white sturgeon populations spawn in the Columbia, Fraser, and Sacramento river systems (Scott and Crossman 1973, Lee et al. 1980, Lane 1991). These populations likely mix in the ocean but only occasional movement of tagged fish has been observed among the three main river systems (DeVore et al. 1999). Many white sturgeon populations and individuals are currently restricted to fresh water by impassable dams or historic natural barriers. Prior to extensive development, populations with access to the ocean probably included a mixture of anadromous and resident life histories with the incidence of anadromy decreasing in the upper river reaches.

White sturgeon historically had access from the ocean all the way to Windermere Lake in the upper Columbia and Shoshone Falls in the upper Snake River (Figure 4). Populations in the upper reaches of the basin were most likely resident but benefited from the availability of anadromous salmon. A Kootenay River population was isolated upstream of Bonnington Falls since the last glaciation approximately 10,000 years ago (Northcote 1973). White sturgeon inhabited the upper Columbia mainstem, lower Spokane River, lower Pend d'Oreille River, and

Kootenay River to Bonnington Falls, and probably also used portions of smaller tributaries including the Sanpoil, Kettle, Slocan, and Salmo rivers (Hildebrand and Birch 1996, Prince 2001). Distribution was probably patchy with fish concentrated in areas of favourable habitat. Significant concentrations of white sturgeon were reported during the early 1900s in the mainstem downstream from Castlegar, the lower Kootenay River, Arrow Lakes, Big Eddy near Revelstoke, and the present site of Mica Dam (Prince 2001).

At least two significant subpopulations remain in the upper Columbia River and other remnant populations consisting of a few individuals occur, or are suspected, throughout other portions of the historic range (Figure 4). The largest subpopulation resides in the free-flowing transboundary reach between Hugh L. Keenleyside Dam (HLK) and Lake Roosevelt (FDR). White sturgeon in the 56 km section of the Columbia River between HLK and the international boundary have been intensively studied since 1990 (Hildebrand and English 1991; RL&L 1993, 1994a, 1994b, 1995, 1996a). Sturgeon in this section are concentrated throughout the year in four deep, low velocity areas: the area downstream from HLK, Kootenay eddy at the Kootenay River confluence, Fort Shepherd Eddy, and Waneta Eddy at the Pend d'Oreille River confluence. Considerably less is known about sturgeon distribution and density in the approximately 40 km section of river between the border and Lake Roosevelt. This area was surveyed for sturgeon in 1998 with limited effort (DeVore et al. 1998, Kappenman et al. 2000). Significant catches of adult sturgeon occurred in the transition zone of the upper reservoir and smaller numbers were caught in other areas upstream to the border. Sturgeon have only occasionally been caught in Lake Roosevelt during years of intensive sampling for other fish species.

The extent of movements and mixing of sturgeon throughout the transboundary reach is unclear. Telemetry studies in the Canadian portion of the reach have identified localized movements between adjacent high use areas and into staging areas for spawning. Long distance seasonal migrations have not been observed although some fish tagged in Canada have moved into U.S. portions of the river and upper Lake Roosevelt. Similar patterns were observed in a small telemetry study conducted from 1988-1991 where sturgeon tagged near Marcus Flats in upper Lake Roosevelt were generally observed to remain in that area (Brannon and Setter 1992).

A second significant subpopulation of white sturgeon currently inhabits Arrow Lake Reservoir (ALR). This subpopulation appears to be substantially smaller than the group in the transboundary reach between HLK and FDR. Sturgeon sampling and telemetry studies have been conducted in ALR from 1995-2000 (RL&L 1998c, 1999b, 2000b). A significant sturgeon concentration was identified in the Beaton Flats area at the confluence of Beaton Arm and the main body of ALR. Radiotagged fish were observed to remain in this area throughout the winter but several fish moved during spring and summer upstream to Revelstoke or into Beaton Arm near the confluence with the Incommappleux River. Despite observations of sturgeon entrained through HLK and anecdotal reports, only one sturgeon has been caught in assessment fisheries in lower Arrow reservoir.

Other small remnant white sturgeon populations occur throughout the historic upper Columbia River range. Adult sturgeon have been collected during systematic investigations in Slocan Lake and Duncan Reservoir of the Kootenay system but not in Kinbasket Reservoir, Revelstoke Reservoir, or Trout Lake (RL&L 1996b, 1996c, 2000a). However, given the large size of these reservoirs and limited sampling effort, the failure to catch a white sturgeon does not necessarily preclude their existence, but may suggest that population densities are very low (RL & L 2000a).

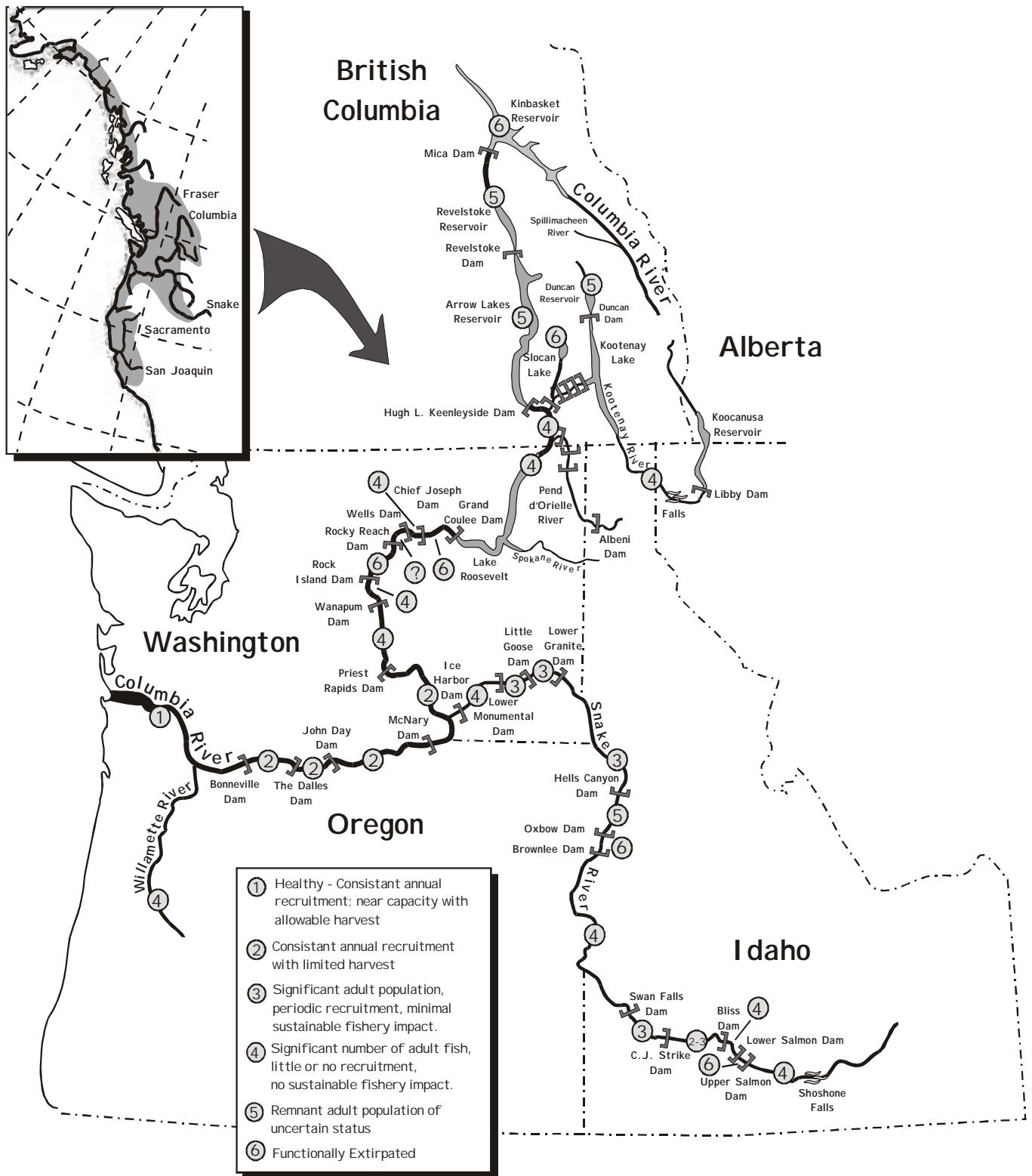


Figure 4. Freshwater and saltwater range of white sturgeon (Scott and Crossman 1973, Moyle 1976, Lane 1991) and the distribution and status of Columbia River subpopulations.

2.3 Genetics & Stock Structure

White sturgeon populations along the Pacific coast of North America are closely related. Anders and Powell (2002) observed 26 unique mitochondrial DNA (mtDNA) sequences (haplotypes) in samples from 13 locations in the Columbia, Snake, Kootenay, Fraser, Nechako, and Sacramento rivers. The two most common haplotypes were represented by 64% of the 260 fish sequenced and were observed at 100% and 85% of the sample sites (Anders and Powell 2002). Similar overlap among populations was reported by Bartley et al. (1985) based on electrophoretic analysis of allele frequencies, Brown et al. (1990) based on mtDNA, and McKay et al. (2002) based on mtDNA. Expansive haplotype distribution indicates little genetic divergence and significant gene flow throughout a major portion of the species' range (Anders and Powell 2002). However, there is little evidence to support high levels of contemporary gene flow, especially in post-impoundment systems (McKay et al. 2002, Anders, personal communication). This conclusion is consistent with observed recaptures of small numbers of tagged Columbia River in the Sacramento and Fraser rivers (DeVore et al. 1999).

Small but significant differences in genetic frequencies and diversity are apparent among populations in the Sacramento, Columbia, and Fraser systems based on electrophoretic and mtDNA analysis (Bartley et al. 1985, Brown et al. 1990, Nelson et al. 1999, McKay et al. 2002, Anders and Powell 2002). Bartley et al. (1985) observed the greatest heterozygosity in the Sacramento population that also contained several variant alleles not observed in other populations. However, more extensive sampling by Anders and Powell (2002) found that all haplotypes represented in the Sacramento River were also present in the more diverse Columbia River population although frequencies were different. Four of eight Sacramento haplotypes were not represented in the Fraser River.

Some differences were apparent between the Fraser and Columbia rivers (Brown et al. 1990, Nelson et al. 1999, McKay et al. 2002, Anders and Powell 2002). Brown et al. (1990) observed 4 unique types in the Fraser and 2 in the Columbia. McKay et al. (2002) observed 5 unique types in the Fraser, 2 in the Nechako, and 7 in the Columbia. Anders and Powell (2002) observed 5 unique haplotypes in the lower Fraser River, 2 in the Nechako River, and another 8 types in the Columbia but not the Fraser. Haplotype and nucleotide diversity was slightly greater in the Fraser than the Columbia (Brown et al. 1990, Anders and Powell 2002). Brown et al. (1990) suggested that following the last ice age, the Columbia River population probably provided the founders for the Fraser River population, based on zoogeographical evidence. They speculated that recent overexploitation and habitat destruction explain the reduced diversity of Columbia River populations relative the more recently colonized Fraser River population. However, Anders and Powell (2002) suggested that this pattern may be due to historical panmixia and that latitudinal-based clinal variation appears to occur less distinctly in white sturgeon than in other North American sturgeons.

White sturgeon genetic studies have consistently documented decreasing diversity with distance upstream (Bartley et al. 1985, Brannon et al. 1987, Brown et al. 1990, McKay et al. 2002, Anders and Powell 2002). Total number of haplotypes were negatively correlated with inland distance from the Pacific Ocean in all river systems studied (Anders and Powell 2002). Genetic differences were most pronounced in the Kootenay River white sturgeon population where heterozygosity was the lowest observed in the Kootenay River (Bartley et al. 1985, Brannon et al. 1987, Setter and Brannon 1990, Anders and Powell 2002). There is also a clear genetic distinction between populations in the upper and lower Fraser River (Brown et al. 1992,

Nelson et al. 1999, McKay et al. 2002, Anders and Powell 2002). This pattern is consistent with a suggestion that anadromous behavioural patterns may be less prevalent among fish in the upper portions of basins.

These results suggest that the genetically composition and other adaptations of the upper Columbia white sturgeon population in Canada and the U.S. upstream from Lake Roosevelt may be unique. Diversity of sturgeon sampled from Lake Roosevelt was the lowest observed among any population except the Kootenay (Anders and Powell 2002).

Significant genetic differences also reflect population differences in other characteristics. For instance, the genetic unique Kootenai River white sturgeon have been observed to spawn at consistently lower temperatures and water velocities than other white sturgeon populations. This behaviour may represent an adaptation to local conditions.

2.4 Abundance & Population Trends

White sturgeon abundance in the Columbia River between HLK and the Canada-U.S. border has been estimated at about 1,400 adults based on mark-recapture sampling from 1990-2001 (RL&L 2002). Estimates are based on steadily increasing recapture percentages of marked fish in each year of sampling. Approximately one out of every two white sturgeon captured since 1995 was a recapture of a fish previously marked by researchers. Population size is similar to that of the ESA-listed Kootenay River white sturgeon (1,470 adults in 1995: V. Paragamian, Idaho Department of Fish and Game, personal communication).

The population status in the U.S. portion of the Columbia River above Lake Roosevelt is unknown. The Canadian estimate mainly reflects the number of white sturgeon that reside in the four high-use areas north of the border and is likely an underestimate of the total population in the transboundary reach between HLK and Lake Roosevelt. One year of catch and catch per unit effort data is available for the U.S. portion of the transboundary reach but data is not adequate to estimate abundance. Differences in size composition, growth, and condition of sturgeon sampled in U.S. and Canada portions of the transboundary reach (RL&L 1996b; DeVore et al. 2000) may suggest that fish near Lake Roosevelt are a localized population that does not frequently intermix with stocks in the Canadian portion of the Columbia River.

An aging, decreasing cohort of large sturgeon are now present in the transboundary reach and Lake Roosevelt. As the current population has aged, size distribution in Canadian samples has steadily shifted over the last 20 years from a population dominated by juvenile and subadult fish less than 100 cm in length to one dominated by subadult and adult fish greater than 100 cm in length (Figure 5). The reported size distribution of white sturgeon in Roosevelt Lake is similarly dominated by adult fish (Figure 5).

Current abundance in Arrow Lakes Reservoir is unknown but is apparently much less than the transboundary population. A total of 25 white sturgeon have been captured from 1995-1999 (RL&L 2000a). All were 38 years of age or older (i.e., 1957 year-class). These fish either were trapped in the reservoir following construction of HLK in 1968, or have since moved into the reservoir via the boat lock. Like the transboundary population, the ALR fish are all large subadults or adults. One spawning event was documented near Revelstoke in 1999 but the absence of younger fish in the ALR population indicates a failure of natural recruitment (RL&L 2000b).

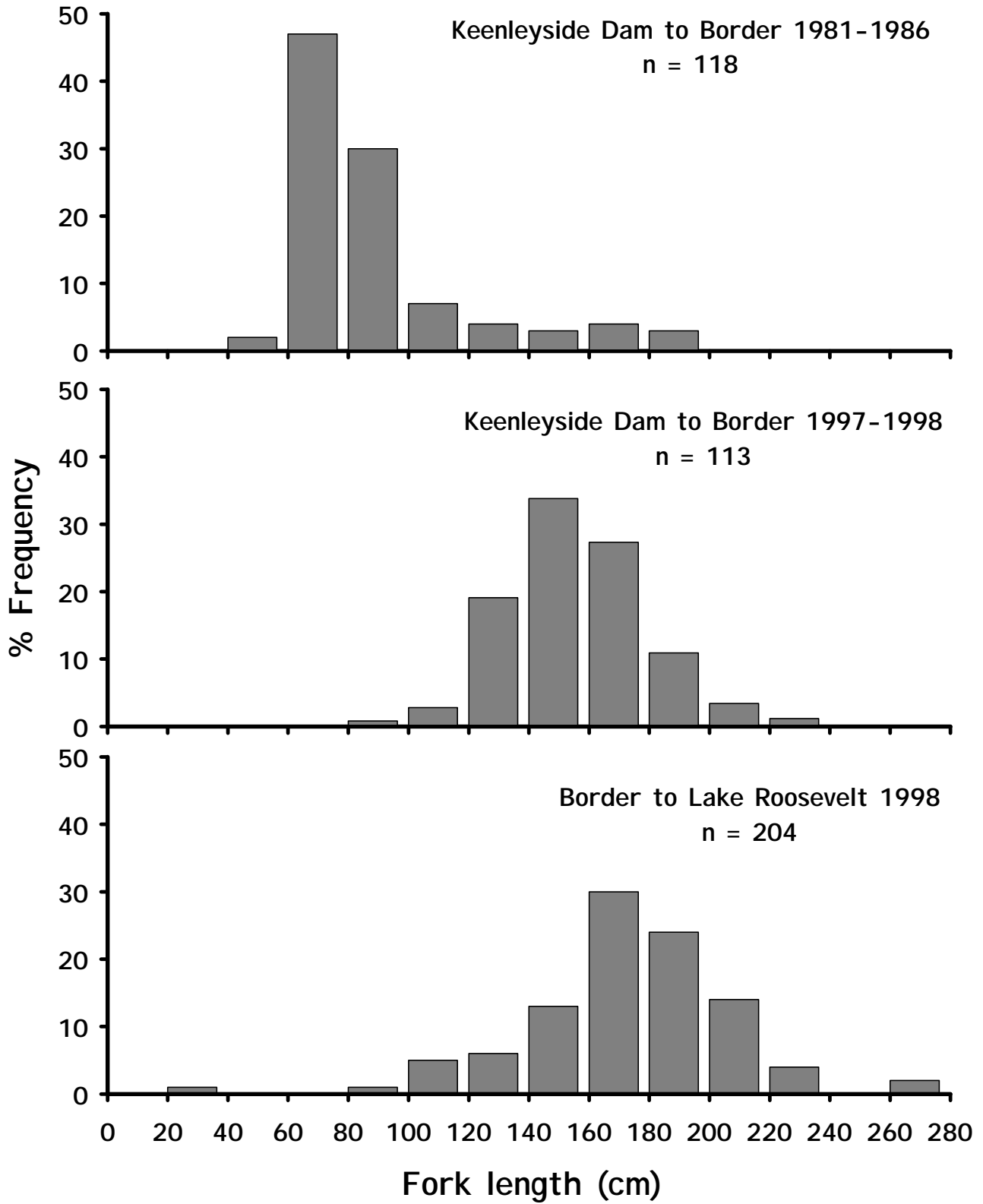


Figure 5. Length-frequency distributions of white sturgeon captured in the upper Columbia River (RL&L 2002; DeVore et al. 2000).

2.5 Growth, Condition, Maturation, & Survival

Individual growth, condition, maturation, and survival are sensitive indicators of sturgeon population productivity and key drivers of population size composition, biomass, reproductive potential, and future trends. In general, faster growth, better condition, increased survival, and earlier maturation all contribute to healthier, more robust populations. Weak, threatened, or endangered populations are generally associated with low values in one or more of these population parameters.

Individuals from inland sturgeon populations tend to grow slower and reach smaller sizes than fish in populations with access to the ocean. Reduced growth of inland sturgeon typically results from cooler temperatures, low system productivity, and lack of access to abundant food resources. Problems have been compounded by the loss of anadromous sources of food and nutrients. Maximum sizes collected during survey sampling in the upper Columbia River were approximately 270 cm fork length (RL&L 1996b; DeVore et al. 2000). On average, white sturgeon in the upper Columbia River population have been estimated to grow at 3-5 cm per year through age 30 and 2-3 cm per year for ages 30-50 based on ages assigned from circulus counts in fin ray sections. Growth rates reported by RL&L (1996b) for Canadian portion of the transboundary reach ($k = 0.027$) were less than those reported by DeVore et al. (1999a) for the U.S. portion ($k = 0.035$). Individual growth rates are highly variable. Many tagged fish appeared to grow at two-three times the average rate while others did not grow at all even after several years at large (RL&L 1996b). However, recent growth data for tagged Kootenay and lower Columbia river white sturgeon indicates that annual increments are less than projected from fin rays and that sturgeon may be substantially older than previously thought (Paragamian and Beamesderfer, In review).

Condition factor is also typically lower for inland than for anadromous white sturgeon populations (Beamesderfer 1993). Condition factor is an index of skinniness or plumpness based on weight for a given length. Condition factor reported for upper Columbia River sturgeon by RL&L (1996b) is near average for white sturgeon but considerably less than reported in downstream populations. Condition factor in the U.S. portion of the transboundary reach was less than average for white sturgeon.

Sexual maturity of white sturgeon does not occur until relatively large sizes and advanced ages (Semakula and Larkin 1968; Chapman 1989; Welch and Beamesderfer 1993). Maturation occurs over a wide range of sizes and ages and substantial differences occur among populations depending on growth. Males typically mature at smaller sizes and ages than females, and may spawn in all or most years following maturation. Females typically mature at larger sizes and older ages and do not spawn every year. In the upper Columbia River, mature male white sturgeon were observed at sizes of 106 - 207 cm FL and ages of 16 - 46 (RL&L 1996b). Most males greater than 150 cm and age 25 were mature. Mature females were observed at sizes of 137 - 271 cm FL and ages of 27 - 65. Most females greater than 170 cm and age 30 were mature. Frequencies of ripe, developing, and resting stages suggest that the spawning interval at full female maturity in the upper Columbia River may be significantly greater than the 3 years reported for in lower Columbia River (Welch and Beamesderfer 1993). Sizes of maturation in the upper Columbia River was similar to those reported by Welch and Beamesderfer (1993) for lower Columbia River populations.

Annual survival rates for long-lived fish like white sturgeon are typically quite high in the absence of fishing and often exceed 90% (Semakula 1963, Cochnauer 1983, Kohlhorst et al. 1991, Beamesderfer et al. 1995, DeVore et al. 1993). Because sturgeon are so long-lived, population trends are extremely sensitive to very small changes in survival of only a few percent. Most methods of estimating survival are not accurate enough to discern differences this small. Survival rates have not been estimated for the upper Columbia River white sturgeon population in part because of confounding effects of declining recruitment. However, annual survival rates of 90% or greater are consistent with maximum ages observed in the population. Maximum ages of 65 and 96 years were reported for the transboundary sturgeon population by RL&L (1996b) and DeVore et al. (1999a), respectively.

2.6 Food & Feeding

White sturgeon are primarily benthic feeders on invertebrates and fish but are often surprising selective in their choice of food. Food items are probably detected with chemo- and electro-receptors located on four sensory barbels and the snout rather than by sight (Brannon et al. 1985; Buddington and Christofferson 1985). However, white sturgeon have been observed actively pursuing prey throughout the water column (S. King, Oregon Department of Fish and Wildlife, personal communication). No information is available on food habitats in the upper Columbia River but other white sturgeon juveniles are reported to eat amphipods, isopods, mysids, clams, snails, small fish (such as sculpins and assorted fry), and fish eggs (Muir et al. 2000; McCabe et al. 1993). Larger sturgeon feed increasingly on fish including eulachon, northern anchovy, American shad, lamprey, Pacific herring and various salmonids (McCabe et al. 1993; Sprague et al. 1993). Large adult sturgeon are capable of consuming large prey including adult salmon.

Diet can vary substantially with time of year as white sturgeon take advantage of seasonally abundant prey items, especially anadromous and estuarine fishes in areas where they are accessible. The lower Columbia River white sturgeon population feeds heavily on the eulachon run during late winter, adult shad and lamprey in late spring and early summer, anchovies that enter the estuary in summer and early fall, and salmon that are present primarily from spring through fall. Blockages of anadromous fish runs into the upper Columbia have eliminated a food source that was likely important to the pre-development white sturgeon population. This food source was most abundant in the fall and may have provided an important energy source for overwintering with significant implications for spawning frequency and fecundity (Hildebrand and Birch 1996).

Many movement and migration patterns appear related to feeding. Where habitat is relatively homogenous such as in marine waters, estuaries, low gradient mainstem areas of the lower basin, and reservoirs, white sturgeon move frequently and range widely in search of scattered or mobile food resources. Fish are more sedentary in the upper basin where the river consists of interspersed rapids and pools where fish can hold and feed on prey delivered by the river. High-use areas by white sturgeon in the Canadian portion of the upper Columbia River and the river-Lake Roosevelt transition zone are all depositional environments where food items settle out and become available to benthic-oriented feeders such as white sturgeon. These low velocity areas adjacent to fast water allow sturgeon to optimize energetic benefits. In the case of holding areas below dams, entrained fish likely represent an important food source for white sturgeon.

2.7 Spawning Behavior & Habitat

White sturgeon spawn during spring and early summer by broadcasting eggs over clean rocky substrate in turbulent river habitats. Fish gather in aggregations to spawn and several males spawn with each female. Spawning is accompanied by darting, rolling, and breaching activity. Many lower basin white sturgeon populations undertake upstream spawning migrations beginning in fall or winter while populations in close proximity to spawning sites display more localized movements.

White sturgeon generally spawn at temperatures of 14 to 18°C (Figure 6). These temperatures correspond with optimums identified during incubation experiments. Based on laboratory experiments with white sturgeon collected from San Francisco Bay, Wang et al. (1985, 1987) reported that (i) the optimum temperature range for incubation was between 14 and 16°C; (ii) successful incubation was observed from 10 to 18°C; (iii) temperatures in excess of 18°C caused substantial abnormalities; and (iv) temperatures below 14°C extended incubation and hatching times, but did not result in developmental abnormalities. RL&L (1997a) incubated wild-caught eggs *in situ* in capsules and showed generally lower hatch success at temperatures exceeding 18°C.

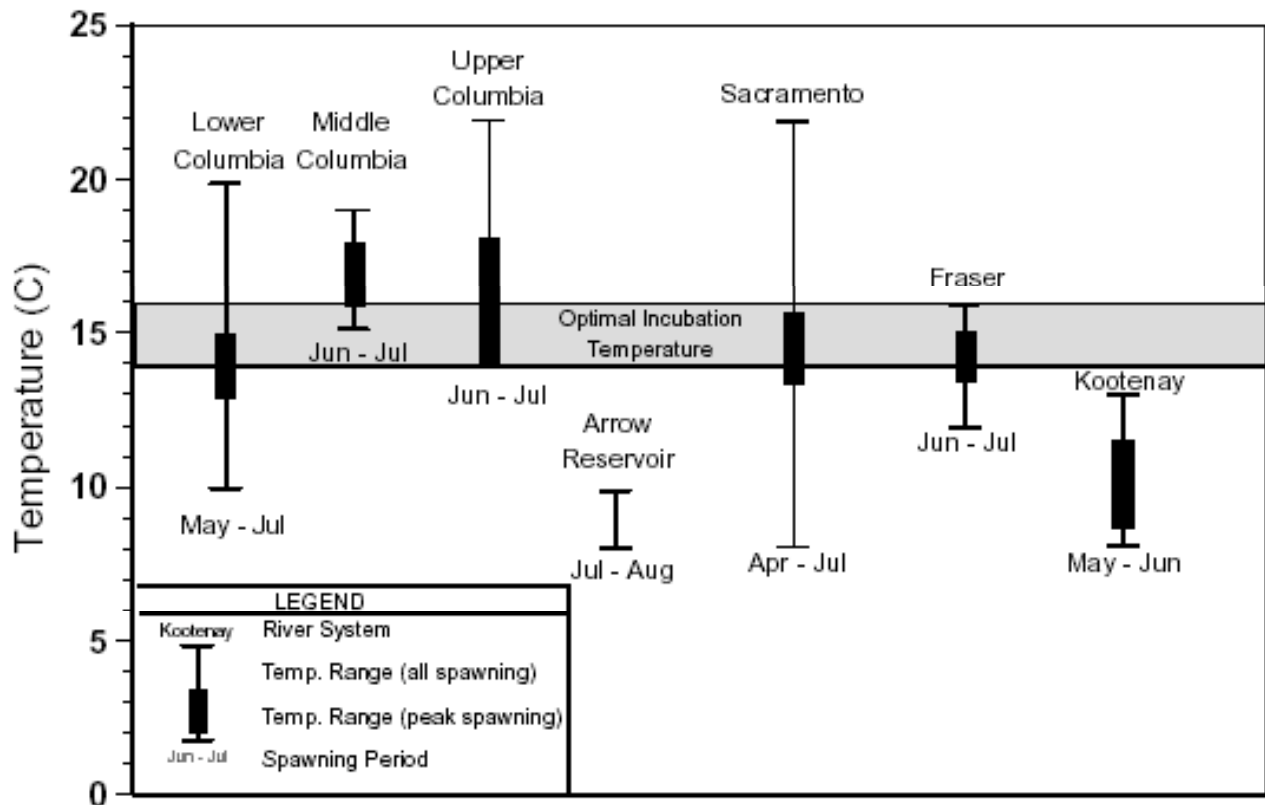


Figure 6. Water temperatures associated with spawning by white sturgeon (Anders and Beckman 1993; Parsley et al. 1993; Hildebrand and Mckenzie 1994; RL&L 1995, 1996a, 1996b, 1996c, 1997a, 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d; Perrin et al. 1999, 2000).

Water temperature prior to spawning may also affect sturgeon spawning success. Exposure of gravid cultured white sturgeon females to ambient water temperatures (10-19°C) from October to March has been found to result in a high incidence of ovarian regression during late oogenesis (Webb et al. 1999; Webb et al. 2001). Similar problems were not apparent at colder temperatures. Cold water requirements for successful completion of ovarian development have also been documented in other sturgeon species (Kazanskii 1963; Kazanskii and Molodtsov 1973; Williot et al. 1991; Chebanov and Savelyeva 1999).

Spawning often occurs later in the year and over more contracted periods in upper basin and northern populations, in part due to colder spring temperatures. However, Arrow Lakes Reservoir and Kootenay River populations spawn at temperatures well below presumed optimums that no longer occur (or never occurred) in those systems during the typical spawning timeframe. Optimum spawning temperatures for these populations may be less than those identified for Sacramento River white sturgeon.

Spawning sites are selected based on substrate, water velocity, depth, and other factors that are poorly understood. Preferred spawning substrates are large cobble and rock where fine material has been cleared from interstices by the current (Figure 7). Smaller substrate appears to be used by populations in the Sacramento, Fraser, and Kootenay systems but data on those systems is either limited (Sacramento and Fraser) or suggests use of fine substrate is not successful (Kootenay). Evidence to support the active selection of clean coarse substrates is available for other sturgeon species. For instance, following the introduction of coarse, clean rock in a known lake sturgeon spawning area, most spawning activity occurred over the new rock substrate.

High water velocity is a key attribute of spawning site selection. Mean water column velocities typically range from 0.5 to 2.5 m/s (Figure 7). Parsley et al. (1993) also observed consistently greater spawning success in reaches and high-discharge years that provided higher velocities. Lower than average spawning velocities (0.2 – 1.0) have been reported for Kootenay white sturgeon but spawning in that system is not successful (Paragamian et al. 2001). High velocities scour fine material that can smother eggs, exclude potential predators, and may help disperse larvae. Habitat suitability criteria developed for U.S. populations of white sturgeon identify 0.8 m/s as a minimum and 1.7 m/s or greater as optimum (Parsley et al. 1993; Parsley and Beckman 1994). RL&L (1996a, 1996b, 1996c), in reviewing available information on sturgeon spawning requirements, recommended water velocities of greater than 1.5 m/s to provide for sturgeon spawning in the Upper Columbia River.

Spawning site selection also appears related to turbulence (M. Parsley, U.S. Geological Survey, personal communication), although this effect is difficult to quantify. Sturgeon spawning commonly occurs in only a portion of the available area that meets general substrate, velocity, and depth criteria.

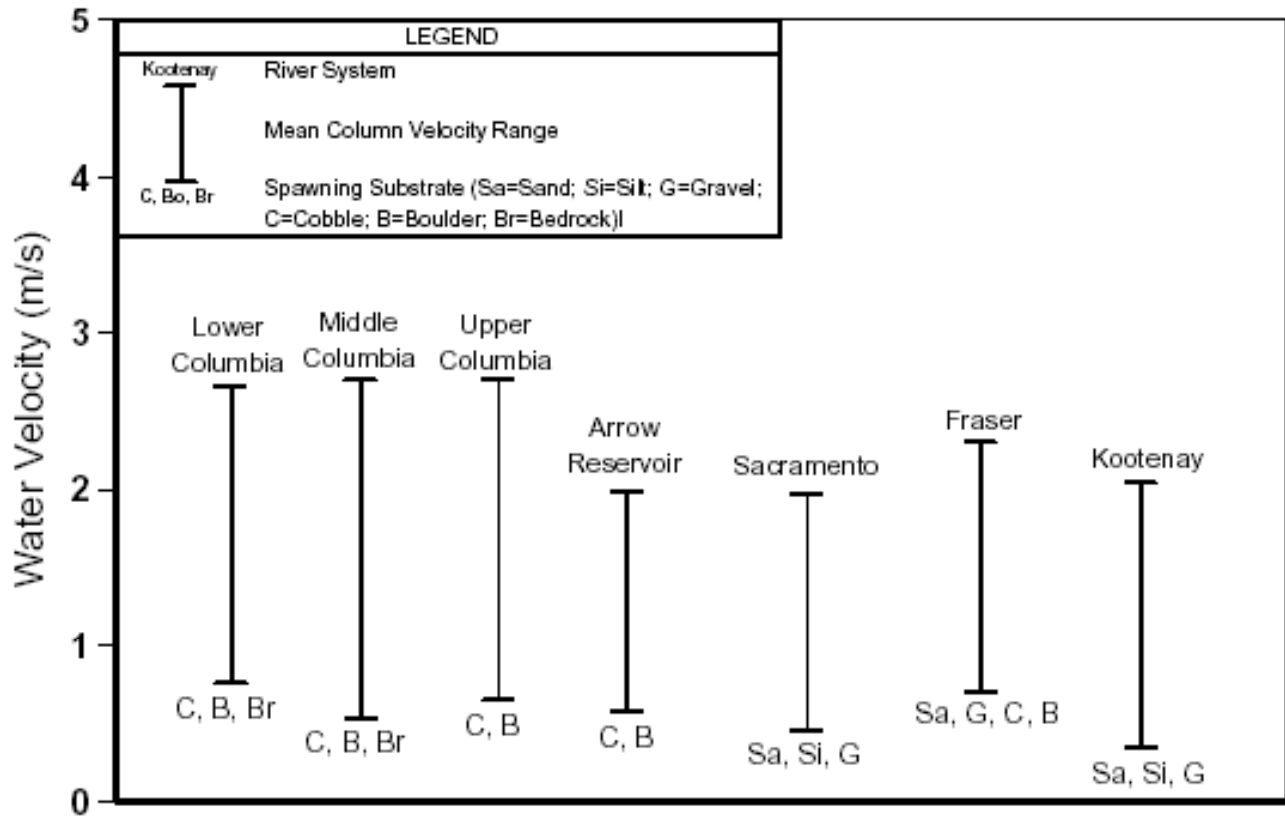


Figure 7. Substrates and water velocities associated with sturgeon spawning site selection (Parsley et al. 1993; RL&L 1996a, 1996b, 1996c; Perrin et al. 2000).

White sturgeon spawn at a wide range of water depths (0.5 to 50 m) and depth does not appear to be a highly critical factor influencing spawning site selection. Spawning depth observations include: 3 – 5 m at the Pend d’Oreille – Columbia River confluence (RL&L 1996a, 1996b), 4.5 – 25 m in the lower Columbia (Parsley and Beckman 1994), 2 – 24 m in the lower Fraser River in 1998 (Perrin et al. 1999), and 0.5 – 6.5 m in the lower Fraser River in 1999 (Perrin et al. 2000). Parsley and Beckman (1994) proposed a relationship between suitability for spawning and depth that was 0 at depths of 2 m or less, increased linearly from 0 to 1 between 2 m and 4 m, and remained at 1 for all depths from 4 to at least 25 m.

Spawning of white sturgeon has been documented in the Columbia River near Waneta (Figure 8) every year since surveys began in 1993 (RL&L 1995, 1996a, 1996b, 1996c, 1997a, 1997b, 1999a, 1999b, 1999c, 1999d). The number of distinct spawning events has ranged from 4 in 1994 to 9 in each of 1995 and 1996 (RL&L 2002). Both the Waneta and Fort Shepherd eddies are used for staging by pre-spawning white sturgeon. Spawning occurs at the confluence of the Pend d’Oreille River which is several degrees warmer than the Columbia River during spring and largely retains a natural hydrograph. The confined channel morphology downstream from Waneta results in turbulent outflow and high water velocities over a wide range of discharges. Spawning in the Waneta area often occurs at water temperatures greater than the 18°C identified as a maximum for successful spawning.



Figure 8. White sturgeon spawning area at the confluence of the Pend d'Oreille and Columbia river. Spawning occurs in the bridge area within the influence of the Waneta Dam tailrace (RL&L 1994a).

Numbers of spawning events and eggs collected at Waneta were considerably greater in 1995 and 1996 than in other years. The main difference between years was the timing and volume of peak discharges from the Pend d'Oreille River. Discharges were higher and declined more steadily in 1995 and 1996. These patterns suggest a positive relationship between spawning activity and discharge. It is important to note in this respect that this observation pertains to discharge as opposed to water velocity, and that the relationship between discharge and mean velocity is generally not linear.

Discharge spikes frequently in of the lower Pend d'Oreille River during the spawning period due to load shaping operations at Waneta Dam and other facilities upstream. The occurrence of spawning during load shaping periods suggested that daily or weekly fluctuations in flow may not preclude spawning, if the proper cues are present prior to the spawning act to stimulate vitellogenesis and ovulation and if sufficient discharge is provided to maintain velocities in spawning habitats above a critical level. There is some concern, however, that fluctuating discharge during the spawning period may influence both the intensity of spawning and egg survival. Based on the limited data collected, spawning intensity was greatest when discharges were high and steady, as was the case in 1995 and 1996. Sustained high discharges may increase egg survival by providing high velocities that exclude predators in egg deposition areas and high turbidity that inhibits visual predation.

Use of other spawning sites in the upper Columbia River is unclear. No spawning has been documented in the U.S. portion of the transboundary reach although little work has been conducted there (Kappenman et al. 2000). No spawning has been documented in the HLK tailrace despite apparently-suitable velocities and substrates and widespread observations of tailrace spawning in lower Columbia River impoundments (RL&L 1998a). Spawning was documented upstream of ALR near Revelstoke in 1999 (RL&L 2000b). Many historic spawning sites may no longer be available. Based on the presence of suitable habitat and anecdotal observations of local residents, spawning may have occurred at numerous locations along the mainstem Columbia River or in larger tributaries, including Kettle Falls, Tin Cup Rapids at the outlet of Lower Arrow Lake, the Narrows between Lower and Upper Arrow Lakes, the canyon section above Revelstoke, and the canyon section in the lower Pend d'Oreille River (Hildebrand and Birch 1996).

2.8 Early Life History & Recruitment

Despite annual spawning of transboundary sturgeon at Waneta, recruitment of juvenile sturgeon into the population has been very low since at least 1980 (Figure 9). The first year of life is a critical period and appears to be the bottleneck that has led to the dire status of sturgeon in the transboundary reach. Spawning occurs every year and removal of eggs to a hatchery setting has demonstrated their viability. However, few naturally-spawned individuals are surviving from egg to age 1.

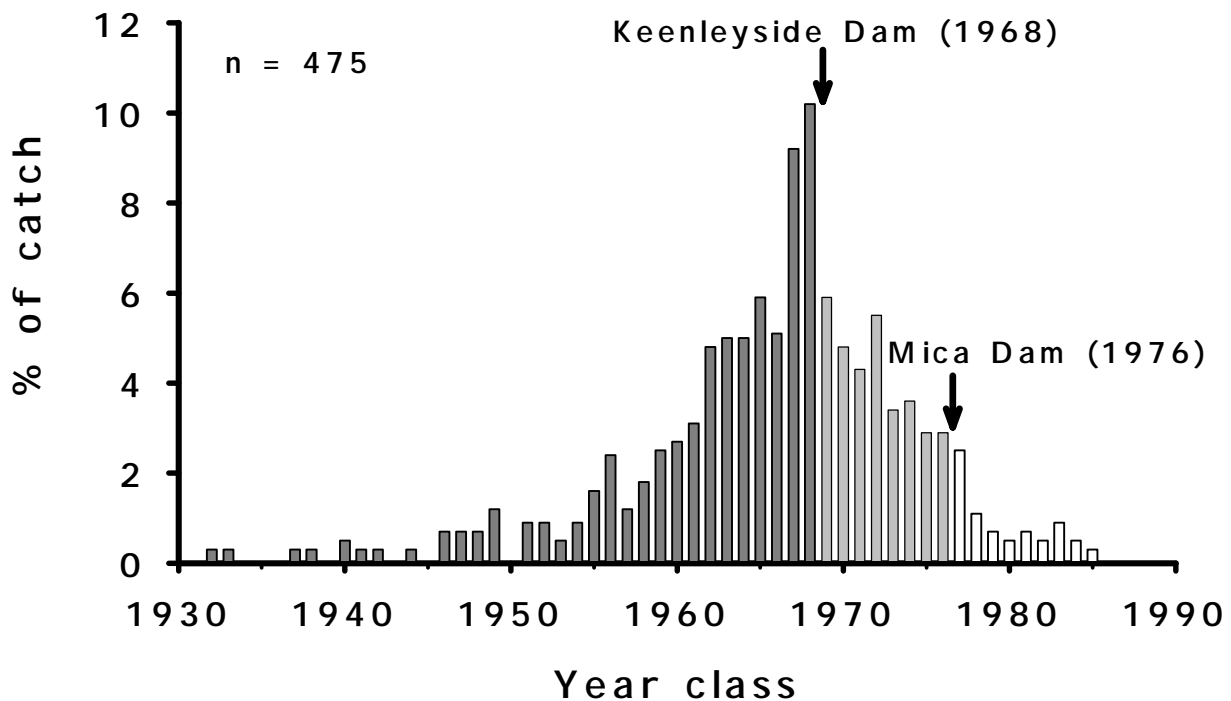


Figure 9. Reflection of historic recruitment and mortality rates of upper Columbia River white sturgeon based on current age composition expressed in terms of year class (RL&L 1994; Hildebrand and Birch 1996).



Figure 10. Juvenile white sturgeon at approximately 2-3 months of age.

Early life history includes incubation, hatching, dispersal, and hiding phases (Parsley et al. 2002). Hatching typically occurs 5-10 days after spawning depending on temperature (Wang et al. 1985). Upon hatching, larval white sturgeon enter a swim-up phase in which they leave the substrate and are suspended in the water column (Brannon et al. 1985). This behaviour disperses larval sturgeon into available rearing habitats. The swim-up phase may last up to 5 or 6 days with time spent in the water column inversely related to water velocity (Brannon et al. 1985; Conte et al. 1988). In the Columbia River below Bonneville Dam, white sturgeon larvae are transported over 175 km downstream from spawning areas (McCabe and Tracy 1993). Following dispersal, white sturgeon enter a hiding phase in which they avoid light and seek refuge in the substrate. The hiding stage for white sturgeon generally lasts 20-25 days until the yolk is absorbed, whereupon the fish move out of the substrate to begin feeding (Parsley et al. 2002). Young white sturgeon appear to remain closely associated with rough substrates throughout their first summer as evidenced by their very low susceptibility to sampling by any method.

White sturgeon eggs, larvae, and young-of-the-year are vulnerable to a variety of mortality factors and first year survival rates are very low even under optimum conditions. Eggs are vulnerable to extreme temperatures, abrupt temperature changes, suffocation by sediments, mechanical damage, infection, contaminants, and fluctuating flows that allow predator access into egg deposition areas (Parsley et al. 2002). Larvae are particularly vulnerable to predation at the swim-up stage and factors that increase time spent in the drift (i.e., slower current velocity

due to reduced discharge from upstream dams) or visibility (i.e., increased water clarity due to upstream impoundments) will undoubtedly reduce survival. The dispersal phase might also transport larvae into downstream reservoirs where food may be scarce or introduced predators may be abundant. Larvae may starve during the transition from endogenous to exogenous feeding, particularly if environmental factors have reduced food availability at this critical time. Effects of any one of these mortality factors may be small but the compounded effects of many incremental increases in mortality may be enough to explain current recruitment failures.

Following the first year or two, mortality of juvenile white sturgeon appears to be relatively low. Juveniles use a wide variety of habitats. Juvenile white sturgeon in the lower Columbia River occur in many of the same low to moderate velocity habitats as adults and subadults. In the lower Fraser River, slough and large backwater habitats adjacent to the mainstem provide important rearing habitats (Lane and Rosenau 1995); these types of habitats are unavailable in the Columbia River between HLK and Lake Roosevelt.

While factors controlling year class strength are poorly understood, recruitment has been widely correlated with flow volume in many sturgeon species including white sturgeon (Votinov and Kasyanov 1978; Kohlhorst et al. 1991; Anders and Beckman 1993). Kohlhorst et al. (1991) positively correlated white sturgeon year-class strength with the volume of freshwater flow through the Sacramento-San Joaquin River Estuary. In the lower Columbia River high springs flows were correlated with the availability of high velocity spawning habitat, spawning success, and subsequent recruitment (Anders and Beckman 1993). Further, differences in recruitment among several subpopulations were related to channel morphology effects on velocity at different flows. Flow effects may be related to: 1) increased availability of suitable spawning sites, 2) reduced predation on eggs, 3) decreased predation on larvae and juveniles, 4) increased flooding of side channel and slough areas that provide higher quality rearing habitats than mainstem areas, or 5) effects of related conditions such as temperature.

Table 1. Critical areas and periods for white sturgeon life history stages in the transboundary reach of the upper Columbia River (Hildebrand and Birch 1996).

Life Requisite	Critical Period	Critical Areas	Comments
Spawning	Late May to late July	Pend d'Oreille-Columbia confluence	represents the only confirmed spawning area for white sturgeon in the Columbia River between HLK and Grand Coulee dams; spawning has occurred annually at this location since 1993 with an estimated 3 to 8 spawning events per year; limited data suggest spawning intensity is related to discharge and temperature although recruitment appears minimal in all years
Incubation	Late May to late July	Pend d'Oreille-Columbia confluence	Eggs incubate for 5-10 days depending on water temperature. Survival to hatch may depend on water quality and substrate characteristics that protect embryos from physical damage and predation
Rearing <i>Larval</i>	Early June to late August	Unknown; suspected to occur in upper portions of Lake Roosevelt	represents the period following hatch when endogenous feeding larvae undertake passive movements to suitable downstream rearing habitats; this may be the most critical period in the recruitment cycle; predation and high levels of total dissolved gases may influence survival rates
<i>Young-of-the-year</i>	August to December	Unknown; suspected to occur in upper portions of Lake Roosevelt	follows shift to exogenous feeding; may represent next most critical stage in early survival (i.e., suitability and availability of food items in rearing habitats is unknown); pollutant contamination may affect food abundance; predation rates associated with increases in predator abundance and increased water clarity may also reduce survival
<i>Younger juveniles</i>	All year	Unknown; suspected to occur mainly in Lake Roosevelt	represents age-1 to age-7 fish; very low use of transboundary reach for this life-stage; reduced survival at the larval and YOY stages may account for low abundance of younger juveniles
<i>Older juveniles</i>	All year	Within localized areas Columbia R. and within Lake Roosevelt	Ages 8 to 15; low use of Columbia R. by this life-stage; most fish > age-15; found in same habitats as adults; main factors limiting use by this life-stage are habitat availability and suitability. Changes in biotic productivity of the river may influence food availability and thus production.
<i>Adult Feeding</i>	All year; greater use from May to October	Mainly in four localized areas of the lower Columbia River (HLK area, Kootenay, Fort Shepherd, and Waneta eddies); in U.S., also exhibit greatest use of localized areas (e.g., Kettle Falls, China Bend, Dead Mans Eddy)	represents immature sub-adults (15 to 30 years old) and mature adults (generally older than age-30; population in transboundary reach composed mainly of fish older than age-30; limited sampling in U.S. indicates similar size-class (and presumably age-class) composition; population in lower Columbia is about 1400 fish; fish use shallow mainstem areas in the summer; highest use in all seasons is for areas with depths over 15 m; food abundance/composition has likely changed in response to dam operations and exotic species introductions
Overwintering	November to March	Restricted to 4 areas of the Columbia in B.C. (HLK area, Kootenay, Ft Shepherd, Waneta); U.S. sites unknown	in winter, fish tend to be found only in deeper portions (>20 m depth); since the availability of deep-water habitats is limited, the importance of these areas during the winter period is increased; since regulation of the river, winter flows and water temperatures have increased, possibly reducing the suitability of overwintering habitats
Staging (Pre-spawners)	November to late May	Known staging areas are Ft. Shepherd eddy, Waneta eddy, and the HLK area; use of the Kootenay Eddy for staging not documented	represents locations selected by pre-spawning females (and possibly pre-spawning males) that provide suitable low velocity holding areas near spawning areas; higher use of Ft. Shepherd Eddy may reflect depths >50 m at this location; flow fluctuations that increase velocities in staging areas and temperatures increases during the winter period may affect spawning intensity

3.0 REASONS FOR DECLINE

3.1 Exploitation & incidental catch

White sturgeon are extremely vulnerable to overfishing because of their delayed age of maturation (15 years or greater) and longevity (up to 100 years) (Beamesderfer and Farr 1997, Boreman 1997). If significant numbers of subadults are harvested, too few fish survive to adulthood to spawn and replenish the population. Only very low exploitation rates of 5%-10% can be supported by productive sturgeon populations and unproductive populations can sustain no harvest at all (Rieman and Beamesderfer 1990).

The decline of the sturgeon is the cumulative effect of many factors and harvest is likely one of them. Significant harvesting started at the same time as the recruitment problem and has likely accelerated the population decline. White sturgeon were used by native peoples although catches were probably small. Anecdotal information suggests that harvest of sturgeon in the upper Columbia River basin remained low through the 1950s (Prince 2001). Catches of sturgeon during this period were noteworthy events, with accounts periodically published in local newspapers. Angling for sturgeon became popular in the mid-1970s and this popularity increased steadily to the 1990s. Beginning in the late 1980s, several guiding outfits commenced operations on the Columbia River; sturgeon was one of the species targeted by the guides. Harvest data are generally unavailable for upper Columbia River sturgeon. Reported harvests between Lake Roosevelt and the international boundary averaged 60 sturgeon per year from 1988-1995 (Brad James, Washington Department of Fish and Wildlife, unpublished data). Catch and harvest data are available for the Canadian portion of the river (HLK to the border) only from 1992 when an estimated 204 white sturgeon were caught, of which 43 were killed (ARA Consulting Group 1992). Fisheries were largely curtailed by 1996 with protective regulations in Canadian and U.S. sport fisheries and by voluntary reductions in subsistence harvest by First Nations people.

Historic overfishing in the lower Columbia River may have affected numbers of lower basin fish available to migrate into the upper basin although migration rates are unknown. Over fishing collapsed sturgeon populations in the lower Columbia, Fraser, and Sacramento-San Joaquin rivers around the turn of the century. Populations in each of these areas were severely overfished within 10-20 years by unregulated, targeted, commercial exploitation (Semakula and Larkin 1968; Galbreath 1985). These populations have since recovered to varying degrees following enactment of protective fishing regulations but significant improvements required 50 years or more.

3.2 Dams & Reservoirs

Dam and reservoir construction and operation affect white sturgeon by 1) blocking movements between widely-distributed spawning, rearing, and feeding habitats needed to complete the life cycle, 2) flooding productive riverine habitats, 3) eliminating anadromous fish runs that provided food and marine-derived nutrients, 4) reducing habitat suitability by changing temperature patterns, flow, water chemistry, nutrient transport, and water clarity, 5) increasing mortality either directly as a result of dam construction and entrainment, or indirectly as a result of gas supersaturation, and 6) changing species composition and abundance of prey, competitor, and predator species.

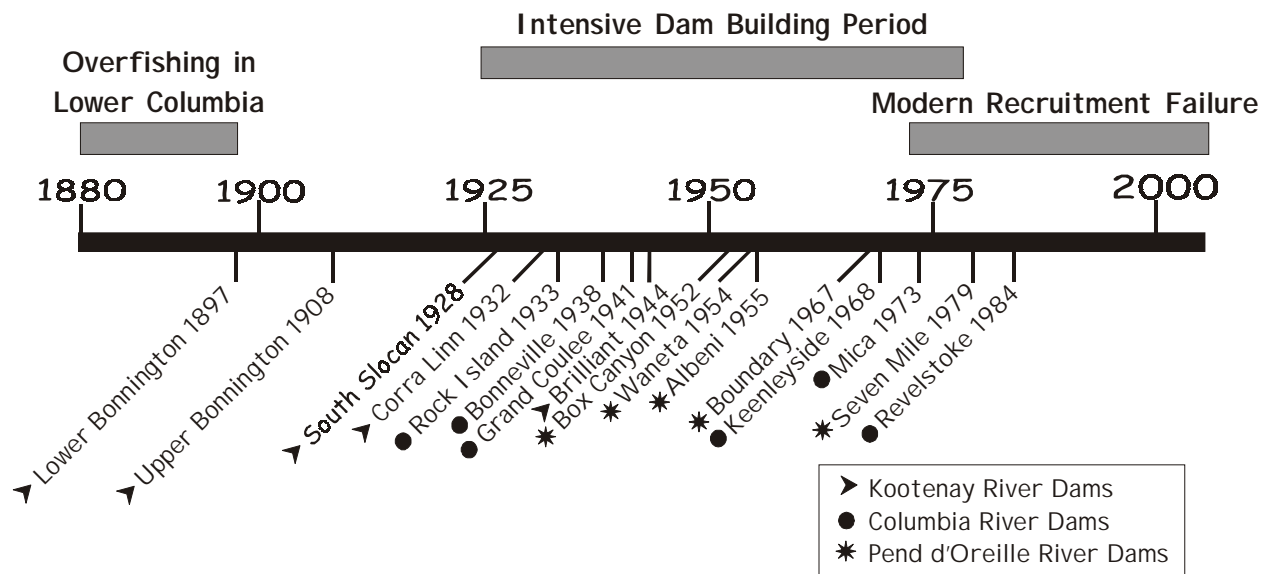


Figure 11. Time line of dam construction and white sturgeon impacts in the Columbia River basin. (Modern recruitment failure may have begun earlier than indicated if sturgeon ages are underestimated as recent data suggests.)

Upper Columbia River sturgeon were cut off from the lower basin population and anadromous food resources by construction of Rock Island (1933), Bonneville (1939), and Grand Coulee dams (1941). These dams were among the first large mainstem dams in an intensive building phase that continued into the 1970s (Figure 11). Mainstem dams fragmented sturgeon habitat into short riverine sections connected by long impoundments. White sturgeon in the Columbia and Snake rivers have been isolated into at least 30 separate reaches, functionally extirpated from 8 reaches, and are likely to become extirpated in another 8 reaches without intervention (Figure 4). Remaining subpopulations are primarily restricted to reaches with significant riverine habitat and subpopulations in marginal habitat areas have been lost or consist solely of a few remnant individuals.

In the Kootenay River, South Slovan Dam (1928) eliminated access to the base of Lower Bonnington Falls. Brilliant Dam (1944) restricted access to the lower 2.8 km of the river and cut off the Slovan River system. Upper Bonnington Dam (1907) and Corra Linn Dam (1932) further fragmented the lower Kootenay River habitat. Access into the Pend d'Oreille River was blocked by Waneta Dam (1954). Other Pend d'Oreille River dams including Box Canyon (1952), Albeni (1955), and Boundary (1967), also had significant effects on water clarity, seasonal temperature ranges, gas saturation levels, and the aquatic community composition experienced by downriver populations of white sturgeon.

The modern recruitment failure in the upper Columbia River white sturgeon population coincides with the construction since 1968 of three large Columbia River mainstem dams. HLK, Mica, and Revelstoke dams were built to provide hydropower generation and flood control following ratification of the Columbia River Treaty between the U. S. and Canada. The construction of the HLK Dam in 1968 isolated sturgeon populations in the former Arrow Lakes, cut off access by fish in the transboundary reach to spawning, rearing and feeding areas in the upper basin, and replaced a highly diverse and productive river-lake ecosystem with a homogenous, oligotrophic reservoir. Mica Dam, constructed in 1973, further fragmented the

river ecosystem above Arrow Lakes Reservoir, flooded over 250 km of the Columbia River mainstem that may have provided spawning and feeding habitats, reduced productivity by trapping nutrients, and increased water clarity by trapping sediments. Revelstoke Dam (1984) effectively eliminated the 130 km section of flowing river between Mica Dam and Arrow Lakes Reservoir and sealed the fate of sturgeon in this segment of the river by eliminating and cutting off access to the upper riverine habitat that may have served as a spawning area.

3.3 Flow Regulation

Increased storage in the upper basin and hydro system operation have generally eliminated floods, reduced spring flows, and increased late summer through winter discharges. Mica, HLK, and Duncan dams provide 15.5 million acre feet (MAF) of usable storage (7.0, 7.1, and 1.4 respectively). These storage reservoirs capture a large portion of the spring runoff for release to meet high power demands in fall and winter (Figure 12). Reservoirs are also drawn down and regulated for flood control from September through April. Unregulated spring runoff peaked during June and July in the upper Columbia River, and about one month earlier in the Kootenay and Pend d'Oreille basin. Spring peak flows at the international boundary often exceeded 4,500 cubic meters per second or cms (160,000 cubic feet per second or cfs) but currently average about 1,700 cms (60,000 cfs). Flood flows occurred in winter following rain on snow events or in spring as a result of snowmelt. The largest recorded flood occurred in June 1894 as the result of rapid melting of an above-normal snow pack and produced an estimated 19,250 cubic meters per second (680,000 cfs) at the international boundary. The lowest recorded historic flow at the boundary was 365 cms (12,900 cfs).

Flow regulation has likely contributed to poor spawning and early-rearing success of white sturgeon in the upper Columbia River. Recruitment of juvenile sturgeon has been widely correlated with spring flow volume (Beamesderfer and Farr 1997). White sturgeon depend on riverine habitats and seasonal floods to provide suitable spawning conditions. Seasonal flow patterns likely cue maturation, migration, and spawning. Adhesive eggs are broadcast over rocky substrates in turbulent high-velocity habitat that accompanies high flow. High flows help disperse eggs and juveniles, and exclude predators. In addition, high flows in unimpounded floodplain systems increase access to food resources in newly inundated areas, and decrease predator densities. Periodic floods also flush fine sediment from river bed cobble and prevent armoring that reduce suitability for egg incubation, larval and juvenile fish rearing, and invertebrate diversity. Flow effects can be complex because of interactions with temperature and turbidity.

Hydro system operation also results in daily flow fluctuations for power load but the effects of these peaking patterns on white sturgeon are unclear. Discharge is generally increased during weekdays and daytime to meet increased power demands. Spawning occurs downstream from Waneta dam despite extensive peaking operations although spawning is not producing significant numbers of juvenile sturgeon. Studies downstream of a lower Columbia River dam showed that these peaking operations can result in scouring of eggs and embryos from the riverbed (Counihan and Parsley 2001). However, successful spawning and recruitment of white sturgeon has been observed downstream of lower Columbia River dams operated for peaking. Studies on Russian sturgeon have identified adverse changes in behaviour and maturation following highly fluctuating discharges during winter that required sturgeon to maintain an increased level of activity. Similar effects have not been documented for white sturgeon, but

recent studies downstream from John Day Dam on the lower Columbia documented that white sturgeon position within the tailrace of the dam during the spawning period was not influenced by operations at the dam (M. Parsley, U.S. Geological Survey, personal communication).

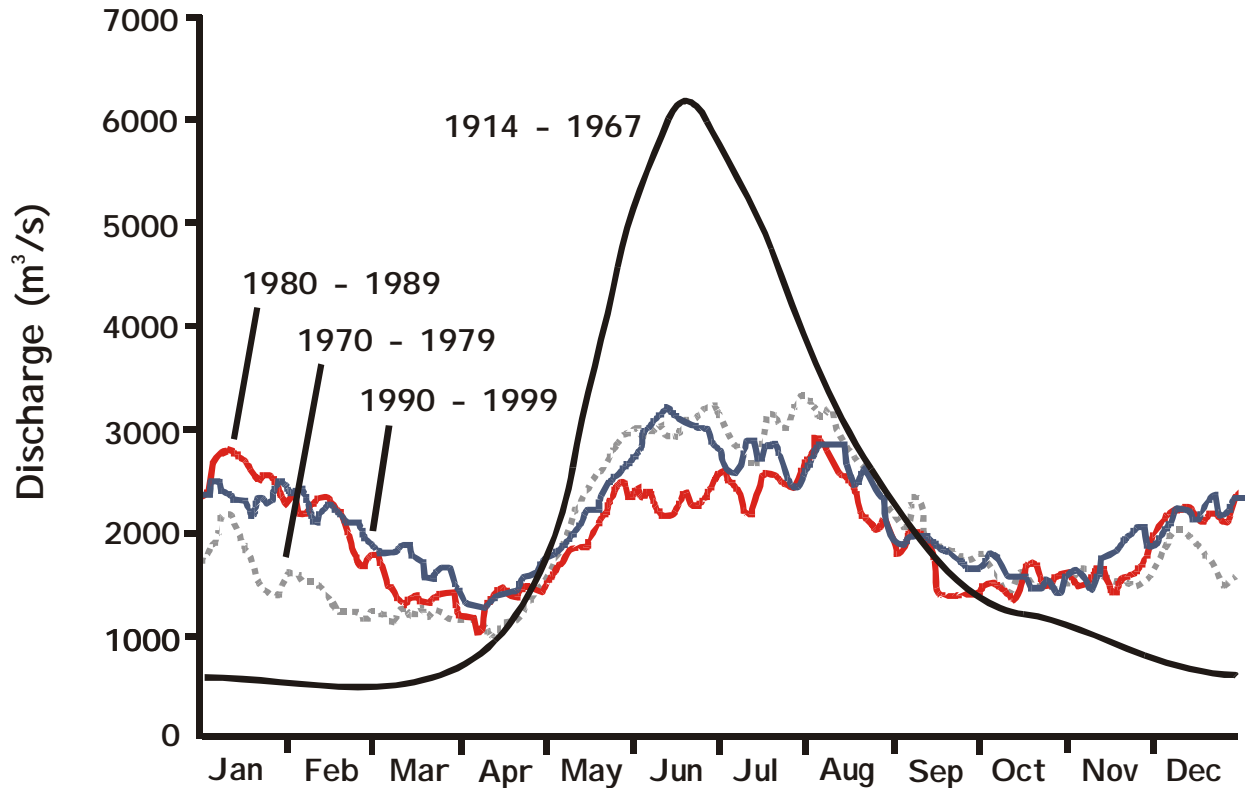


Figure 12. Mean daily discharge in the Columbia River at Birchbank during the pre-Keenleyside Dam period (1914-1967) and for three post-regulation periods, including 1970-1979, 1980-1989 and 1990-1998 (Water Survey of Canada data for stream gauging stations 08NE003 [Trail; for 1914-1937] and 08NE049 [Birchbank; for 1937-1998]).

3.4 Water Quality

Temperature: Significant temperature changes have accompanied construction and operation of dams and reservoirs. Upstream of Revelstoke, water temperatures are similar in summer but warmer in fall and winter as compared to the pre-impoundment period (Figure 13). Downstream of HLK, average fall and winter temperatures are similar but temperatures from May through September are 2-3°C warmer than occurred historically (Figure 13). Recent observations suggest that winter temperatures are warmer and cold winter periods are briefer (Ric Olmsted, personal communication) Pend d'Oreille River temperatures currently rise faster than in the Columbia River during the spawning season and get much warmer (e.g. 24°C in 1998). It is unclear if Pend d'Oreille temperature patterns are similar to historic conditions because pre-impoundment data are lacking. Lake Roosevelt provides a much wider range of temperatures and more complex thermal environment than historically occurred in the river it replaced.

Effects of changing temperature patterns on white sturgeon are poorly understood but are likely to be complex. Water temperature and seasonal patterns in water temperature affect sturgeon maturation, spawning, incubation, development, energy requirements, food production, growth rate, and survival rate. Changes in the timing of temperature-controlled processes could disrupt the synchrony between these and other processes affected by other environmental factors (McAdam 2001). Several sturgeon trapped in portions of the upper basin upstream of HLK Dam may no longer have access to temperatures suitable for spawning.

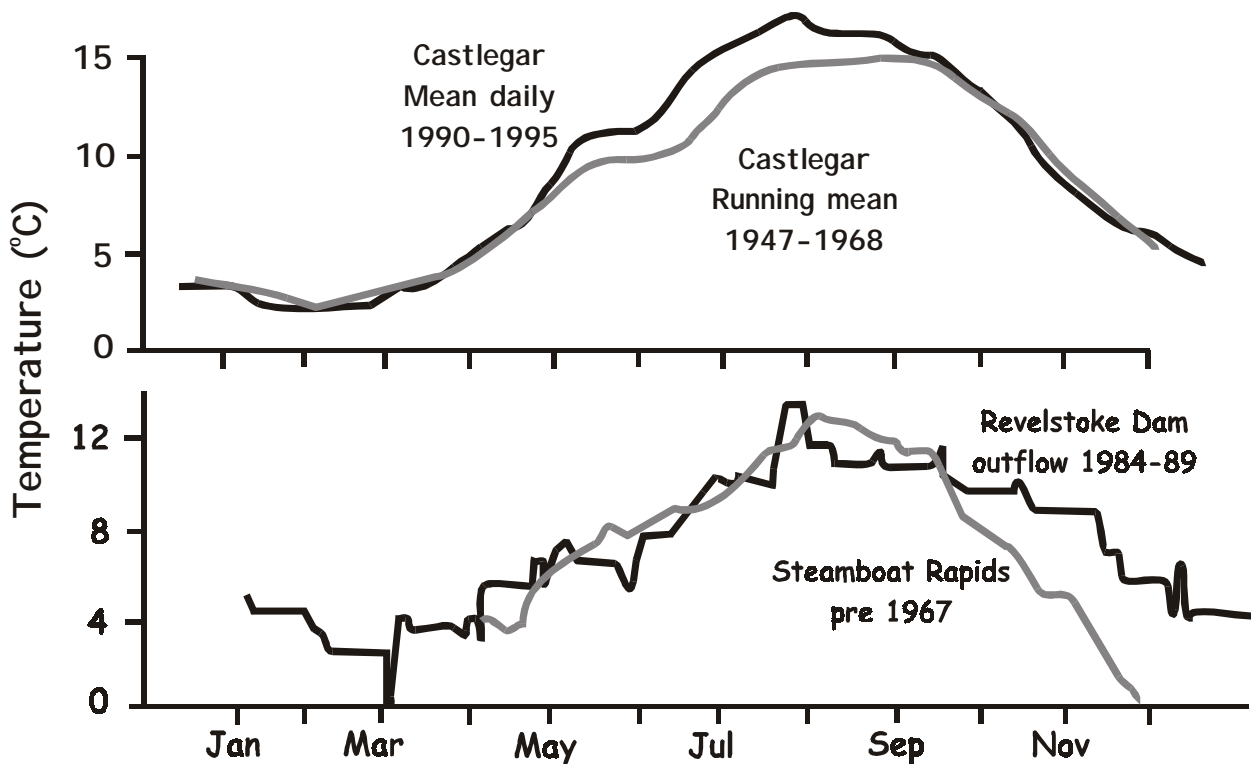


Figure 13. Changes in average Columbia River water temperature at Castlegar and Revelstoke (McAdam 2001).

Turbidity: The construction of upstream reservoirs has drastically reduced river turbidity. Turbidity was historically high because of runoff from glacial systems. However, upstream reservoirs act as settling basins and have reduced sediment transport downstream.

Changes in turbidity may have significant implications for sturgeon. For instance, predation on juvenile sturgeon has likely increased with water clarity, especially during the larval dispersal phase. Laboratory studies by Gadomski and Parsley (2001) documented higher predation rates by prickly sculpins (*Cottus asper*) on white sturgeon yolk-sac larvae (1-2 wk. old) at low turbidities (30 and 23 larvae per trial at 0 and 20 NTU) than at high turbidities (18 larvae per trial at 60 and 180 NTU). Lower turbidities combined with reduced flows decrease the effective search volume for predators hunting for larval sturgeon.

Turbidities associated with successful sturgeon spawning and recruitment were 6 to 92 NTU in the lower Fraser River (Perrin et al. 2000) and 2.2 to 11.5 NTU in the lower Columbia River (McCabe and Tracy, 1993.) Ktunaxa elders report (Bill Green, personal communication) that they historically observed sturgeon spawning in high turbidity (as opposed to high velocity) environments, including the Columbia River in the Spillimacheen area and in the Kootenay River near Bonners Ferry. Current turbidities generally are below 1 NTU year round near Birchbank, B.C. which is downstream from the Kootenay River confluence.

Total Dissolved Gases: Dam construction and operation has increased dissolved gas to supersaturation levels downstream from several facilities including Mica, Revelstoke, HLK, Waneta, and Brilliant. Supersaturation occurs when plunging water entrains air which is dissolved into the water at depth. Dissolved gas levels are referred to as total dissolved gas (TDG) in the U.S. and total gas pressure (TGP) in Canada.

During spring spills, TGP levels in the Columbia, Kootenay, and Pend d'Oreille rivers often exceed the B. C. guideline of 110%. Since 1977, the Columbia River below HLK was identified as having the highest TGP concentrations of the 35 major rivers or lakes examined in B.C. (Clark 1977). TGP in the mainstem below the dam can increase to levels that occasionally exceed 135% and often exceed 120%. TGP levels up to 144% saturation were measured below HLK on 17 August 1976. TGP levels in excess of 135% have been observed below Waneta Dam primarily during spill periods from May through June (RL&L unpubl. data). Levels exceeding 125% can occur downstream of Brilliant Dam on the Kootenay River.

Current dam operations include an extensive TGP monitoring program and measures to reduce excessive levels. For instance, operational modifications at HLK Dam since 1994 have substantially reduced TGP levels during certain periods of the year by increasing discharge through low level ports rather than the spillway. Planned expansions of power plants at HLK and Brilliant are projected to reduce TGP although elevated levels will still occur between June and September in some years (Holms and Pommen 1999; Aspen 2000).

The deleterious effects of high TGP levels on fish have been well documented (Weitkamp and Katz 1980; Fickiesen and Montgomery 1978; Ebel et al. 1975; Ash et al. 1981; Fidler 1988). High TGP levels cause gas bubble trauma (GBT) that involves the growth of gas bubbles internal or external to the animal. GBT occurs when fish exposed to high dissolved gas levels at depth move into shallower water where hydrostatic pressure is low and will not compensate for excess TGP.

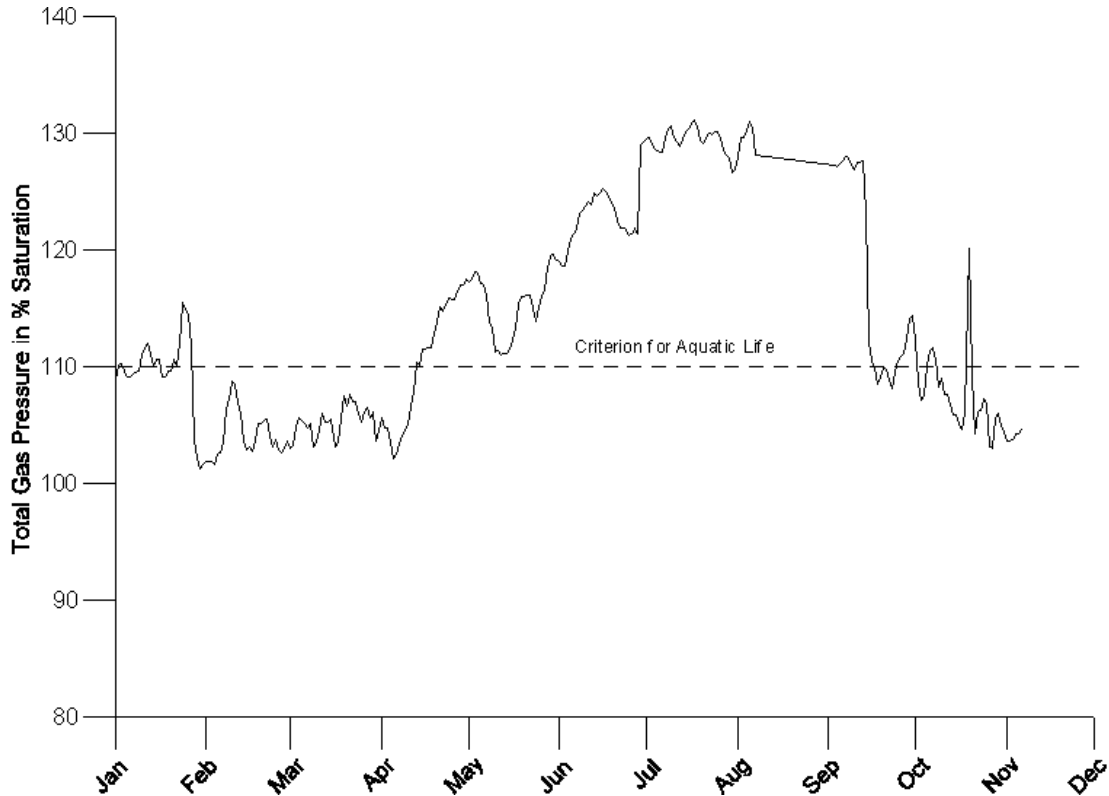


Figure 14. Example of recent TGP patterns in the upper Columbia River at Birchbank, B.C. for 1996 (Holms and Pommen 1999).

High TGP levels have been shown to produce mortalities and affect the behaviour of larval white sturgeon in the laboratory but the significance in the wild and implications for recruitment are unclear. The maximum recommended gas pressure for cultured (and presumably wild) white sturgeon is 110% (Conte et al. 1988). Counihan et al. (1998) documented GBT in larval sturgeon consisting of a gas bubble in the buccal cavity and/or nares. Larvae exposed to 118% TDG for 10 days did not exhibit mortalities but 50% mortality occurred at 131% TGP after 13 days of exposure. Even at apparently sublethal levels, GBT increased buoyancy and reduced the ability of larvae to control their depth which could reduce survival. Counihan et al (1998) reported that 1 to 2 day old white sturgeon displayed signs of GBT following a 15 min. exposure to 118% TGP.

Sturgeon are most likely to be affected by gas bubble trauma during the planktonic, post-hatch dispersal stage when larvae are suspended in the water column and drift at variable depths (Shrimpton et al. 1993). Effects may include direct mortality, altered dispersal patterns, and increased susceptibility to predation. TGP levels exceed thresholds for gas bubble trauma for significant periods of time through the sturgeon spawning, incubation, and dispersion period. Both Brilliant and Waneta dams typically spill during the June to July period when dispersal occurs and spill can also occur at HLK. White sturgeon larvae can be exposed to high TGP levels (up to 138%) in the Pend d'Oreille plume where it enters the Columbia River.

3.5 Contaminants

The Upper Columbia River has several known sources of contaminants including: Cominco Ltd.'s lead-zinc smelter at Trail, Celgar Pulp Co.'s pulp mill at Castlegar, municipal sewage treatment plants (primary and secondary treatment only), Stoney Creek landfill, abandoned mines, and storm water runoff (MacDonald Environmental Sciences Ltd. 1997). Historic and current industrial activity and residential development along the river have contributed metals and a myriad of organic compounds to water and/or sediments (Table 2). These compounds are potentially bioavailable to fish and other aquatic fauna.

When coupled with other habitat alterations, the introduction of contaminants into aquatic systems may increase stress and negatively impact physiologic functions. Contaminant effects can vary from acute (lethal; immediate) to chronic (sublethal; life-long effects). Although acute effects will have an immediate population effect, chronic effects may manifest themselves over time and throughout several generations, potentially altering an organism's behaviour, genetics, reproduction and general ability to function in a "normal" manner (Rand and Petrocelli 1985). Uptake of and effects from contaminants will vary depending on life stage and the type, duration, and nature of exposure (Heath 1995). Exposure can occur through contaminants in water, sediment, suspended sediments, and food (i.e. plankton, periphyton and other fish species) and through parental burden.

Longevity, late maturation, benthic habitats, and position at the top of the food chain could make white sturgeon highly susceptible to exposure and bioaccumulation of contaminants. However, there is little information on bioaccumulation and the physiological effects of environmental contaminants on white sturgeon.

Table 2. List of contaminants thought to be an issue in the Upper Columbia River

Metals
Lead, Zinc, Arsenic, Cadmium, Copper, Chromium, Mercury, Iron, Nickel, Cobalt, Selenium, Strontium, Silver Also others for which little is known (Antimony, Indium, Germanium, Bismuth, Vanadium, Thallium)
Organic compounds
PCBs (Aroclors, mono and di- ortho substituted, co-planar)
Organochlorine pesticides
Dioxins/Furans
Chlorophenols
Resin & Fatty Acids
Pharmaceuticals
Hormones
PAHs (polyaromatic hydrocarbons)
Other Hydrocarbons associated with storm water runoff and industrial spills
Inorganic compounds
Detergents, Chlorine, Ammonia
Potential Persistent Metabolites of the following (chemical spills at Cominco):
Sulphuric acid
Ammonium sulphate
Sodium carbonate
Slag (metals mixtures)
Acid solutions, dusts and other unidentified solutions
PBDE's (polybrominated diphenyl ether; fire retardant)

3.6 Nutrients

Nutrient inputs into the upper Columbia River system have been reduced by the combined effects of elimination of anadromous fish runs, reservoir construction upstream, and reduced effluent discharges. Prior to the construction of Grand Coulee Dam, anadromous fish runs were likely a significant source of marine derived nitrogen, phosphorus, and trace elements in addition to a food source. Upstream reservoirs act as nutrient sinks and reduce downstream transport from the upper basin. Historic effluent discharges from the Cominco fertilizer plant artificially increased nutrient levels in the upper Columbia River and Lake Roosevelt. Municipal and industrial sources have been substantially reduced by widespread construction of sewage treatment plants that provide primary and secondary treatment.

Reduced nutrient levels have substantially reduced the biological productivity of the upper Columbia River ecosystem. Lower productivity has likely reduced food availability for sturgeon and resulted in lower rates of growth, survival, condition, and maturation. These changes have likely reduced the carrying capacity of the system for sturgeon and reproductive potential of the population. Reduced productivity may also have contributed to poor juvenile survival and the lack of recruitment.

3.7 Habitat Diversity & Geomorphology

The riverine habitat structure has been substantially altered by impoundment, channel modification, flood control, and flow regulation. Substantial diversity was lost as a result of impoundment. Changes in river geomorphology as a result of flood control and flow regulation are more subtle but no less significant. Floods help maintain channel diversity by periodically scouring and rearranging materials to create pool and backwater habitats. Regulated flows result in a more uniform river channel and an armoured substrate.

These changes reduce aquatic habitat diversity, alter flow conditions at potential spawning and nursery areas, and alter substrates in incubation and rearing habitats necessary for survival (Partridge 1983; Apperson and Anders 1991). Complex habitats may provide important seasonal forage areas and refuges from high discharges. Side channels and low-lying marshlands provide extremely productive habitats which may be used directly by sturgeon or by important food sources.

3.8 Changes in Fish Species Composition

Substantial changes in the relative composition of fish species have accompanied introduction of exotic species and development in the upper Columbia River. The pre-development fish community included large numbers of anadromous fishes including spring and summer chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), coho salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss*), and Pacific lamprey (*Lampetra tridentata*). The resident fish community included bull trout (*Salvelinus confluentus*) and burbot (*Lota lota*). The primary changes have been the elimination of anadromous species and an increase in introduced species.

The current fish community of the mainstem Columbia River between HLK and Lake Roosevelt is dominated by mountain whitefish (*Prosopium williamsoni*), rainbow trout (*Oncorhynchus mykiss*), northern pikeminnow (*Ptychocheilus oregonensis*), and suckers

(Catostomidae). Whitefish are currently very abundant. Kokanee (*Oncorhynchus nerka*) are also common with most likely entrained from Arrow but a few also originating in Lake Roosevelt. Bull trout numbers are currently low in Columbia River between HLK Dam and Lake Roosevelt.

The current fish assemblage in Lake Roosevelt is a result of anthropogenic actions that have created an unbalanced, ever-shifting, perturbed hybrid lotic/lentic reservoir ecosystem. The community is dominated by introduced species including walleye (*Stizostedion vitreum*) and smallmouth bass (*Micropterus dolomieu*) as well as kokanee salmon. The majority of the salmonid assemblage consists of coastal rainbow trout, brook trout, and brown trout. Native salmonids including bull trout, westslope cutthroat trout, and redband trout are rarely encountered. In addition, mountain whitefish populations have been replaced by lake whitefish.

The Arrow Lakes fish community is currently dominated by kokanee and mountain whitefish. An Arrow Lakes stock of large adfluvial rainbow trout has drastically declined since the completion of Mica and Revelstoke dams. Revelstoke Reservoir fish species include kokanee, rainbow trout, bull trout, mountain whitefish, burbot, longnose sucker, largescale sucker, redband shiner, peamouth, northern pikeminnow, and prickly sculpin. Since impoundment there has been a trend towards increased abundance of kokanee and bull trout, with a corresponding decline in the abundance of mountain whitefish and rainbow trout. Longnose sucker and peamouth numbers increased dramatically from 1985 to 1995. Significant fish species in Kinbasket Reservoir include kokanee, rainbow trout, bull trout, and mountain whitefish. Kokanee were not present prior to impoundment but were stocked to take advantage of the extensive pelagic habitats in the reservoir.

Impacts on sturgeon of changes in the resident fish community are poorly understood but predator and prey species are likely affected. Adult sturgeon are not known to have any predators in fresh water except man. However, other species such as rainbow trout, northern pikeminnow, suckers, and walleye may prey on white sturgeon eggs, larvae, and small juveniles. Abundance of large rainbow trout is very high in the transboundary reach. Northern pikeminnow are a piscivorous cyprinid that consumes fish eggs and a variety of larval and juvenile fish species. Sucker spp. are bottom feeders and are known to consume sturgeon eggs where not excluded by high velocities. Walleye are a highly effective predator on fish and have become very abundant in Lake Roosevelt following illegal introduction. Large numbers of walleye migrate into upper Lake Roosevelt and river upstream from June to August when larval white sturgeon are dispersing downstream and also leaving the substrate to begin feeding.

4.0 EXISTING CONSERVATION MEASURES

4.1 *Inventory & Research*

Relatively little was known about upper Columbia River white sturgeon until the last 10 years. Studies on Columbia white sturgeon in Canada were initiated in 1990 as part of a five-year B. C. Hydro inventory of fish composition, distribution, abundance, habitat use, and movements in the Columbia River below HLK (Hildebrand and English 1991). Based on initial findings of a skewed white sturgeon size and age-class composition, intensive annual studies commenced in 1992 on spawning, sex ratio, maturation, population size, and critical habitats (RL&L 1994a, 1995, 1996a). In 1995 B. C. Environment began coordinating studies on white sturgeon distribution and status throughout the Canadian portion of the Columbia River Basin to: 1) confirm the existence and determine population status of remnant populations of white sturgeon in Kinbasket, Revelstoke, Duncan, and Arrow reservoirs, as well as Slocan and Kootenay lakes; 2) monitor the status of the known population in the Columbia River below HLK; 3) monitor spawning frequency and success at the Waneta spawning site; and 4) radio or sonic tag pre-spawning females to determine locations of other possible spawning areas.

A variety of inventory and directed fish studies have been conducted in the U.S. from Lake Roosevelt to the U.S. border but most of this work has been concentrated in Lake Roosevelt on species other than sturgeon. Lake Roosevelt fisheries and limnology was inventoried by the U.S. Fish and Wildlife Service from 1980 to 1985 (Beckman et al. 1985). The Spokane Tribe has conducted an intensive research program on Lake Roosevelt since 1990 (Underwood 2000). Small, directed sturgeon studies have been conducted on four occasions. Sturgeon were collected from Lake Roosevelt for genetic analysis during the early 1980s (Brannon et al. 1985). A sonic telemetry study was conducted from 1988-1990 to track sturgeon movements (Brannon and Setter 1992). During 1998, 204 sturgeon ranging in size from 33 to 270 cm FL were captured from Lake Roosevelt to the U.S. border by the Washington Department of Fish and Wildlife and the U.S. Geological Survey using setlines, gillnets, and bottom trawls (Kappenman et. al. 2000). Finally, a gillnet survey for juvenile sturgeon in that same area was conducted by the Spokane Tribe in 2001.

4.2 *Listings*

The federal committee on the Status of Endangered Wildlife in Canada (COSEWIC) first listed white sturgeon as Vulnerable in April 1990. In November 1991, the British Columbia Conservation Data Centre designated white sturgeon in the province as BLUE listed (S3 Ranking) (Cannings 1993). This designation identifies a species that is rare, uncommon or susceptible to large-scale disturbances (e.g., may have lost extensive peripheral populations). In December 1994, this ranking was upgraded to RED listed (threatened or endangered). At that time, white sturgeon were separated into four populations for monitoring purposes. These were the Fraser, Nechako, Kootenay, and Columbia populations. The Fraser River population was classed as S2 (imperiled). The Nechako, Kootenay, and Columbia stocks were classed as S1 (critically imperiled). At the time this plan was prepared, the Canadian federal government was considering legislation designed to protect and recover wildlife at risk of extinction in Canada. The proposed Species at Risk Act (SARA) would provide for the protection and recovery of designated species and their habitats. The listing of species under SARA would be based on status assessments and designations by COSEWIC.

In the United States, the U.S. Fish and Wildlife Service listed the Kootenay River population of white sturgeon as Endangered on September 6, 1994 (59 FR 45989) under the authority of the Endangered Species Act of 1973, as amended. Other upper Columbia River white sturgeon populations are not formally listed in the U.S. by Washington state or the Federal government.

4.3 CITES

A Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) provides umbrella protection against illegal or unsustainable international trade. In 1998, parties to CITES including Canada and the U.S. placed all of the world's previously unlisted sturgeon and paddlefish species in Appendix II in response to increasing demands of the international caviar trade and collapse of Caspian sea sturgeon fisheries. Commercial trade in Appendix II species across international borders is subject to regulation and allowed only if permits are obtained stating that trade is non-detrimental to the species' survival in the wild and that the species to be exported was legally acquired. A review process can result in country or species-specific recommendations for measures to maintain the species in its native range (TRAFFIC International, 2001). Implementation of CITES falls under the responsibility of the U.S. Fish and Wildlife Service and the Canadian Wildlife Service's CITES Office. Fish transplants within British Columbia are coordinated by a Federal-Provincial Introductions and Transfers Committee that acts as an advisory body to decision makers in both levels of government. Fish Transplants in Washington are regulated by the Washington Department of Fish and Wildlife.

CITES primarily affects the upper Columbia River white sturgeon recovery effort by requiring appropriate permits for moving white sturgeon across the border. For instance, CITES paperwork has been required to move Kootenay hatchery sturgeon to the Kootenay trout hatchery. This constraint requires significant lead time in planning any inter-boundary transplants.

4.4 Fishery Regulation

The recreational sturgeon fishery in the Canadian portion of the upper Columbia River basin has been severely limited since 1960 and closed completely in 1996 (Table 3). Limited take was permitted until 1993. In 1994, commercial and sport harvesting of sturgeon became illegal in British Columbia, and many First Nations people voluntarily stopped their sustenance harvests. Catch and release fishing was permitted at this time. The Columbia River from HLK to the Canada-U.S. border was closed to all sturgeon fishing including catch and release after 1 April 1996. The closure included the Kootenay River downstream of Brilliant Dam and the Pend d'Oreille River downstream of Waneta Dam.

Table 3. White sturgeon angling regulations in B.C. for the Columbia River from HLK downstream to the Canada-U.S. border.

Period	Regulation
1960s to 31 March 1978	yearly quota of one, by permit only (no size restriction)
1 April 1978 to 31 March 1992	yearly quota of one, by permit only (none under 100 cm TL)
1 April 1992 to 31 March 1993	yearly quota of one, by permit only (none under 100 cm or over 150 cm TL)
1 April 1993 to 31 March 1996	catch-and-release only
1 April 1996 to present	catch-and-release fishery closed; complete angling ban

In the portion of the Columbia River in Washington (U.S. border to Grand Coulee Dam), recreational angling and harvest regulations prior to 1995 allowed the harvest of one sturgeon per day within a slot limit of 1.22 m (48 in.) to 1.68 m (66 in) total length, to an annual limit of 10 fish. Sturgeon retention was prohibited beginning in 1995 but catch and release fishing was allowed. Catch and release fishing in the Washington portion of the upper Columbia River was prohibited in 2002 by the Washington Fish and Wildlife Commission.

4.5 Water Management

Investigations are underway on the effects of Pend d'Oreille River flow management on sturgeon spawning in the Columbia River downstream from Waneta Dam. The program provides for minimum flow releases during the June to July spawning period of 10,000 cfs during the day and 5,000 cfs during the night. The day-time minimum is expected to provide the mean column velocity of 0.8 m/s or greater believed necessary to stimulate spawning. The night-time minimum is expected to achieve target mean column velocities of 0.4 m/s or greater expected to reduce predation on deposited eggs. The program should provide a more stable spawning and incubation regime, particularly during low water years and promote earlier spawning that would reduce the incidence of spawning and egg incubation at temperatures above the optimal development range. Cominco Ltd. committed funds for a minimum five-year monitoring study beginning in 1996 as a condition of approval for their upgrade project at Waneta Dam.

Similar flow augmentation efforts have been attempted in the Kootenay River system but their failure to date to increase wild recruitment demonstrates the multivariate nature of controlling factors. Flows from Libby Dam have been increased during the spawning period from 1991 through 1997. Augmented flows were greater than would otherwise have been expected to occur but were less than historic levels. Results of flow augmentation have been consistently limited. Few to many eggs are obtained each year but with few viable larvae (USFWS 1999).

Water management recommendations of the present recovery plan will be an important consideration of the Water Use Planning (WUP) process in the Canadian portion of the Columbia Basin. This program was developed by the B. C. provincial government to evaluate and refine the operations of water use projects throughout the province. At the direction of the provincial government, B. C. Hydro has undertaken WUP processes for all of its facilities, including those in the Columbia Basin. Given that WUP processes are a means of examining and modifying system operations to address various interests in the watershed, including fisheries, the Columbia WUP process represents an important mechanism for consideration and

implementation of Upper Columbia white sturgeon recovery measures related to water management.

4.6 Water Quality Protection & Restoration

A ruling against the U.S. Environmental Protection Agency in 1994 prompted a process for dealing with total maximum daily loads (TMDLs) in imperiled (303(d) listed) water bodies throughout Oregon, Washington, and Idaho. A TMDL is a written, quantitative assessment of water-quality problems and contributing pollutant sources (EPA 2002). It specifies the amount of a pollutant or other stressor that needs to be reduced to meet water-quality standards, allocates pollution-control responsibilities among sources in a watershed, and provides a basis for taking actions needed to restore an imperiled water body. TMDL's address point, non-point and naturally occurring sources and are developed to provide an analytical basis for planning and implementing pollution controls, land management practices, and restoration projects needed to protect water quality.

The States of Idaho, Oregon, and Washington, and the U. S. Environmental Protection Agency (EPA) are working in coordination with the Columbia Basin Tribes to develop Total Maximum Daily Loads (TMDL) for temperature and Total Dissolved Gas (TDG) on the Columbia River (EPA 2002). States must develop TMDLs that will achieve water quality standards, allowing for seasonal variations and an appropriate margin of safety. Completion of a TMDL typically takes three to five years and each of the states and territorial water quality agencies are responsible for implementing the TMDL process. In Washington State, the Department of Ecology has been charged with TMDL development.

4.7 Pollution Control

There are several sources of contaminants to the Upper Columbia River watershed in British Columbia and the United States, including Cominco Ltd. at Trail, B.C., Celgar Pulp Company at Castlegar, B.C., municipal sewage treatment plants, abandoned mines, and tailing dumps. Many of these sources have made substantial effort to establish cleaner operating procedures within the last 25 years; however, a great deal of contaminant input occurred prior to these upgrades and potential effects to sturgeon are unknown.

Cominco has been operating since 1906 (MacDonald Environmental Sciences Ltd. 1997). However, over the past 25 years, the industry has initiated a long-term program to modernize and expand its operations at the Trail plant. Some of the major improvements include an effluent treatment plant, zinc electrolyte stripper, mercury removal plant, drainage control system, heat exchanger, elimination of phosphate-based fertilizer plant, and a slag containment facility. These modernization projects have significantly reduced loading of metals to the Columbia River. Accidental discharges currently comprise the majority of contaminant inputs. Between January 1987 and January 1993, there were a total of 56 spills from Cominco Ltd., into the Upper Columbia River. These spills released multiple tons of compounds containing sulphuric and phosphoric acid, zinc (various forms), gypsum, mercury, copper sulphate, ammonia, coal dust, furnace and compressor oils, sodium bisulphite, phosphate, ammonium sulphate, arsenic, cadmium oxide, chlorine, lead, slag, oxide dust, and various undetermined solutions.

Celgar Pulp Company facility is permitted to release up to 135,000 m³ of treated effluent and cooling water per day (MacDonald Environmental Sciences Ltd. 1997). The effluent is

discharged into the river in the reach between the HLK Dam and the community of Castlegar. The characteristics of the industrial effluent have changed dramatically since the plant expansion and upgrade which included a new wastewater treatment system. Loadings of biological oxygen demand and total chlorinated organics have decreased by 93% and 88% respectively between 1989 and 1994. Total suspended solids were reduced by 37% after 1993 and solid composition shifted from fiber and lime in nature to a low-impact bacteria composition (B. Duncan, personal communication.) Technological improvements at the mill have also resulted in decreased loading of phosphorus, nitrogen, chlorophenols, resin acids, and phenolics.

There are two major municipal discharges to the Columbia River between HLK and the US border. The City of Castlegar (population 7,002) discharges secondary treated sewage to the Columbia River at Castlegar. The cities of Trail, Warfield and Rossland as well as the communities of Rivervale and Oasis (total population 13,600) collect and discharge their primary treated sewage by outfall into the river near Trail. Primary treatment facilities physically remove wastes that may be screened, float to the top or settle to the bottom. Secondary treatment facilities remove remaining organic particles through bacterial action in aeration basins. Neither treatment removes all polluting chemicals such as metals and organic compounds that may interfere with endocrine function (Raloff 1998). Little information pertaining to organic and metal content of effluents is available for these sewage treatment plants or from other non-point sources of drainage, runoff, or septic tank seepage. Therefore, little has been done to abate contaminant input from these sources. However, efforts are now being focused on both sides of the border to address these issues using a “watershed approach” to environmental protection.

There are numerous abandoned mines and inactive mining districts throughout the Upper Columbia River watershed (Raforth et al. 2000). Inactive and abandoned mines, waste rock dumps, and tailings can be a source of contaminated water, including acid rock drainage, that has the potential to severely impact nearby streams. Almost no data are available to evaluate the extent of the problem; however, the British Columbia government, U.S. EPA and the Washington Department of Ecology are beginning to address some of these issues through investigations and studies, some of which are being conducted under existing legislative mandates.

During the past 10 years, several studies have been conducted to assess impacts of existing levels of contaminants on fish in Lake Roosevelt and the Upper Columbia River (Bortleson et. al. 1994; CRIEMP 1994; Munn et. al 1995; Raforth et. al 2000; Sedar et al. 1997; Era and Serdar 2001; G3 Consulting Ltd. 2001; EPA 2002). During 1991-1993, a Columbia River Integrated Environmental Monitoring Program (CRIEMP) was initiated to define the status of the aquatic environment between HLK and the International Boundary. This survey incorporated water, sediment, and biological indicator parameters to identify influences of chemical constituents. The CRIEMP survey also set the stage for development of water, sediment, and tissue standards and monitoring objectives for the Upper Columbia River in Canada (MacDonald Environmental Sciences Ltd. 1997).

Although TMDLs primarily focus on parameters such as dissolved gas, suspended solids, pH and temperature, the Upper Lake Roosevelt watershed has also been slated for assessment of PCBs, arsenic, dioxins and sediment bioassays. These assessments will be used to establish and/or revise tissue and sediment guidelines as well as establish current distribution and effects on the aquatic environment.

4.8 Reservoir Fertilization

Fertilization projects undertaken in Kootenay Lake and Arrow Reservoir may benefit sturgeon as well as other members of the aquatic community. Fertilization of Kootenay Lake was initiated in 1992 as a mitigation technique to restore the nutrient balance and assist in the recovery of salmonid populations which had suffered from a lack of forage. Phytoplankton populations at sampling stations closest to the fertilization zone responded positively (up to 4 times mean biomass) to fertilizer loading. Zooplankton and mysid populations increased in abundance and biomass with high fertilization loading (1992-1996). Kokanee populations increased in both escapement and in-lake abundance to levels previously observed in the late 1970's. In years when fertilizer loading was reduced (1997-2000), phytoplankton, zooplankton and kokanee populations began to decline. Total kokanee escapement to Meadow Creek has increased from a mean of 678,844 (1969-1991) to a mean of 787,920 (1992-2001). Mean female kokanee spawner length at Meadow Creek has also increased from a mean of 21.6 cm (1969-1991) to mean of 23.1 cm (1992-2001). Monitoring has shown that phytoplankton and kokanee abundances appear to track the fertilizer loading fairly closely (i.e., decreased fertilizer loads causes reduced phytoplankton and kokanee abundances).

A fertilization operation was initiated on the Arrow Lakes Reservoir in 1999 in response to dramatic declines in kokanee escapement, spawner size, and low in-lake abundance. After only three years of fertilization, phytoplankton, zooplankton, and mysid densities have increased from pre-fertilization levels. Initial changes in kokanee populations have been similar to changes observed in Kootenay Lake with improvements to in-lake abundance, escapement, spawner size, and fecundity. Spawner size increased in the first year of fertilization, but has declined with increased fish abundance in Year 3. In Year 2 of fertilization, kokanee in-lake abundance was considerably higher (11.6 million) than the long-term average of 3.2 million (1988-1998). In Year 3 of fertilization, in-lake kokanee abundance showed a further increase. Escapement increased in fertilization years from 101,000 kokanee in 1999 to 137,000 in 2000 and 142,000 in 2001, compared with the years preceding fertilization (mean of 76,000 kokanee in 1994-1998).

4.9 Kootenay River Sturgeon Recovery Program

A formal recovery plan adopted for Kootenay River white sturgeon in 1999 provides a blueprint for many of the measures included in this plan for the upper Columbia River. Recovery of the Kootenay River white sturgeon was deemed contingent upon re-establishing natural recruitment, minimizing additional loss of genetic variability to the population, and successfully mitigating biological and physical habitat changes caused by the construction and operation of Libby Dam. Conservation or enhancement measures being investigated or implemented by the USFWS for the recovery of this population include:

- 1) experimental flow manipulations of the Kootenay River to stimulate spawning and enhance spawning success;
- 2) operation and maintenance of an experimental white sturgeon hatchery by the Kootenay Tribe of Idaho at Bonners Ferry, Idaho;
- 3) fertilization of Kootenay Lake to increase biological productivity and thereby increase the potential prey base for white sturgeon;
- 4) development of a computer model to assess the effects of Libby Dam operations and develop Integrated Rule Curves (IRC's) to balance competing water demands

- 5) continued research and monitoring to identify environmental factors limiting the population and to recommend appropriate conservation and management actions.

The Kootenay sturgeon hatchery is designed to help preserve wild genetic variability, help rebuild the natural age-class structure, and prevent extinction until natural recruitment can be restored. Experimental releases of hatchery-reared offspring (age 1-4) and subsequent recaptures have provided valuable information on movements, habitat use, survival, and growth of juveniles. The Kootenay Trout Hatchery operated by the British Columbia Ministry of Water, Land, and Air Protection at Fort Steele provides a failsafe rearing facility for Kootenay River sturgeon spawned at the Kootenay River sturgeon hatchery. Juvenile sturgeon are reared at the Kootenay Trout Hatchery to ensure brood year production is not lost if problems arise at the Bonners Ferry facility. Failsafe fish are released in Kootenay Lake to experimentally determine lake suitability and capacity for sturgeon, released in the Canadian portion of the Kootenay River to seed available habitat, or sacrificed where in excess of recovery or research needs.

4.10 Upper Columbia River Sturgeon Conservation Hatchery Program

A pilot hatchery for Columbia white sturgeon has been developed by modifying an existing provincial trout hatchery (Hill-Mackenzie Creek Hatchery) located at Galena Bay, north of Nakusp, British Columbia. Broodstock collection and spawning began in 2001 and juveniles were released in 2002. The hatchery provides holding facilities for up to 12 adult sturgeon, incubation capacity for 4-6 families of sturgeon, and rearing capacity to produce 1,000-2,000 fish per family. Sturgeon are reared in quarantine/isolation - no other fish are reared at the site. Water sources are ground water and creek water. Heated water is available for adult holding, incubation and rearing facilities. Hatchery equipment includes an adult transport tank and trailer to move fish from capture location to the holding facilities. The hatchery also includes an adult spawning facility.

Total cost of hatchery modifications for sturgeon was approximately CAD \$600,000 and all funds were provided by B. C. Hydro. Capital work completed at the hatchery included:

- 1) Assessment of existing buildings and process systems including: mechanical, electrical, water systems and controls.
- 2) Structural, mechanical and electrical alterations to the existing generator and aeration building to incorporate: new propane water heating system; new aeration columns; new head tanks; distribution piping; electrical service and controls.
- 3) Structural, mechanical and electrical alterations to existing hatchery building including: construction of an "isolation wall" between adult holding and incubation/fry rearing areas; construction of a spawning room; removal of existing raceways; installation of circular ponds; removal and replacement of water supply system; relocation of process water drains.
- 4) Construction of effluent water infiltration pond.
- 5) Acquisition of various fish culture equipment required for the culture of sturgeon at the site including transport and rearing equipment.

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 span 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'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.

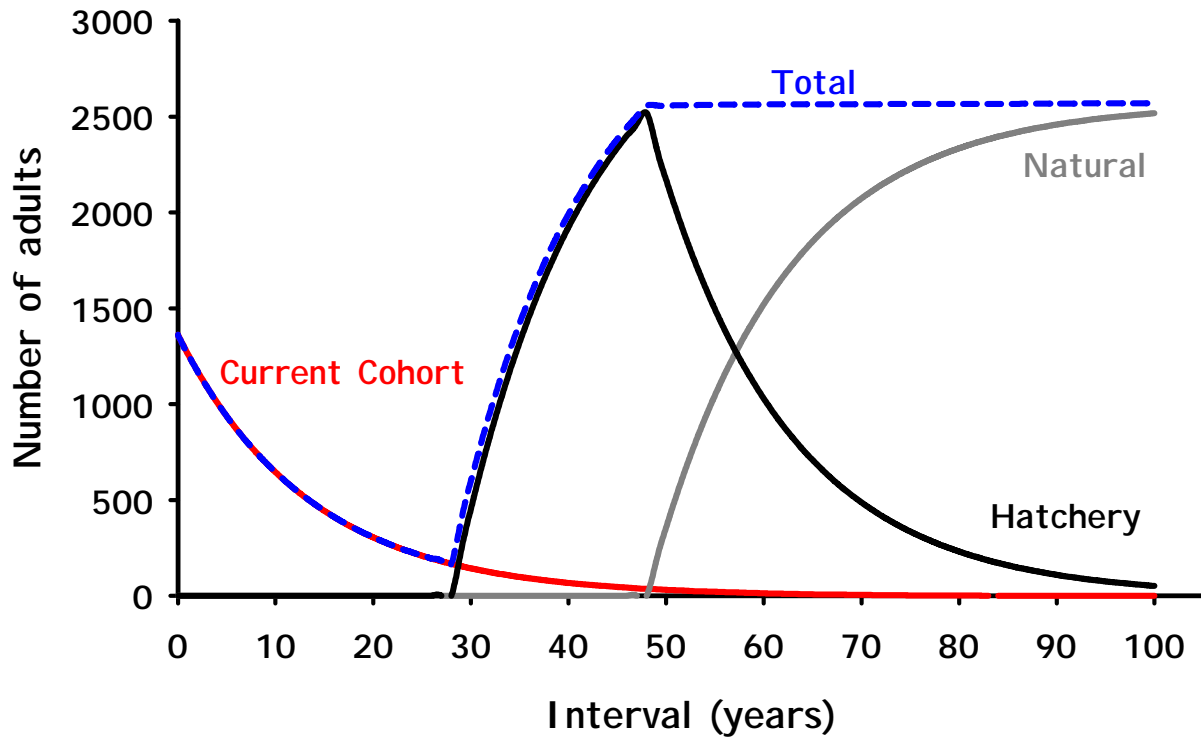


Figure 15. Hypothetical future wild and hatchery sturgeon numbers in the transboundary recovery area.

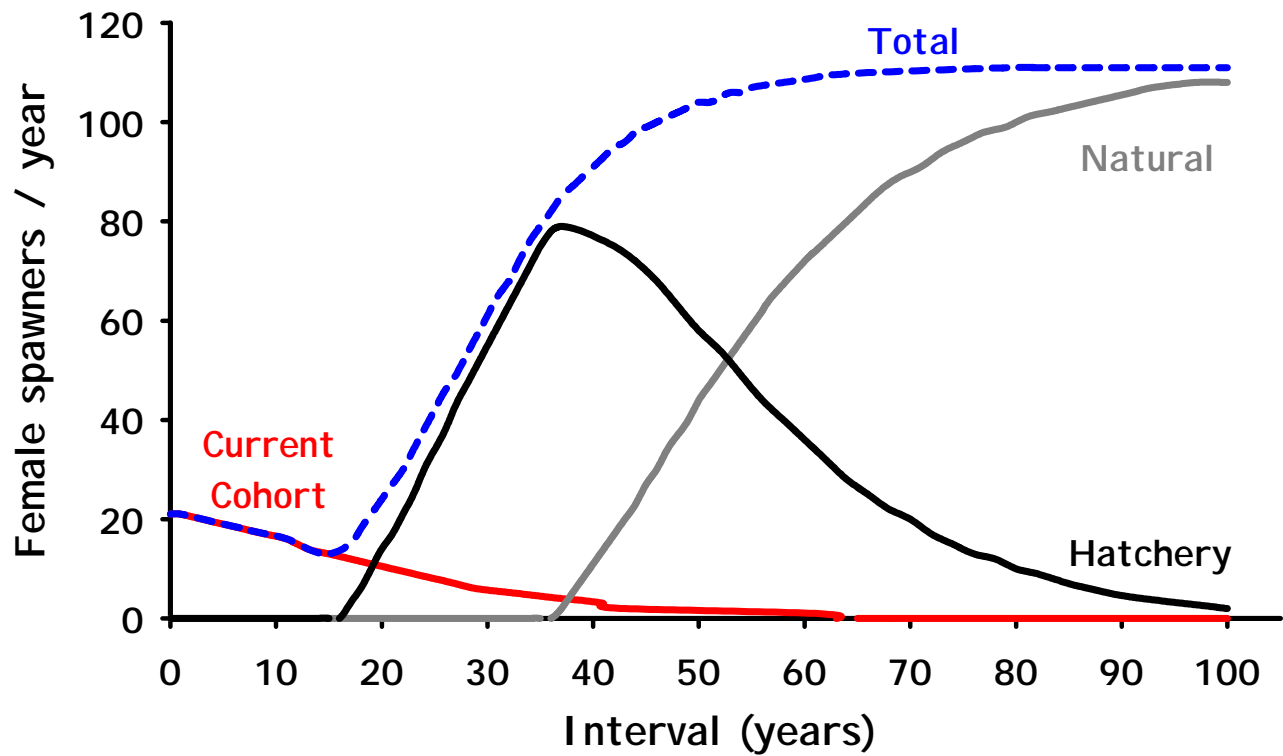


Figure 16. Future reproduction potential of sturgeon based on implementation of hatchery-based sturgeon recovery measures and restoration of natural production.

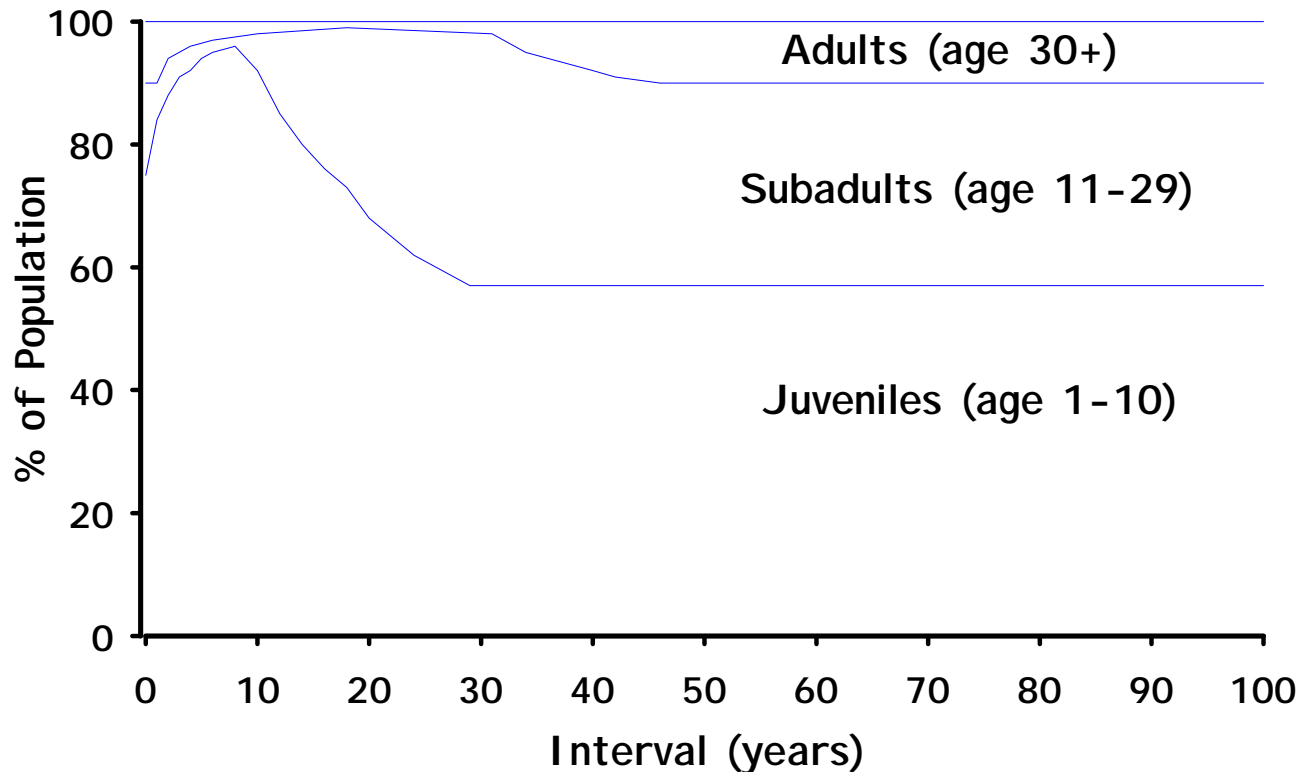


Figure 17. Hypothetical changes in sturgeon age composition following implementation of hatchery-based sturgeon recovery measures and restoration of natural production.

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) Establish 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 and 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:

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

Schedule: Short- Long term

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

Measure	Schedule		
	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. Propagation	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
(2) Habitat Restoration			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

6.0 IMPLEMENTATION SCHEDULE

The following schedule describes a list of activities for implementation consistent with the goals and objectives of this plan. Actual implementation schedules will be contingent upon the resources available for plan implementation. Evolving knowledge, economic, social, and legal considerations will guide decisions on proceeding with any of the various elements in the implementation schedule. More specific description of an implementation schedule will be included in the Implementation Action Plan identified in measure 5.5.10(2) of this recovery plan.

6.1.1 Short Term (within 5 years)

Objective: Assess population status and act to prevent further reductions in white sturgeon distribution, numbers, and genetic diversity within the current geographic range.

1. *Evaluate and eliminate where feasible direct anthropogenic sources of adult mortality.*
 - 1a. Eliminate non-research and non-conservation culture capture throughout geographic range. [5.5.1(1), 5.5.1(2)]
 - 1b. Identify and reduce sources of direct dam and other industrial related mortality. [5.5.2(1), 5.5.2(2)]
2. *Increase early life stage survival through improved water and habitat management*
 - 2a. Initiate adaptive water storage/release management plan within recovery areas. [5.5.4(1), 5.5.4(2), 5.5.4(3), 5.5.4(4), 5.5.4(5)]
 - 2b. Initiate water quality improvement plan within recovery areas (temperature, turbidity, and TGP). [5.5.5(1), 5.5.5(2), 5.5.5(3), 5.5.7(6)]
 - 2c. Initiate habitat restoration plan and undertake select habitat improvements (minimum of 1 project/recovery area). [5.5.7(2), 5.5.8(10), 5.5.8 (6)]
 - 2d. Initiate studies to clarify the sources and level of predation mortality. [5.5.8(10)]
 - 2e. Identify sources and impacts of predation mortality. [5.5.8(10), 5.5.7(5)]
 - 2f. Initiate investigations of contaminant effects on sturgeon. [5.5.6(1), 5.5.6(2), 5.5.6(3)]
3. *Develop/implement pilot fish cultural facility(ies) to maintain adult population abundance and genetic diversity.*
 - 3a. Culture and release sufficient hatchery reproduced juveniles/families to meet minimum conservation target (i.e., maintain existing population size) within each recovery area. [5.5.3(1), 5.5.3(3)]
 - 3b. Provide adequate numbers of cultured juvenile sturgeon to support research plans. [5.5.3(2)]
 - 3c. Investigate feasibility of experimental culture/fail safe hatchery facility for US portion of the transboundary recovery area. [5.5.3(7), 5.5.3(9)]
4. *Track population status and survival rate within geographic area.*

- 4a. Identify methods and establish population monitoring program to track short term targets 1-3 within recovery areas. [5.5.3(6), 5.5.3(5), 5.5.8(7)]

6.1.2 Medium Term (within 10 years)

Objective: Determine survival limitations (bottlenecks) for remaining supportable populations and establish feasible response measures to reduce or eliminate limitations.

1. Undertake research designed to define survival limitations

- 1a. Provide for peer review of research plans. [5.5.10(1)]
- 1b. Research plan completed and recruitment limitations identified for each recovery areas. [5.5.10(1), 5.5.8(9)]
- 1c. Minimize significant sources of direct dam and other industrial related mortality. [5.5.6(7), 5.5.6(9)]

2. Increase survival through improved water, habitat, and fisheries management

- 2a. Complete preliminary adaptive water management experiments within recovery areas. [5.5.4(3), 5.5.4 (1)]
- 2b. Complete feasible water quality improvements within recovery areas. [5.5.5(1), 5.5.5(2), 5.5.5(3)]
- 2c. Complete feasible habitat improvements for each recovery area. [5.5.7(2)]
- 2d. If predation is identified as a potential bottleneck, implement measures to reduce predation, which could include habitat improvements. [5.5.8(7)]
- 2e. Employ political and regulatory means to reduce or eliminate new exotic species introductions, and implement fisheries management measures to minimize impacts of predatory game fish on white sturgeon.

3. Evaluate the feasibility of a conservation culture & release program to address recruitment failure.

- 3a. Complete full scale conservation culture plan for recovery areas including locations (assess land acquisition and water suitability), permitting, breeding/genetic plan, supplementation strategy etc. [5.5.3(1), 5.5.3(6), 5.5.3(9)]
- 3b. Maintain pilot conservation culture operations to meet conservation targets (increase population to minimum sustainable levels while maintaining genetic diversity) within recovery areas. [5.5.3(4), 5.5.3(7), 5.5.3(8), 5.5.8(8)]

4. Track habitat conditions and population status within geographic range.

- 4a. Maintain monitoring program to track habitat conditions and population structure within recovery areas. [5.5.6(5), 5.5.7(1), 5.5.8(1), 5.5.8(3), 5.5.8(4), 5.5.8(9), 5.5.8(2)]
- 4b. Monitor indices (juvenile abundance) which demonstrate significant probability of population persistence throughout geographic range. [5.5.8(4), 5.5.8(5)]

6.1.3 Long Term (within 50 years)

Objective: Re-establish natural population abundance levels, age structure, and beneficial uses through self-sustaining recruitment in two or more recovery areas.

- 1. *Maintain adequate survival through optimal water and habitat management programs***
 - 1a. Provide and monitor results of 10 years of implementation of best-case water management regime. [5.5.4(3), 5.5.4(4)]
- 2. *Establish stable population structure for more than one recovery area.***
 - 2a. Ensure juvenile abundance adequate to support an adult population of 2,500/recovery area. (i.e., 5,000 - 7,500 adults/geographic range assuming 2 or more recovery areas). [5.5.3(1)]
 - 2b. Provide an average rate of recruitment that exceeds that required for population replacement. [5.5.3(1)]
 - 2c. Ensure adequate sexually mature adults are present to meet conservation targets within recovery areas. [5.5.3(10)]
 - 2d. Develop management plans for limited harvesting when adult population size, population growth rates, and age structure indicate that population recovery objectives will be achieved. [5.5.1(3)]
- 3. *Complete establishment of broad fail-safe population measures:***
 - 3a. Assess feasibility and acceptability of expanding the geographic range and presence of supportable recovery area populations to provide further fail-safe population measures. [5.5.3(3)]
 - 3b. Implement fail-safe population(s) program (assume 1 fail-safe population in Canada and 1 in the USA). [5.5.3(3)]
- 4. *Maintain and/or expand conservation culture and release program, as required.***
 - 4a. Necessary culture facility(ies) constructed and operational to meet conservation targets within recovery areas (until such time as natural recruitment is sufficient to maintain population). [5.5.3(8), 5.5.3(7)]
- 5. *Track habitat conditions and population status within geographic range.***
 - 5a. Maintain monitoring program to track habitat conditions and population structure within recovery areas. [5.5.6(5), 5.5.8(1), 5.5.8(2), 5.5.8(3)]
 - 5b. Monitor indices (juvenile abundance) which demonstrate significant probability of population persistence throughout geographic range. [5.5.3(6), 5.5.8(5)]

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8.0 GLOSSARY

Acipenser transmontanus.— Scientific name of the white sturgeon.

Anadromous.— Fish life history type involving freshwater spawning and migration to the ocean at some part of the life cycle.

Anthropogenic.— Of human cause or origin.

APG.— Action Planning Group consisting of policy representatives of government and stakeholders convened to aid in implementation of recovery plan.

Beneficial use.— Typically used to refer to subsistence harvest, recreational fishery harvest, or recreational catch and release fishing.

Benthic.— Bottom oriented

Bioassay.— Test for toxic effects on an organism typically conducted by exposure to varying concentrations in a laboratory.

Bycatch.— Incidental or unintended catch of nontarget species.

CDC.— British Columbia Conservation Data Centre.

CITES.— Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Condition factor.— Index of skinniness or plumpness based on weight for a given length.

Conservation hatchery.— An artificial fish production facility operated for the purpose of preservation of weak, threatened, or endangered species as opposed to the production of fish for harvest or commercial purposes.

COSEWIC.— Committee on the status of endangered wildlife in Canada.

CRIEMP.— Columbia River Integrated Environmental Monitoring Program.

Critical population benchmark.— Effective population sizes corresponding to potentially irreversible genetic consequences that may threaten long term health and sustainability of a population.

Entrainment.— Involuntary capture and downstream passage of water or fish at a dam.

ESA.— U.S. Endangered Species Act

Extirpation.— Local extinction of a population or population unit.

Failsafe population.— In this context, a sturgeon population established separate from the population units being recovered to provide a hedge for unforeseen circumstances. Failsafe

populations are not expected to reproduce naturally and may be established in areas that historically produced sturgeon or in other areas where sturgeon are not present.

Functional Extinction.— Small population size below which severe genetic and demographic bottlenecks make recovery unlikely.

GBT.— Gas bubble trauma. Fatal or sublethal fish syndrome resulting from exposure to high levels of dissolved gas in the water.

Genetic risk.— Threat to population composition and productivity as a result of loss of inherited diversity and potential inbreeding which may increase expression of deleterious recessive traits.

Geomorphology.— Physical configuration of the river channel in relation to surrounding topography and geology.

Haplotype.— Unique DNA sequence used to distinguish differences among individuals and populations.

Heterozygosity.— Genetic diversity.

Hydrograph.— Seasonal water flow pattern.

HLK.— Hugh L. Keenleyside Dam, the current upstream boundary of the transboundary reach.

Longevity.— Life span typically thought to approach or exceed 100 years of age for white sturgeon.

PIT tag.— Passive Integrated Transponder tag. An internal fish tag about the size of a grain of rice that can be used to individually mark fish. Tags can be read by an electronic detector passed along the body.

Recovery.— For purposes of this plan, refers to a population level that ensures the persistence and viability of naturally-producing populations of white sturgeon and provides opportunities for beneficial use if feasible.

Recovery area.— Area defined for this purposes of this recovery plan to include all U.S. and Canada mainstem and tributary waters of the Columbia River system upstream of Grand Coulee Dam except for the Kootenay River basin upstream of lower Bonnington Dam and the Pend d'Oreille River basin upstream from Boundary Dam.

Recovery goal.— see recovery.

Recovery measure.— Specific task identified in the recovery plan as potentially beneficial to sturgeon recovery.

Recovery objective.— Short, medium, and long term directions by which recovery goal may be accomplished.

Recovery strategy.— Overarching approaches to sturgeon recovery described in more detail by objectives and measures.

Recovery target.— Interim benchmarks describing population attributes by which progress toward recovery will be measured.

Recovery team.— Group of technical convened to develop and oversee implementation of recovery plan.

Recruitment.— Successful natural reproduction and survival of juvenile fish to a size or age where many are likely to survive contribute to future generations.

SARA.— Canadian Federal Species at Risk Act. (Proposed but not adopted.)

Staging.— In this context, used to describe local migration and concentration near spawning sites prior to spawning.

Swim up.— Dispersal life stage of sturgeon where larvae leave the bottom and enter the water column where they are transported downstream.

TDG.— Total dissolved gas. Measure of gas pressure in water typically used in the U.S.

TGP.— Total gas pressure. Measure of gas pressure in water typically used in Canada.

TMDL.— Total maximum daily load. A written quantitative assessment of water-quality problems and contributing pollution sources typically associated with U.S. Environmental Protection Agency.

Transboundary.— Reach of the Columbia River extending from Grand Coulee Dam in the U.S. to H.L. Keenleyside Dam in Canada that includes the most significant remaining white sturgeon population in the upper Columbia River basin.

Transition Zone.— Typically used to refer to semi-riverine upper portion of Lake Roosevelt.

WUP.— Water Use Plan. Process initiated by British Columbia to evaluate and refine operations of water use projects throughout the province.